Portland General Electric
121 SW Salmon Street • Portland, Ore. 97204
PortlandGeneral.com

May 31, 2019

Via Electronic Filing
puc.filingcenter@state.or.us

Public Utility Commission of Oregon
Attn: Filing Center
201 High Street SE, Suite 100
P.O. Box 1088
Salem, OR 97308-1088

RE: Portland General Electric Company's 2019 Smart Grid Report

Portland General Electric Company (PGE) respectfully submits our 2019 Smart Grid Report as required by Commission Order No. 17-209 in Docket No. UM 1460, regarding updates to our strategy, goals and objectives for adoption of smart grid technologies and the status of our smart grid investments. In addition, PGE was required to provide opportunities for the public to contribute input on PGE's smart-grid investments and applications.

If you have any questions or require further information, please call me at (503) 464-8129.

Please direct all formal correspondence, questions, or requests to the following email address: pge.opuc.filings@pgn.com.

Sincerely,

Andy Macklin
Director, Product Marketing

cc: UM 1460 Service List
UM 1657 Service List

Smart Grid Report

June 2019

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Acronyms

ADR .... Automated Demand Response
AMI .... Advanced Metering Infrastructure
ADMS .... Advanced Distribution Management System
AC .... Alternating Current
AGC .... Automated Generation Control
AMI .... Advanced Metering Infrastructure
ANSI .... American National Standards Institute
ARRA .... American Reinvestment and Recovery Act
BIS .... Battery Inverter System
BPA .... Bonneville Power Administration
CAA .... Community Action Agencies
CCS .... Command-and-Control Systems
CELID .... Customers experiencing long interruption durations
CEMI .... Customers experiencing multiple interruptions
CIP .... Critical Infrastructure Protection
CIS .... Customer Information System
CPP .... Critical Peak Pricing
CVR .... Conservation Voltage Reduction
DA .... Distribution Automation
DC .... Direct Current
DGA .... Dissolved Gas Analyzer
DER .... Distributed Energy Resources
DERMS .... Distributed Energy Resource Management System
DLC .... Direct Load Control
DMS .... Distribution Management System
DR .... Demand Response
DSG .... Dispatchable Standby Generation
DSP .... Distribution System Planning
DTS .... Distribution Temperature Sensing
EMS .... Energy Management System
EPRI .... Electric Power Research Institute
EV .... Electric Vehicle
FAN .... Field Area Network
FCI .... Faulted Control Indicator
GIS .... Geographical Information Systems
HRZ .... High Reliability Zone
ICT .... Information & Communication Technology
IED .... Intelligent Electronic Device
IHD .... In-Home Display
IRP .... Integrated Resource Plan
kW .... Kilowatt

kWh.. Kilowatt-hour
MDC....................................... Meter Data Consolidator
MDMS..................................... Meter Data Management System
MW .... Megawatt
MWa .... Average Megawatt (8,760 mega-watt hours)
MWh .... Megawatt-hour
NEEA...................................... Northwest Energy Efficiency Alliance
NERC...................................... North American Electricity Reliability Commission
NIST....................................... National Institute of Standards and Technology
OMS....................................... Outage Management System
O&M....................................... Operations and Maintenance
OPUC .... Oregon Public Utilities Commission
OSU....................................... Oregon State University
PCC .... Portland Community College
PDC .... Phasor Data Concentrator
PGE .... Portland General Electric
PMU....................................... Phasor Measurement Unit
PNNL .... Pacific Northwest National Lab
PV.. Photovoltaic
PSU .... Portland State University
RAS .... Remedial Action Schemes
RD&D..................................... Research, Development and Deployment
RTCA...................................... Real-Time Contingency Analysis
RTU .... Remote Terminal Unit
SAM....................................... Strategic Asset Management
SCADA................................... Supervisory Control and Data Acquisition
SE.. State Estimator
SEI... Software Engineering Institute (of Carnegie Mellon)
SEGIS..................................... Solar Energy Grid Integration Systems
SGMM..................................... Smart Grid Maturity Model
SPS.. Special Protection Scheme
SSPC...................................... Salem Smart Power Center
SSPP .... Salem Smart Power Project
T&D.. Transmission & Distribution
TIS .... Transactive Incentive Signal
TOD .... Time-of-Day
TOU .... Time-of-Use
USDOE................................... United States Department of Energy
VAR .... Volt Ampere Reactive
WECC..................................... Western Electricity Coordinating Council
WISP...................................... Western Interconnection Synchrophasor Program
WTC....................................... World Trade Center (Portland, OR)

Section 1. Preamble

1.1. History of the Smart Grid Work in the Northwest

The concept of the Smart Grid has evolved, and PGE is providing the following history to show that the electric sector is at a pivotal moment in smart grid development. This section is a review of much of the Smart Grid work undertaken over the past several decades, both federally and in the Northwest.

As we present this Smart Grid Report, PGE's smart grid activities have gone beyond research and development to implementation. PGE's implementation of smart grid technology has evolved to a collective practice, and an investment which we call the Integrated Grid. These investments by PGE into the Integrated Grid will support a new service paradigm that meets the FERC standards for distributed energy resource (DER) inclusion, supports regulatory and policy direction for distributed resource development, and provides customers with choice.[1] Our first demonstration of the Smart Grid as a reality will be the PGE Testbed.

1.2. The FERC and the Smart Grid

One can trace the concept of an efficient, broadly connected grid whereby greater inclusion can lead to just and reasonable rates for consumers to earlier actions by the Federal Energy Regulatory Commission (FERC). The Federal Power Act[2] grants the FERC the powers to oversee the sale and transmission of interstate power including the creation of wholesale energy markets. These markets are necessary for the creation of just and reasonable rates. Traditionally, these markets have been judged to be "whole" when all supply side generation resources are either sold, bid or scheduled into these markets. But recently this paradigm is changing by including new types of generation, demand-side resources, energy efficiency, demand response, energy storage and soon distributed energy resources.[3] This dynamic change and vision for how the country procures and delivers energy and energy services is well-developed and just now is beginning to affect the Pacific Northwest and Oregon. Portland General Electric is participating in the California Independent System Operator's (CAISO) Energy Imbalance Market (EIM).

Changes which allow for distribution-sited resources to provide services to the wholesale markets have come about through a series of FERC Orders which began in 2008.

The FERC Order 719[4] was the first of the major FERC Orders requiring market operation changes to include a new form of energy resource, demand response. Here the FERC in large part found that wholesale energy markets cannot produce just and reasonable rates unless

[1] When PGE discusses new service paradigm we mean to do so in broad terms. However, we do recognize that the traditional service paradigm, principally characterized by a one-way flow of electrons to the customer service point will need to change and is changing as the smart grid concept becomes a customer enabling reality.
[2] Federal Power Act 16 U.S.C. 791 (1935)
[3] See generally FERC Order 841 and RM18-9-000
[4] 125 FERC P 61,071, Docket Nos. RM07-19-000 and AD07-7-000, *Wholesale Competition in Regions with Organized Electric Markets* (Issued October 17, 2008).

demand can bid into the market to demonstrate response or pricing flexibility at times of high prices or system capacity and energy constraints.[5]

The FERC Order 745[6] followed and was meant to address the market barriers and the unique operating capabilities of demand response to assure that the markets, ratepayers and demand response receive the greatest benefit from the resources' participation. The FERC here found that demand response can be a cost-effective resource and included a cost effectiveness test with the Order for determining when to accept bids from demand response. This Order was granted certiorari by the US Supreme Court in 2015 and was found to be within the power of the FERC. The primary question of jurisdiction, state versus federal, was at issue here as demand response is found primarily on the distribution system. These two Orders 719 and 745 both challenged the limits of the FERC's jurisdiction but also demonstrated an understanding that the resources of the grid are distributed. Through these Orders the FERC began to set the stage for development of the Smart Grid leaving space for each state jurisdiction to move at its own pace toward that end. Since then the FERC has issued two Orders to incorporate energy storage in the wholesale energy and ancillary services markets.

The FERC Order 755[7] outlined how energy storage should be compensated for its dispatch response and performance accuracy. The FERC Order 841[8] similarly advanced rules for electric storage participation in wholesale markets. During the Notice of Proposed Rule process for the FERC Order 841 the Commission and the FERC Staff contemplated creating similar rules for distributed energy resources to participate in wholesale markets. The FERC opened a docket in 2017 to review this proposal in advance of a notice of proposed rulemaking and held a technical conference requesting comment in Docket AD18-10-000.[7] As part of this proceeding, PGE's Vice President, Larry Bekkedahl, gave testimony before the FERC and later submitted written comments on the complexity of leveraging distribution-sited resources for bulk grid services. PGE believes these concerns can be informed by our Integrated Grid work currently underway and described in this Smart Grid Report. This program drives to understand and develop the technical capabilities to leverage the distribution system for resource development.

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[5] 125 FERC P 61,071, Docket Nos. RM07-19-000 and AD07-7-000, *Wholesale Competition in Regions with Organized Electric Markets* (Issued October 17, 2008).

[6] 134 FERC P. 61,187, Docket No. RM10-17-000, *Demand Response Compensation in Organized Wholesale Energy Markets* (Issued March 15, 2011)

[7] 137 FERC P 61,063, Docket Nos. RM11-7-000 and AD10-11-000, *Frequency Regulation Compensation in the Organized Wholesale Power Markets*, (Issued October 20, 2011)

[8] 162 FERC P 61,127, Docket Nos. RM16-23-000 and AD16-20-000, *Electric Storage Participation in Market Operated by Regional Transmission Organizations and Independent System Operators*, (Issued February 15, 2018).

1.3. Smart Grid Development in the Northwest

1.3(a) The Hood River Conservation Project

The Hood River Conservation Project (HRCP) was intended to test the upper limits of a utility retrofit program. HRCP sought to install an extensive package of retrofit measures in all the electrically heated homes in Hood River, Oregon. The careful planning for the Project and its evaluation and the Project's ongoing attention to collecting and managing data yielded a rich information resource. This resource has been extensively mined, both to address the issues for which HRCP was designed and to examine other important energy issues for the Pacific Northwest.

Figure 1: The Hood River Conservation Project

The Hood River Conservation Project (HRCP), a $20 million program in the early 1980's, tested the limits of the cost effectiveness of a residential energy improvement program. HRCP installed, for free, any weatherization measures that a household energy assessment showed were within a prescribed cost threshold per unit of energy saved. HRCP's marketing was based on social science research that analyzed the social networks within the community. Most customers learned of the program through word of mouth. The program achieved a high response rate for home energy assessments (91% of all eligible participants) and for the subsequent implementation of conservation measures (85% of all eligible participants).[9]

The PGE Smart Grid Testbed is built on many of the same concepts and principles as The Hood River Conservation Project with goals such as 66% participation from residential customers and acceleration of the development of demand side resources. Projects like the Hood River Project and the PGE Testbed are important steps in smart grid development.

[9] Diving Demand for Home Energy Improvements, LBNL, Fuller, Kunkel, Et al. (2010)

1.3(b) The Energy Web

Bonneville Power Administration developed one of the first concepts of the "Smart Grid" in the 1990's with an idea known as the "Energy Web." Shown in Figure 2 below, this idea was of an interconnected grid whereby all resources regardless of whether they were connected to the transmission system or the distribution system had a place and a service to offer the grid.

Notice the close relationship conceived between demand-side resources, "Dispatchable DSM", and the energy market. Here, though not yet a reality, the electric and grid-connected car is shown as "hyper car." Most notable are the connections shown between each asset in the picture. These connections represent the buildout of the information technology across the physical infrastructure to operate a smart grid. This underlying infrastructure is to PGE's Integrated Grid concept.

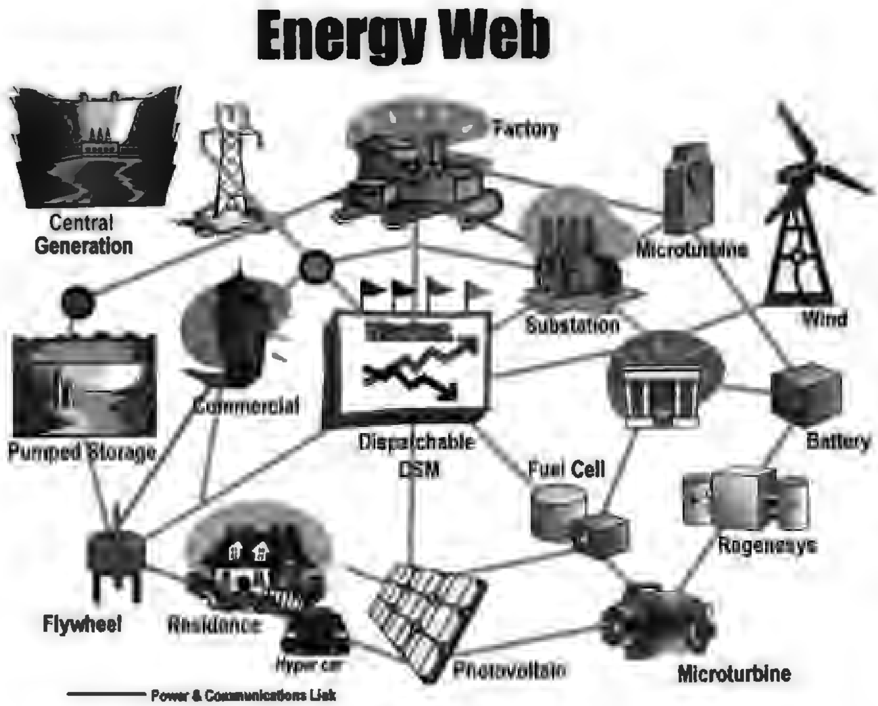


Figure 2: The Energy Web

1.3(c) The Olympic Peninsula Project

One of the first major smart grid projects set in the Pacific Northwest was the *Gridwise*, Pacific Northwest National Laboratory, Olympic Peninsula Project. This project demonstrated distributed energy resources, and what is now known as the Internet of Things (IoT), being leveraged to supply grid services.

Conducted from 2004 to 2006, the purpose of the Olympic Peninsula Project was to create and observe a futuristic energy-pricing experiment that illustrates several values of grid transformation that aligned with the GridWise concept. The central principle of GridWise is that inserting intelligence into electric-grid components at the end-use, distribution, transmission and generation levels will significantly improve both the electrical and economic efficiencies within the electric power system. Specifically, this project tested whether automated, two-way communication between the grid and distributed resources would enable resources to be dispatched based on the energy and demand price signals they receive. In this manner, conventionally passive loads and idle distributed generators would be transformed into elements of a diverse system of grid resources providing near real-time active grid control and a broad range of economic benefits. Foremost, the project controlled these resources to successfully manage the power flowing through a constrained feeder-distribution circuit for the duration of the project. The project tested whether it was possible to decrease the stress on the distribution system at times of peak demand. The immediate objectives of the project were to:

- show that a common communications framework can enable the economic dispatch of dispersed resources and integrate them to provide multiple benefits;
- gain an understanding of how these resources perform individually and when interacting in near real-time to meet common grid-management objectives; and
- evaluate economic rate and incentive structures that influence customer participation and the distributed resources they offer.

1.3(d) The Pacific Northwest Smart Grid Demonstration Project

The Pacific Northwest Smart Grid Demonstration (PNWSGD), a $179 million project co-funded by the U.S. Department of Energy (DOE) in late 2009, was one of the largest and most comprehensive demonstrations of electricity grid modernization ever completed. The project was one of 16 regional smart grid demonstrations funded by the American Recovery and Reinvestment Act. It was the only demonstration that included multiple states and cooperation from multiple electric utilities, including rural electric co-ops, investor-owned, municipal, and other public utilities. No fewer than 55 unique instantiations of distinct smart grid systems were demonstrated at the project's sites. The local objectives for these systems included improved reliability, energy conservation, improved efficiency, and demand responsiveness. The demonstration developed and deployed an innovative transactive system, unique in the world, that coordinated many of the project's distributed energy resources and demand-responsive components.

Figure 3: The Pacific Northwest Smart Grid Demonstration Project

With the transactive system, additional regional objectives were also addressed, including the mitigation of renewable energy intermittency and the flattening of system load. Using the transactive system, the project coordinated a regional response across the 11 utilities. This region-wide connection from the transmission system down to individual premises equipment was one of the major successes of the project. The project showed that this can be done and that assets at the end points can respond dynamically on a wide scale. In principle, a transactive system of this type might eventually help coordinate electricity supply, transmission, distribution, and end uses by distributing mostly automated control responsibilities among the many distributed smart grid domain members and their smart devices.

Through our Salem Smart Power Center, PGE participated in the Pacific Northwest Smart Grid Demonstration Project learning about battery development, operations and microgrid schemes. Participation in the project and the subsequent reports help inform PGE on next steps of smart grid iteration.

1.3(e) The Portland General Electric Smart Grid Testbed Project

The PGE Smart Grid Testbed is a continuation of work the region has undertaken to develop distribution resources as grid assets. The first phase, currently underway, focuses on demand response and customer participation and engagement. The customer is central to the development of the Smart Grid. Through the relationship with the customer and offering choices to customers, PGE seeks to accelerate the development of demand response. PGE will additionally leverage other funding resources to test and adapt smart grid technologies to optimize distributed resource development within the Testbed. Integrated Grid technologies such as advanced SCADA and communication networks will be folded into the work of the PGE Smart Grid Testbed to extract benefits and lessons which can be more broadly applied throughout the service territory. PGE is currently designing our residential energy storage program. It is our intention to first offer the residential energy storage program within the Testbed. This approach seeks to concentrate behind the meter storage within the Testbed where we can capture a greater number of lessons.

1.4. Oregon Policy

The State of Oregon has also been advancing policy around distribution sited grid assets. In 2015 the Oregon legislature passed energy storage legislation, HB 2193.[10] The Oregon Public Utility Commission took up the charge by opening Docket UM 1756 which outlined various use cases for energy storage. Later the Commission received energy storage proposals from both PacifiCorp and PGE. With the passage of SB 1547[11], the Coal to Clean Bill, the 2015 Oregon legislature advanced transportation electrification policy and created a loading order placing energy efficiency and demand response on the top of the loading order stating that no utility shall make investment in generation until first procuring cost effective energy efficiency and demand response.[12]

The Oregon Public Utility Commission has similarly developed demand-side management (DSM) policy for energy storage, electric vehicles, and recently initiated distribution system planning in Docket UM 2005. Additionally, the Commission concluded a proceeding to address Senate Bill 978[13] from the 2017 Oregon legislature. In its final report, the Commission touched

[10] House Bill 2193, 78th Oregon Legislative Assembly 2015 Available at https://olis.leg.state.or.us/liz/2015R1/Downloads/MeasureDocument/HB2193

[11] Senate Bill 1547, 78th Oregon Legislative Assembly 2016, Available at https://olis.leg.state.or.us/liz/2016R1/Downloads/MeasureDocument/SB1547/Enrolled

[12] Senate Bill 1547, Section 19(3)(a) & (b) – "As directed by the Public Utility Commission by rule or order, plan for and pursue the acquisition of cost-effective demand response." Similarly (a) "Plan for and pursue all available energy efficiency resources that are cost effective, reliable and feasible."

[13] Senate Bill 978, 79th Oregon Legislative Assembly 2017

on questions regarding changes to the regulatory paradigm and importance of customer-sited energy resources.[14]

[14] Oregon Public Utility Commission, SB 978 Final Report, Available at https://www.puc.state.or.us/Renewable%20Energy/SB978LegislativeReport-2018.pdf

Section 2. Executive Summary

2.1. Background

This report is PGE's sixth Smart Grid Annual Report filing in compliance with OPUC Order No. 12-158 in Docket No. UM 1460. In addition to providing an update on PGE's Smart Grid initiatives, this report incorporates several innovations not included in prior smart grid reports. For example, we discuss the commencement of PGE's Integrated Grid Program as the foundation of advanced distribution operations. This work relies heavily on integrating several technologies including communications such as Supervisory Control and Data Acquisition (SCADA) and Field Area Network (FAN), geospatial information systems (GIS), distribution automation (DA), and advanced distribution management system (ADMS). This work will enable PGE to integrate customer programs and technologies such as those in the Smart Grid Testbed in the distribution system with bulk system resources variable energy resources (wind and solar) thus beginning realization of the Smart Grid at scale.

2.2. Strategy

In 2015, PGE commenced a process to develop a clear, cross-company vision, roadmap, and strategic approach to integrating and deploying smart grid technologies. This approach included an internal, cross-functional task force informed by the Smart Grid Maturity Model, the task force outlined a three-staged iterative approach for PGE to build an Integrated Grid that delivers value to all customers:

- Model & Monitor (Plan Ahead)
- Engage (Successfully Pilot)
- Integrate (Move to Scale)

Moreover, this first strategic step point to pursuit of the smart grid as a proactive and collaborative process enabled by on-going stakeholder dialogue and continued maturation of grid technologies. These efforts are information-driven and evolutionary in nature. Included in this report is a roadmap that continues to build on the original strategy from 2015 over the coming years. This evolution remains informed by the four goals identified in Order No. 12-1258 to enhance:

- the reliability, safety, security, quality, and efficiency of the T&D network
- the ability to save energy and reduce peak demand
- customer service and lower cost of utility operation
- the ability to develop renewable resources and distributed generation

Just as the smart grid strategy has evolved with technology and capabilities, so has PGE's corporate strategy. While honoring the goals identified above, the investments PGE makes in smart grid technologies are linked directly to our corporate strategic imperatives:

- **Decarbonize:** Reduce GHG emissions by more than 80 percent by 2050
- **Electrify:** Increase electricity to 50 percent of energy use by 2050 to meet state GHG emissions reduction goals
- **Modernize:** Use intelligent digital technologies and innovative operational practices

- **Perform:** Deliver operational excellence and be sound stewards of energy ecosystem resources

PGE's corporate imperatives provide a foundational framework for how this Smart Grid Report categorizes PGE's smart grid activity across the organization. Current work to build PGE's Integrated Grid ties the Smart Grid strategy with corporate strategy. More information about these imperatives and how they align with customer benefits are set forth in three PGE white papers, available on PGE's website:

- Our Vision for a Clean and Reliable Energy Future[15]
- A Modernized Grid Platform for a Clean Energy Future[16]
- The Path to a Decarbonized Energy Economy[17]

2.3. System Planning

PGE includes smart grid technologies as viable resources in the IRP as they mature, similar to the way cost-effective energy efficiency and demand response are considered. As such, many of our Smart Grid initiatives will continue to be part of an evolving, two-way conversation between program/system planners and the IRP team, and will be included in PGE's IRP process. In 2017 and 2018, PGE held 11 stakeholder workshops in the IRP planning process which included smart grid-related content. Going forward, the continued development of distribution system planning (DSP) within PGE will become an increasingly important planning component linking the needs of the IRP, the contribution of distributed energy resources, and traditional transmission and distribution planning.

2.4. Smart Grid Initiatives

PGE has made considerable investments in smart grid initiatives, staff, and research. PGE has completed, is deploying, or is considering more than 50 smart grid initiatives across the Company, organized in this report into six categories for ease of consumption: customer engagement and empowerment, data and analytics, connecting and enabling technology, transportation electrification, research and development, physical and cyber security, and completed and archived.

Consistent with our Smart Grid Strategy, PGE is always monitoring the landscape for emerging technologies and opportunities to create value for our customers. Section 4 of this report outlines each of PGE's Smart Grid initiatives and their status, organized by the categories noted above.

[15] *Vision for a Clean Energy Future*, Available at https://www.portlandgeneral.com/-/media/public/our-company/energy-strategy/documents/pge-vision-white-paper.pdf?la=en

[16] *A Modernized Grid Platform for Clean Energy Future*, Available at https://www.portlandgeneral.com/-/media/public/our-company/energy-strategy/documents/pge-smart-grid-white-paper.pdf

[17] *Exploring Pathways to Deep Decarbonization*, Available at https://www.portlandgeneral.com/-/media/public/our-company/energy-strategy/documents/exploring-pathways-to-deep-decarbonization-pge-service-territory.pdf?la=en

2.5. Related Activities

As PGE is developing a portfolio of smart grid technologies, the company must have means to evaluate the costs of new resources in relation to their benefits to the system, our customers, and broader societal goals. Because each of these DERs is unique in how they provide benefit to the system, PGE looks forward to future stakeholder engagement on how to standardize a variety of efforts underway to quantify and determine value streams associated with various types of DERs.

2.6. What is the Smart Grid

The Smart Grid is best described as the product of efficiencies achieved through integration of technological assets, data analytics, innovative organizational practices and incentivized customer offerings. The objective of the Smart Grid is to create a customer energy use experience that is clean, reliable, equitable, and affordable. The differences between a smart grid and what most people would recognize as the legacy grid are reflected in three attributes:

- **Collecting:** Devices and sensors capture large volumes of information and data used to plan and operate the grid more efficiently, affordably and reliably
    - Examples: SCADA, Intelligent Electronic Devices (IEDs), synchrophasors

- **Communicating:** Bi-directional communications enabling 1) active, informed and flexible real-time data aggregation, 2) participation by customers in energy use decisions, and 3) customer technologies to fulfill grid service needs.
    - Examples: Field Area Network, AMI, Demand Response signals

- **Visualizing:** Digital technologies allow the Smart Grid to be holistically managed and operated. This enables the development of flexible loads such energy storage, transportation electrification and advanced demand response to assist with the integration of renewables
    - Examples: Distributed Energy Resource Management System or (DERMS), Advanced Distribution Management System or (ADMS), Energy Management System or (EMS), Outage Management System or (OMS), and Geographic Information System or (GIS).

2.7. Organization of the Report

This report is presented in two volumes, a hard copy volume and an online volume. In compliance with Order No. 12-158, the report has been produced in print with an electronic formatted version being filed electronically through the OPUC filing center. We have provided a policy background in the preamble to provide a broad historical context of concept of smart grid and related work in the Northwest. We have then reviewed prior smart grid report filings, and the historic purpose of the Smart Grid report. We then move into PGE’s Smart Grid strategy which leads into a discussion of the Smart Grid evolution from concept, research and development to now present practice through development of the Integrated Grid. Lastly, we present a compendium of our current smart grid activities within PGE. These activities will inform existing or lead to new Integrated Grid work.

PGE questions whether future Smart Grid Reports as envisioned in 2012 are necessary. As PGE continues to engage with the Commission through UM 2005, outlining the requirements of distribution system planning, PGE believes the Smart Grid Report in large part may become redundant to present planning and programmatic activity. Our Integrated Grid work encompasses much of the activity delineated in the 2019 Smart Grid Report. We envision distribution system planning and distribution resource planning will meet the intent of the Commission's vision of the Smart Grid Report as a progression to planning for distribution resource development.

Section 3. Smart Grid Report History and Requirements

3.1. Smart Grid Report History and Purpose

In 2012, the OPUC issued Order No. 12-158 in Docket No. UM 1460 to establish the Commission's smart grid policy goals and objectives, utility reporting requirements, and guidelines for utility actions related to smart grid.18

OPUC's Policy Goals and Objectives: The Commission's goal is to benefit customers of Oregon investor-owned utilities by fostering utility investments in real-time sensing, communication, control, and other smart grid measures that are cost-effective to consumers and that achieve some of the following:

- Enhance the reliability, safety, security, quality, and efficiency of the transmission and distribution network
- Enhance the ability to save energy and reduce peak demand
- Enhance customer service and lower cost of utility operation
- Enhance the ability to develop renewable resources and distributed generation

Required Elements of Annual Reports:

- Smart Grid Strategy
- Status of Smart Grid Investments
- Smart Grid Opportunities and Constraints
- Targeted Evaluations
- Related Activities

Through the various stakeholder engagements over the many years of smart grid reports, PGE understands the Smart Grid Report is used for a variety of purposes including:

- As a reference document for tracking a wide range of utility initiatives and programs that are not captured in the IRP and other OPUC filings;
- As a tool to resource plan;
- As a tool to inform government agency planning and outreach to smaller municipal utilities; and
- To provide vendors with insights into upcoming initiatives to help plan for potential RFPs.

The OPUC acknowledged the value of the Smart Grid Report in response to PGE's filing of its 2017 report by indicating that the report has evolved into a cohesive, comprehensive and helpful report that reflects PGE's substantial efforts in producing a quality product.[19]

This is the sixth Smart Grid Report that PGE has filed pursuant to OPUC Order No. 12-158, in Docket No. UM 1460. When adopted in 2012, Order 12-158 required that Smart Grid Reports

[18] Oregon Public Utility Commission Docket UM 1460, Order No. 12-158. Available at http://apps.puc.state.or.us/orders/2012orders/12-158.pdf

[19] *See* OPUC, Aug. 11, 2017, UM 1657, Staff's Comments, Portland General Electric Annual Smart Grid Report at page 2, https://edocs.puc.state.or.us/efdocs/HAC/um1657hac165319.pdf

be filed annually, and PGE filed smart grid reports each year between 2013 and 2017. At a workshop led by PUC staff on May 15, 2017 involving PGE, Pacific Power, Idaho Power, ETO, and ODOE, stakeholders determined that a two or three-year reporting cycle for the Smart Grid Report would be more valuable than an annual reporting cycle. The reporting requirement was modified following the filing of the 2017 PGE Smart Grid report to require that PGE file smart grid reports every other year. This is the first Smart Grid report filed on a biennial reporting cycle. The filing dates of prior Smart Grid Reports are presented in Table 1. Copies of prior reports and PUC acceptance orders can be accessed via the OPUC website Docket No. UM 1460.

Table 1: History of PGE Smart Grid Annual Report

Date	Order No.	Event Detail
05/08/2012	12-158	OPUC Outlines smart grid goals & reporting requirements
06/01/2013	N/A	2013 Smart Grid Annual Report Filed
08/28/2013	13-311	Acceptance of 2013 Smart Grid Annual Report
06/01/2014	N/A	2014 Smart Grid Annual Report Filed
10/01/2014	14-333	Acceptance of 2014 Smart Grid Annual Report
05/28/2015	N/A	2015 Smart Grid Annual Report Filed
10/13/2015	15-314	Acceptance of 2015 Smart Grid Annual Report
05/31/2016	N/A	2016 Smart Grid Annual Report Filed
10/20/2016	16-405	Acceptance of 2016 Smart Grid Annual Report
05/31/2017	N/A	2017 Smart Grid Annual Report Filed
11/06/2017	17-446	Acceptance of 2017 Smart Grid

3.2. Stakeholder Engagement

This PGE Smart Grid report was created with input from external stakeholders. PGE views dialogue with stakeholders as highly valuable, and we are committed to continuing this dialogue. In preparation for filing this report, PGE established a formal stakeholder engagement protocol that included the activities delineated in the following table.

Table 2: Stakeholder Engagement

Date	Milestone
05/01/2019	Smart Grid Report Stakeholder Workshop
05/06/2019	Draft report shared with stakeholders
05/19/2019	Receipt of comments from stakeholders
05/31/2019	Smart Grid Report filed

3.3. Required Elements of the Smart Grid Report

Order No. 12-158 mandated that, at a minimum, the PGE Smart Grid report address the following elements:

- Smart-grid strategy, goals, and objectives
- Status of smart grid Investments the utility plans to take in the next five years
- Smart grid opportunities and constraints
- Targeted evaluations of technologies and applications pursuant to Commission-approved stakeholder recommendations
- Related activities such as investment to addressed physical-and cybersecurity, privacy, customer outreach and education, IT and communication infrastructure, as they relate to smart-grid activities.

These are the elements minimally required for reporting. Order No. 12-158 does not preclude the reporting of additional elements, and this report includes information that goes beyond the minimum required.

3.4. Senate Bill 978 and Social Equity

PGE recognizes the need for equity and the existence of historic and systemic barriers experienced by low-income households, people with disabilities, non-English speakers, communities of color, and other underserved communities within PGE's service territory that have prevented these groups from achieving equal outcomes in access, opportunities, and advancement in the energy system. PGE is committed to ensuring that its smart grid investments are consistent with the findings of the SB 978 process conducted by the OPUC in 2018. Initiatives aimed at mitigating barriers low income customers face in accessing, using and paying for energy are critical to PGE's customer engagement and empowerment strategy.

In recognition of the importance of equity, PGE has created a standalone Diversity, Equity & Inclusion department supported by three full-time staff positions and consulting support to ensure that equity is an essential element of PGE's programs. Additionally, the Smart Grid Testbed includes resources to deploy three community outreach personnel to better identify and understand the barriers and challenges of our customers. The data and information collected will help PGE better address the challenges and barriers of low income, diverse and marginalized members of the communities we serve. PGE is working with our information technology team and new data sets acquired from the entities like the Oregon Department of Environmental Quality, federal census information to identify environmental justice issues affecting our customers and thus how PGE can help to address such issues as industrial process noise, road noise, air pollution, and water quality. PGE is also focusing on projects that range from hardening upgrades, such as undergrounding wires and battery storage, to recovery upgrades like distributed microgrids for essential services and self-healing grid technologies. We work alongside emergency services, local governments and community organizations to participate in training exercises for disaster preparedness. Finally, projects like PREPHub, a collaboration between PGE, the City of Portland, Portland State University, and the Massachusetts Institute of Technology, can deliver a new type of infrastructure that can operate off-grid to provide services like power, communication and emergency first aid supplies.

3.5. Synopsis of Prior Smart Grid Reports

Preceding smart grid reports provide a roadmap of steps PGE has taken to investing in, planning and operating smart grid assets for the benefit of PGE customers. The significant milestones PGE has achieved along the way, as reported in prior smart grid reports, include:

2013 Report

The first PGE Smart Grid Report identified projects and initiatives targeting building out Advanced Metering Infrastructure (AMI), implementation of a Supervisory Control and Data Acquisition (SCADA) system, and research and development projects. PGE reported having made prior investment of almost $200 million in these and other smart grid assets, including Dispatchable Standby Generation (DSG) and the Salem Smart Power Center for exploring the technical feasibility and economic value of smart grid services involving utility-scale energy storage. At the time the 2013 report was filed, about 825,000 digital smart meters had been installed in the PGE service territory, SCADA had been implemented at 70 percent of PGE substations, and the company controlled almost 90 MW of DSG.

2014 Report

The 2014 report projected a view of smart grid assets becoming viable alternatives to supply-side resources akin to the way cost-effective energy efficiency and demand response are considered as supply-side resource alternatives in the IRP. Planning and implementation of platforms necessary for future grid enhancements and use of AMI data were emphasized, including an Outage Management System and Distribution Management System. Encouraging findings from the Conservation Voltage Reduction pilot launched in 2013 were reported. With the approximately 730 public EV charging stations in Oregon positioning Oregon as having the highest number of public stations per capita in the United States at the time, R&D projects involving time-of-use and smart charging demand response were outlined.

2015 Report

The 2015 report delineated more than 50 smart grid initiatives underway, spanning grid optimization, customer engagement, and distributed and renewable resources. At the time the Report was filed, 74 percent of PGE substations were being controlled by SCADA. The Report identified several new engineering and project management positions dedicated to smart grid asset planning and management created over the prior two years. The 2015 report was filed amidst a major effort by PGE to re-align smart grid planning and operations with the eight domains of the Smart Grid Maturity Model (SGMM). Working groups were organized to inform each of these domains in anticipation of filing the next year's smart grid report in 2016. Review of the 2015 report led OPUC to recommend future smart grid reports place greater emphasis on devising and reporting smart grid asset reliability and operability metrics and on providing greater detail on smart grid R&D and pilot projects.

2016 Report

Among the critical initiatives delineated in the 2016 report was CET Customer Touch Points, an 18-month project to re-engineer technology platforms to make them compatible with AMI and enable deployment of new distributed resources and delivery of pricing and demand-side management programs to customers. The 2016 report also described a pilot anticipated as a precursor to substantial enhancement of PGE transmission and distribution system analytics capabilities. The 2016 report showed PGE positioned to pilot or launch deployment of the Energy Tracker energy information system, distribution automation, conservation voltage reduction, distribution fault detection, along with installation of synchrophasors at three substations. Other pilots delineated in the 2016 report were the Nest Rush Hour Rewards smart thermostat pilot, flex pricing, spectrum infrastructure communications modernization. Seventy-six percent of PGE substation were controlled by SCADA at the time the 2016 report was filed.

2017 Report

At the time the 2017 report was filed, 80 percent of PGE substations were controlled and monitored by SCADA. PGE's resource portfolio included 120 MW in dispatchable standby generation from 86 generators controlled by 38 customers at 58 sites. The 2017 update reported 4,800 customers enrolled in the NEST smart thermostat programs. The PGE Electric Avenue EV charging station installed at the PGE Salmon Street headquarters had delivered 200,000 kWh and powered an estimated 1 million electric miles. PGE deployed new systems to support smart grid including: an outage management system and transmission outage management system, an expanded transmission and distribution system analytics capabilities, and integrated energy management system state estimator and real time contingency analysis (RTCA) tools. Planning was underway for: a smart water heater pilot demand response project, a demand response testbed, and activities to reach 77 MW of customer-enabled demand response capacity as well as a deployment of at least 5 MWh of energy storage by 2021.

3.6. 2017 Report OPUC Recommendations

In response to PGE's 2017 report, the OPUC made several recommendations in Order No. 17-446 to be addressed in this 2019 report. Table 4 summarizes PGE's response to the recommendations.

Table 3: 2017 OPUC Recommendations

Category	Recommendation	Response
Demand Response Projects	PGE report on the effectiveness of the proposed changes to the Energy Partner, Smart Thermostats, and other demand response pilot projects.	PGE has given regular updates on Energy Partner, smart thermostats, and other demand response pilot projects. PGE created the demand response advisory group (DRAG) to help inform and give updates to Staff regarding PGE's demand response activities. Additionally, PGE has made preliminary filings and made a commitment to file a more comprehensive report on all demand response activities.

Distributed Energy Resources	PGE provide an update on cost-effectiveness methodologies of DERs.	As discussed at a workshop April 28, 2017, current PGE valuation practices are based on capacity savings in-line with our current acknowledged IRP. PGE anticipates additional and more granular avoided costs data would be developed through the forthcoming PUC DR docket. The 2019 IRP and the Distribution System Planning (DSP) docket UM 2005 may also grant additional insights and information.
Distribution System Planning (DSP)	PGE provide an update to its DSP efforts as directed through LC 66 and other pertinent dockets	The OPUC opened a formal investigation into DSP on March 22, 2019 (UM 2005). PGE will be providing updates to the DSP consistent with the schedule and requirements coming out of UM 2005. The beginnings of a DSP-like tool, hosting capacity, is likely to be developed as part of UM 2005.
Customer Engagement Transformation Projects	PGE provide specific examples of how CIS and MDMS projects are enabling demand response and Customer Engagement Transformation project	CIS/MDMS enables Demand Response in the following ways: • Supports a high number of pricing buckets within a day (previous limit was 3). • Better identification of people associated to accounts allows for more tailored marketing efforts for programs • Can reflect credits associated with DR on the bill • Supports the display of DR events and the customer's actions via self-serve channels such as the web

Section 4. PGE's Smart Grid Strategy

4.1. PGE's Smart Grid Goal

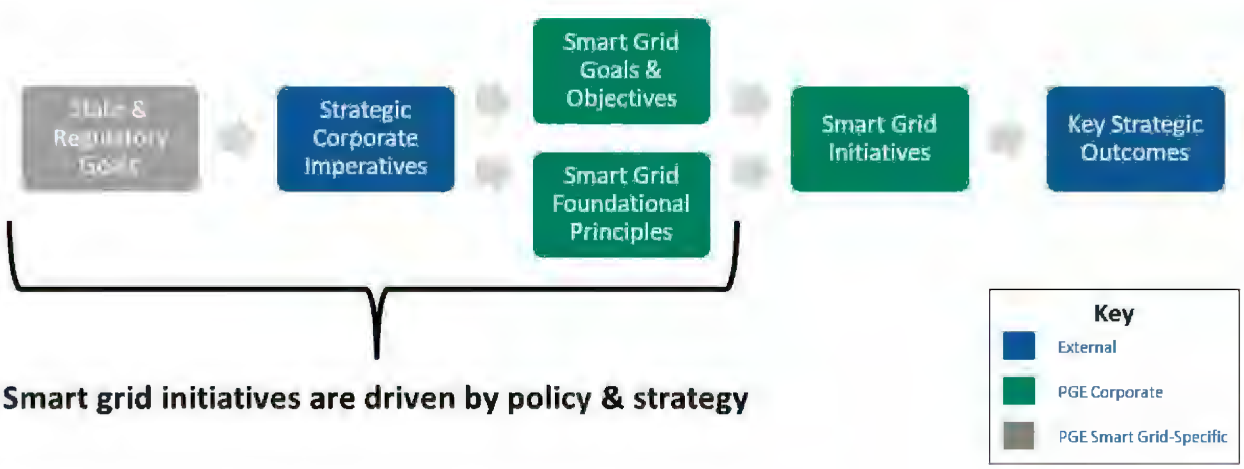
The goal of the PGE Smart Grid is to empower PGE customers with access to clean, reliable, affordable and equitable electricity through intelligent integration of automated and connected technologies and innovative operational practices and customer offerings. The goal affirms PGE's commitment to put customers first.

4.2. PGE's Smart Grid Strategy Approach

PGE has not developed its smart grid strategy in a vacuum. It is shaped by a combination of PGE's corporate imperatives, the regulatory environment, environmental realities, and market pressures. PGE's smart grid investments are directly tied to the Smart Grid Strategy and its key elements.

Figure 4 depicts how PGE's Smart Grid Strategy is driven by policy and imperatives. The roles played by strategic corporate imperatives, foundational principles, the value proposition and strategic themes are delineated in the balance of this report.

Figure 4: Smart Grid Strategy Methodology



4.3. PGE Strategic Corporate Imperatives

PGE's corporate imperatives were developed in a collaborative process involving PGE management and staff, customers, regulatory and policy stakeholders, and business partners. The imperatives cover four strategic themes.

- **Decarbonize:** Reduce GHG emissions by more than 80 percent by 2050
- **Electrify:** Increase electricity to 50 percent of energy use by 2050 to meet state GHG emissions reduction goals
- **Modernize:** Use intelligent digital technologies and innovative operational practices

- **Perform:** Deliver operational excellence and be sound stewards of energy ecosystem resources

More information about these imperatives and how they align with customer benefits are set forth in three PGE white papers, available on PGE's website:

- Our Vision for a Clean and Reliable Energy Future[20]
- A Modernized Grid Platform for a Clean Energy Future[21]
- The Path to a Decarbonized Energy Economy[22]

The reflection of PGE's corporate imperatives in the Smart Grid Strategy seeks to ensure that related initiatives are focused on decarbonizing, electrifying, modernizing and performing. PGE's current work to build the Integrated Grid is a manifestation of our Smart Grid Strategy as an enabler of regulatory goals and corporate strategy, and the evolution of the company's practices and capabilities as we seek to satisfy those higher-level drivers.

4.4. PGE's Smart Grid Goals & Objectives

The objectives of PGE's investments in the Smart Grid are to:

- Align the Smart Grid ecosystem planning with goals and processes set forth in statutes and orders of the PUC;
- Mature analytic capabilities to better inform smart grid energy system investments and operations;
- Continue strengthening transmission and distribution system reliability and resiliency;
- Protect customer investments in grid infrastructure amid potentially disruptive market or nefarious actors;
- Identify strategy for deployment and use of flexible load to accommodate deployment of renewable resources;
- Empower customers with the ability to manage their energy use with dynamic pricing signals that vary, providing customers choice to use energy when it's most affordable;
- Optimize projected growth in customer adoption of electric vehicles;
- Reduce emissions by reducing peak demand, increasing energy conservation and integrating renewable generation sources;
- Automate grid self-healing through the capacity to anticipate and respond to system disturbances and enhance operational resiliency against natural disaster and attacks by malign actors; and

[20] *Vision for a Clean Energy Future*, Available at https://www.portlandgeneral.com/-/media/public/our-company/energy-strategy/documents/pge-vision-white-paper.pdf?la=en

[21] *A Modernized Grid Platform for Clean Energy Future*, Available at https://www.portlandgeneral.com/-/media/public/our-company/energy-strategy/documents/pge-smart-grid-white-paper.pdf

[22] *Exploring Pathways to Deep Decarbonization*, Available at https://www.portlandgeneral.com/-/media/public/our-company/energy-strategy/documents/exploring-pathways-to-deep-decarbonization-pge-service-territory.pdf?la=en

4.5. Foundational Principles

The three foundational principles that underlie the PGE Smart Grid are:

- **Clean & Green:** Customers expect the Smart Grid to help meet their energy needs while addressing greenhouse gas emissions
- **Equitable & Affordable:** Customers expect smart grid investments to result in fair prices and equitable access to energy
- **Reliable:** Customers expect smart grid investments to build a more reliable, resilient, clean, and secure grid

Figure 5: Smart Grid Foundational Principles

4.6. Clean and Green as a Foundational Principle of the Smart Grid

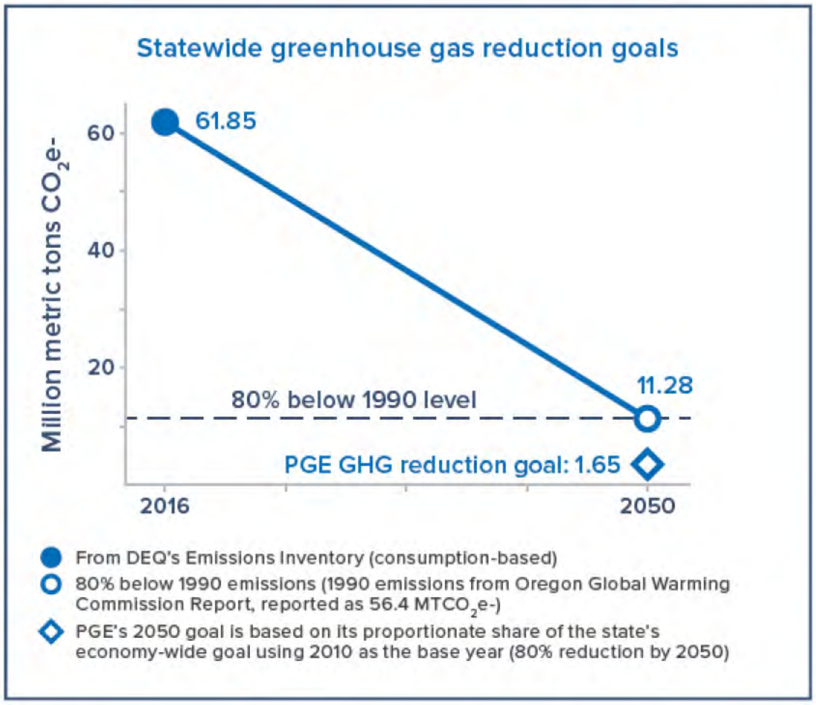
We are committed to helping our customers and the communities we serve achieve a clean energy future. The benefits of such a future are real: we must do our part to reduce the threat of climate change, improve air and water quality, and live a more sustainable way of life.

Oregonians are at the forefront of a dramatic transformation. Several cities have proclaimed resolutions to move to 100 percent clean and renewable energy, and over 204,000 PGE customers voluntarily participate in the nation's top renewable power program. Additionally, more than 10,000 customers are early adopters of electric vehicles. Oregonians have a pioneering spirit and our customers are taking clear steps to create a clean energy future by making choices and assuming responsibility for their energy consumption. In 2016, we collaborated with environmental groups and customer advocates to pass one of the most progressive clean energy laws in the nation. The resulting landmark legislation — the Oregon Clean Electricity and Coal Transition Plan — sets a target of 50 percent renewable energy by 2040 and also transitions Oregon off of coal-fired electricity by 2035. As a result, Oregon's electricity sector will substantially reduce greenhouse gas emissions; PGE will be 70 percent carbon-free by 2040. And we can't stop there. We have more to do to achieve our new 2050 greenhouse gas reduction goal.

In the near term, we are continuing to pursue renewable resources to meet our customers' needs and decarbonize our portfolio. With the additional 100 MWa of renewables approved by the Oregon Public Utility Commission in December 2017, we will be on track to serve approximately 50 percent of our customers' energy needs with clean and renewable energy by the end of 2020. Simultaneously, we are pursuing new renewable product offerings for our customers who want to decarbonize even faster, such as the Green Future Impact, PGE's recently approved green tariff product, whereby businesses and municipalities can purchase directly from a new, additional renewable facility.

As our region's population and industries grow, we are planning for new, cost-effective and more sustainable ways to generate electricity using renewable resources. We are also developing new capabilities to more efficiently integrate these renewable resources into our portfolio to lower costs and enhance reliability. This includes joining the Western Energy Imbalance Market and embarking on new initiatives to support the development of flexible distributed resources, such as energy storage and smart technologies.

Figure 6: Greenhouse Gas Reduction Goals



4.6(a) Modernize through a smarter, more resilient grid

We will build and operate a smarter, more flexible and resilient grid to improve operations and enable seamless integration of new technologies. The efficient integration of devices and information will require innovation and development of new grid capabilities. We are committed to providing customers with a platform capable of interconnecting and leveraging these technologies to benefit the communities we serve and support the transition to our clean energy future.

4.6(b) Empower our customers in their energy technology choices

Our customers' expectations are changing as new energy technologies, like solar panels, smart technologies and battery storage, are finally available to suit their desires. We will partner with our customers to integrate their own technologies, provide them with real-time information and maximize usage of clean energy through a modern, enhanced grid.

4.7. Equitable and Affordable as a Foundational Principle of the Smart Grid[23]

When PGE envisions the future, we're inspired by the growth of clean energy, along with the environmental benefits and job opportunities that come with it. We see a two-way power grid that

[23] PGE will be publishing a strategy paper that details its vision for an equitable energy future in 2019. Once published, it will be available at: https://www.portlandgeneral.com/our-company/energy-strategy/oregons-clean-energy-future

lets customers choose when and how to use energy, with incentives for helping us manage demand.

Societal inequities, though, make it harder for some people to access energy-saving and clean energy programs, technologies and jobs. For everyone to benefit from a clean energy future, we must break through economic, cultural and linguistic barriers to ensure everyone has a seat at the table when making decisions that define our path forward.

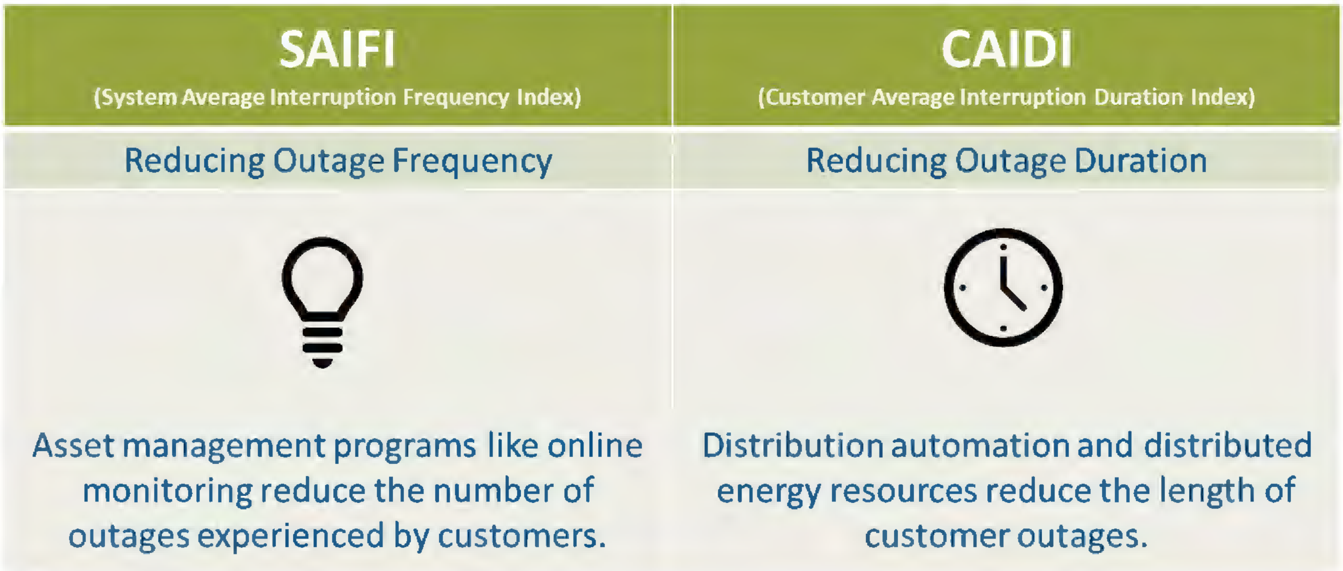
At PGE, we deliver an essential service that plays a critical role in the vitality of our communities. We must continue to transform our energy system in an inclusive manner that addresses disparities head on. We must also avoid policies and regulations that shift costs from higher-income customers to lower-income customers. This is a serious commitment, and we embrace our role in connecting energy resources, partners and customers with a truly Integrated Grid. Our work requires ongoing collaboration with other energy providers, municipal and public partners, and those we serve. For example, community groups play a critical role in shaping public processes and must continue to be invited to discussions about equitable policy-making. Together, our efforts drive toward an equitable, clean energy future in which everyone can participate.

4.8. Reliability and Resilience as a Foundational Principle of the Smart Grid

Smart grid technologies are instrumental in increasing grid reliability and strengthening resiliency. These technologies allow threats to system operations to be identified early and for corrective action to be taken. Self-healing properties of smart grid technology mean that threats to system integrity are prevented or repaired even before they threaten widespread failures. The location of failures can be pin-pointed quickly and accurately, requiring fewer truck rolls during restoration and leading to reduced system restoration costs and total outage time, reducing potential costs to customers due to lost productivity, public health and safety hazards, food spoilage, and inconvenience from schedule disruptions. System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI) are two indexes used by PGE to monitor and measure smart grid reliability (Figure 7).

As PGE gains more experience with batteries and microgrids through our UM 1856, UM 1751, and SB 2193 activity we will better understand how such investments and strategies are part of our foundational activity. The activity we are and will be undertaking in UM 1856 will highlight how best to utilize energy storage to provide reliability and resiliency to address emerging grid issues. Co-optimizing the capabilities and value streams of batteries paired with local generation for microgrid capabilities will inform PGE, the Commission and stakeholders of distribution system values, local customer values and broader grid values. As an example, PGE envisions batteries as a strategy to address distribution system limitations and high current, high demand transportation electrification requirements for large fleet vehicles such as municipal fleets like buses and short to long haul electrified trucking demand.

Figure 7: Smart Grid Reliability Indices



4.9. Key Strategic Outcomes

By investing in the Integrated Grid, the Smart Grid concepts related to customer products and services, and a bi-directional grid, will become a reality. The bi-directional grid will be enabled by technology investments, such as the ADMS and FAN, and allow PGE to offer and incorporate customer adopted technologies such as rooftop solar, energy efficiency, demand response, and electric vehicles.

Additional information about strategic outcomes of the Integrated Grid are detailed in Section 3.

4.10. Smart Grid Value Proposition

The value of smart grid investments arises from capital deferral, operations and maintenance efficiency, revenue capture, energy source and environmental externalities, reliability, safety and customer satisfaction. PGE, through our demand response program efforts, has invested in the development and utilization of a demand response management system or DRMS. DRMS and Distributed Energy Resource Management Systems (DERMS) have two similar primary functions; to dispatch and monitor resource performance. This capability is an important operational requirement for Integrated Grid work. As we look to leverage distributed resources to serve grid needs we need a way to dispatch and monitor performance as we would with any supply side generator. While current DRMS and DERMS are not as detailed and sophisticated as generator controls and operations interfaces they will evolve. Our current DRMS is part of our cost-effective investment in demand response. As our demand response program capabilities evolve into flexible demand and expand to include control of electric vehicle charging infrastructure and distributed generation and storage so too will our DRMS/DERMS capabilities. As our capabilities, confidences and sophistication of control, communication and visibility evolve through these and our Integrated Grid investments we will enable greater utilization and penetration of distributed energy resources. In monetary terms, the operational benefits of smart grid investments may not be exactingly quantifiable through traditional benefit/cost models. Value derives from the stacking of use cases, as in the case of battery storage.[24] Many smart grid technologies are foundational, meaning that their value is spread throughout the generation, transmission and distribution system as well as at the customer touchpoint, making it difficult to isolate the benefits and costs without more granular system modeling. Additionally, it is difficult to quantify societal benefits as demonstrated by US EPA's attempts to model the social cost of carbon. PGE will be conducting modeling efforts within our Distribution System Planning work and will be sharing the development of and output from these models with the Commission and stakeholders in the Commission Distribution System Planning Docket UM 2005.

4.11. PGE Smart Grid Report Themes

In this Smart Grid Report, PGE has modified the way we have organized smart grid initiatives to reflect higher levels of integration than captured in prior reports. Initiatives are grouped by theme in a way that reflects how different technology assets and operational practices enable and empower customers. The themes identified in the following table are used to organize PGE's Smart Grid initiatives.

Table 4: Smart Grid Report Themes

Report Theme	Description
Customer Engagement & Empowerment	Initiatives that deliver: • Customer choice • Customer access to dynamic usage information • Customer convenience and affordability • Customer bill management tools • Customer total energy usage control • Future orchestration of internet-of-things smart appliances and other grid-connected network devices
Data & Analytics	Initiatives that enable PGE to: • Ensure availability and access to energy system and customer information • Optimize decision-making whether for real-time operations or long-term planning • Gain insights into grid planning and operation challenges • Gain insights into barriers and challenges faced by customers

[24] OPUC Docket No. UM 1751 Order No. 17-118, Available at: https://apps.puc.state.or.us/orders/2017ords/17-118.pdf

Connecting & Enabling Technology	Initiatives that enable: • Interoperable communications • Self-healing grid capabilities • Autonomous data collection to enhance situation awareness • The ability to stack distributed energy resource use cases to cost effectively address planning needs • Optimal deployment of advanced distributed technologies to support cost effective decarbonization • Enhance grid reliability, resilience and safety
Transportation Electrification	Initiatives that enable PGE to optimize customer adoption of electric vehicles while accelerating TE in Oregon.
Research & Development	Initiatives that yield insights for: • Cost effective innovation of new products and systems • Improvement in the performance of existing products and systems • Validation of emerging technologies that may hold promise for future efficiencies
Physical & Cyber Security	Initiatives that enable PGE to prevent unauthorized incursion, attack, vandalism and/or theft of PGE and customer physical and technology assets

Section 5. Evolution of Smart Grid

5.1. Moving from Concept to Reality: Integrated Grid as the Smart Grid at PGE

5.1(a) Transitioning from Report to Action

PGE's activities to develop a smart grid are a response to policy and market dynamics. PGE is aware that customer choice is necessary and must be met with a system capable of supporting the new dynamics of connectivity, choice and control. As legislators and regulators in Washington D.C. and Oregon look to future energy needs and the imperative to decarbonize while containing costs, they are looking to the utility to advance the electric grid in support of those drivers. It is critical that this grid be enabled by technology to reach deep into the distribution system to acquire benefits such as flexibility from connected DERs to support the broader system. PGE now envisions this system as the Integrated Grid, a network as first envisioned in the PGE 2014 Smart Grid Report.

The arc of PGE's Smart Grid Reports shows a progression from concept to action. The 2012 Smart Grid Report identified smart grid assets such as demand response and distributed energy resources as viable alternatives to supply side resources. This first report was an exploration of what a smart grid might be. Over subsequent years the number and complexity of the projects increases, and project funding has shifted focus to the distribution system. Incrementally, the Smart Grid initiatives explored by PGE focus on technologies meant to communicate, visualize and control assets on the distribution system. At the time of the 2019 PGE Smart Grid Report, PGE has progressed to a point where PGE's vision of the Smart Grid has progressed past concept to implementation. Through the combination of two major activity streams, the Integrated Grid and distributed energy resource development, PGE is now planning for and investing in the Smart Grid first envisioned in earlier PGE Smart Grid Reports.

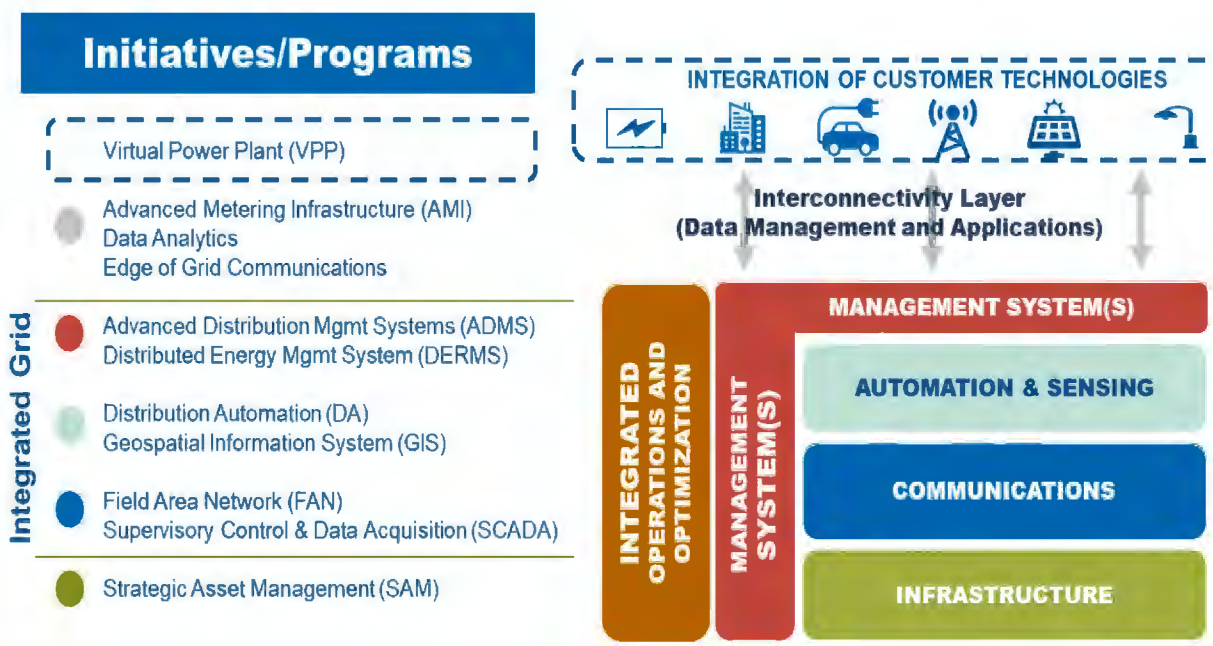
Additionally, we have seen a new pathway emerge in the 2017 and 2019 Smart Grid Reports, electrification of the transportation sector. This is a major policy concern for not only Oregon but the rest of the country, directly connecting the transportation sector to electric sector to capture significant additional reductions of GHG emissions. Though PGE is not like the Oil Majors (Shell, British Petroleum) or the vehicle manufacturers, the utility does have a place in communicating and making available the benefits of transportation electrification. An electric vehicle, unlike a fossil fueled vehicle, can be plugged into this larger shared system. The ability to engage the Smart Grid empowers the customer to extract additional benefits from their transportation electrification investment. The vehicle owner can spread those benefits, keep or share with a larger system and community. In Oregon the transportation sector is responsible for more GHG emissions than any other sector. [25] This is not the case for the remainder of the country. To accelerate Oregon's reduction in GHG emissions it must be prepared to support the development of transportation electrification. PGE has a duty to ensure that the development of transportation electrification limits the strain on the electric grid, the need for new resources and rate increases and at the same time accesses the flexible load potential of transportation

[25] Oregon Department of Energy, Greenhouse Gas Emissions Data, Available at https://www.oregon.gov/energy/energy-oregon/Pages/Greenhouse-Gas-Snapshot.aspx

electrification as a resource. All of this activity must be done while also ensuring equity and fairness.

BPA's Energy Web, the Olympic Peninsula Project and the Pacific Northwest Smart Grid Demonstration Project all looked to leverage the electric distribution system. It was thought at that time that this was the Smart Grid concept. However, what lacked was a large enough information technology (IT) machinery to reach, communicate and visualize these resources. Most of this was done by modeling or simple dispatch notices; on/off notification for hour long periods of time. Now with an IT infrastructure on the backbone of the physical infrastructure, we can develop resources sited on the distribution system. Therefore, our Integrated Grid concept is our first conceptualization of what we will be planning for in the distribution system planning docket UM 2005. Developing this Integrated Grid comprised of physical and IT infrastructure will empower customers through product and service choices, whether brought to those customers by the utility, the Northwest Energy Efficiency Alliance, the Energy Trust or a third party. Because the concept of the reasonable rate is tightly tied to lowest cost, our network needs to be large and capable enough to handle high data volumes, interoperable languages, and partnership. Thus, a very robust system such as the Integrated Grid is needed, where we can build such a robust system through the integration of DERMS, ADMS, FAN, SCADA, EMS, OMS, and FAN (refer to Section 6.3).

Figure 8: Integrated Grid Program Visual



We contend therefore that the evolution of the Smart Grid and the Smart Grid Report has progressed to a point where the Smart Grid for PGE is a reality and should be treated as such, a major event, an area of investment for PGE and its customers. PGE questions whether future Smart Grid Reports as envisioned in 2012 are necessary. As PGE continues to engage with the Commission through UM 2005, outlining the requirements of distribution system planning, PGE believes the Smart Grid Report in large part may become redundant to present planning and programmatic activity. Our Integrated Grid work encompasses much of the activity delineated in the 2019 Smart Grid Report. We envision distribution system planning and distribution resource planning will meet the intent of the Commission's vision of the Smart Grid Report as a progression to planning for distribution resource development.

5.1(b) The Regulatory Compact, "Affected with a public interest" utility as public shared investment to spread public benefit

The U.S. Supreme Court in the case of Munn v Illinois found that when an entity's activities within the market are so pervasive to have been "affected with a public interest" such activities and the rates they charge should be regulated by the government.[26] This eventually led to the idea that to deliver electricity in the most economically efficient manner monopoly of service could be granted to an entity. Such monopolies allowed for collective investment in large, expensive and long-lasting infrastructure capable of serving all customers. In exchange for monopoly service these "utilities" would allow the government to regulate their rate of return on investment. This balance of shared investment, monopoly service and regulated profits is known generally as the "regulatory compact". Though we now live in a world where such business models are easily disrupted through digital technology offerings the concept of a shared investment in necessary infrastructure is just as valid. To capture and deliver the benefits which a smart grid can offer customers, investments must be made according to an approved plan. Developing the Integrated Grid and its information technologies, advanced communication and grid operation capabilities is most efficiently developed through shared investment. Such a platform system, once developed, will enable customers greater control of their overall energy costs whether to heat or cool their home or power their vehicles. Such a system with distributed intelligence can allow customers to extract various monetary benefits for participation and sharing of benefits with a larger community. PGE believes the Smart Grid represents such investments and our Integrated Grid will be a manifestation of these smart grid capabilities which will serve as a platform to highlight and spread benefits of a carbonless, distributed system of resources and intelligence which can be "plugged into" by the customer and other new market entrants.

5.2. Integrated Grid Roadmap

To empower customers with energy service choices, PGE is guiding investments in formation of an Integrated Grid. The Integrated Grid is necessary to enable future distributed energy resource development. The Integrated Grid Roadmap is a series of initiatives that will enable more connected and dynamic distribution system operations being deployed through a series of coordinated projects in the next five-year timeframe.

In addition to emerging pilots and programs, it is important to be mindful of expected changes coming to our system. Over the next 5-years, PGE anticipates substantial growth of distributed solar, demand response, electric vehicles, central wind generation, and energy storage:

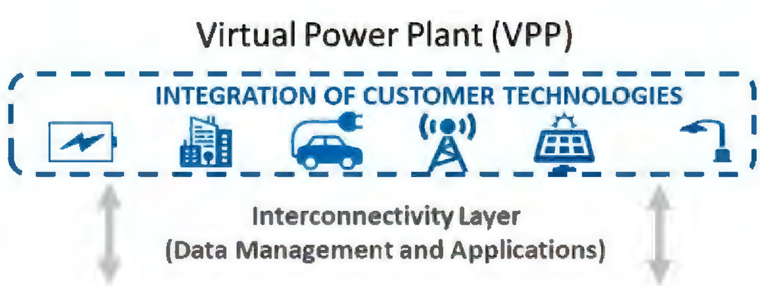
[26] Munn v. Illinois, 94 U.S. 113 (1876)

Figure 9: Integrated Grid Roadmap

	2019	2020	2021	2022+
INTEGRATED GRID INITIATIVES				
DERMS	Operation of existing platforms		Select Future Architecture/Toolset	DERMS Implement/Interface
ADMS	Project Planning Phase	Phase 1 DSCADA, DMS Core	FLISR & Advanced Applications	
DA	10 Feeders 40 Switching Devices	16 Feeders 64 Switching Devices	22 Feeders 88 Switching Devices	22 Feeders 88 S.D. 2022 & 2023
GIS	Update GIS data model to support ADMS implementation and operation			
FAN	Design/Phase 1 Implementation	Phased construction of full network		
SCADA	Ongoing deployment of advanced SCADA to distribution substations for reliability and automation purposes			

The above roadmap of Integrated Grid activities enables the following customer program activities and services. These customer programs have been visually represented as part of the complete Integrated Grid in Figure 8 above.

Figure 10: Integrated Grid Customer Programs



5.3. Integrated Grid Strategic Outcomes

5.3(a) Transportation Electrification

The Integrated Grid enables PGE to manage costs associated with serving the transportation sector. Through our communications network and transportation electrification initiatives, PGE will be able to better manage the high-energy, intermittent load inherent in electric vehicle charging, across the spectrum of small personal vehicles to large fleet trucking vehicles. PGE is working in UM 1811 and UM 1826 to craft customer programs which leverage the capabilities of the Integrated Grid to capture benefits and reduce overall system costs. PGE will be submitting a Transportation Electrification plan pursuant to Docket No. AR 609. This plan will also highlight the connection to the Integrated Grid.

5.3(b) Demand Response

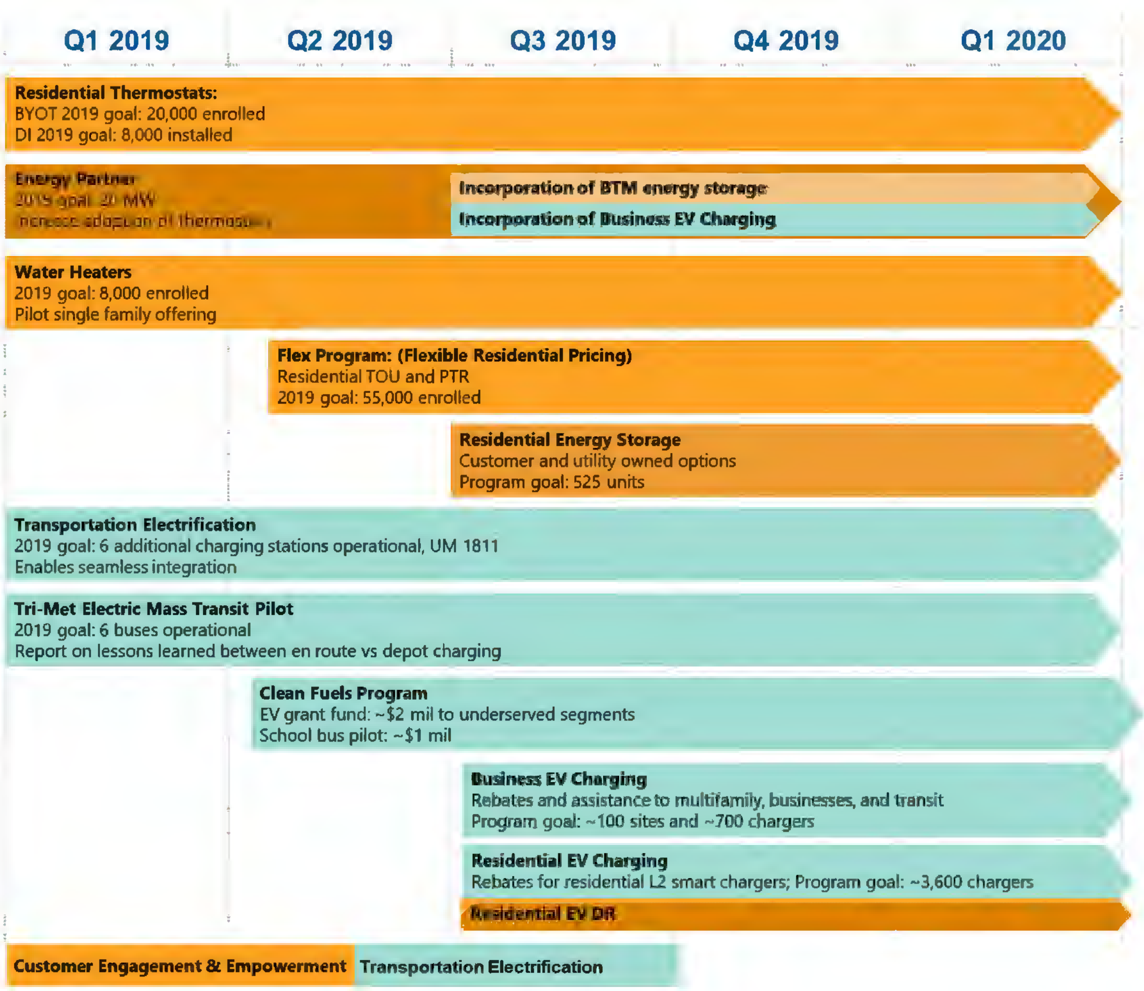
PGE's work to develop customer-enabling demand response programs has matured rapidly since 2015. Through Docket No. UM 1708, UM 1514, and the Commission's decision in docket LC 66, PGE has worked hard to build a portfolio of demand response programs which meet future flexible grid needs. The ability to evolve traditional demand response programs, which operate on a limited capacity basis, to flexible load programs, will be dependent on the implementation of the Integrated Grid.

5.3(a) Energy Storage

Energy storage will be a major resource of the future electric grid. The Integrated Grid will enable the unique capabilities of energy storage, allowing energy storage solutions to provide a host of services to balance intermittent generation, store overproduction, and provide resiliency, reliability, and non-wire solutions.

The following figures present a high-level roadmap of the above customer programs, which are enabled by the Integrated Grid.

Figure 11: High-Level Roadmap, Customer Programs Enabled by Integrated Grid



5.4. Alignment with Integrated Resource Plan (IRP)

In the decades ahead, PGE’s smart grid efforts will facilitate interconnection of increasing amounts of variable renewable resources to our system. System operators will be able to leverage demand-side resources and a more dynamic grid to help balance an increasingly variable power supply. This evolution, in conjunction with increased efficiency of the transmission system and PGE’s participation in the Energy Imbalance Market will optimize the use of resources to provide a clean and green, equitable and affordable, and reliable grid. PGE includes smart grid technologies as viable resources in the IRP as they mature, similar to the way cost-effective energy efficiency and demand response are considered. As such, many of our Smart Grid initiatives will continue to be part of a continued two-way conversation between program/system planners and the IRP team and will be included in PGE's IRP process.

Table 5: Smart Grid Studies to Inform IRP

Report Name
Navigant Distributed Resource and Flexible Load Study
Navigant Electric Vehicle Charging Infrastructure Study
ICF Distribution Resource Planning Study
Deep Decarbonization Pathways Study
Residential Appliance Saturation Survey
Customer Insights Study
Cadmus Flex 1.0 Pilot Evaluation Study

Table 6: IRP Public Meetings discussing Smart Grid

Date	IRP Meeting
5/10/17	Energy Efficiency
8/24/17	Decarbonization
2/14/18	Decarbonization Study Results
2/14/18	Customer Insights
2/15/18	EE Impact Forecast
2/15/18	DER Modeling
7/11/18	DER and Flexible Load Study Update
8/22/18	DER and Flexible Load Study Methodology Overview
9/26/18	DER and Flexible Load Study Final Results
11/28/18	Final IRP DER Scenarios
12/19/18	Distribution Resource Planning

5.5. Future of Smart Grid Report

PGE, as stated above, believes that the Smart Grid Report and many of the activities found within the Reports over the years have evolved from R&D, pilot and coordinating activities to utility standard course of business and major investments which now have separate dockets of their own or new processes are being developed to guide the activity.

For example, over the last two to four years and as a result of Order 17-386, PGE's demand response activity has rapidly matured and is now significant enough to require a process and dockets of its own. The activity additionally resulted in technical and feasible potential studies which have been reviewed by the IRP stakeholder group and have been incorporated into and thus is informing the activity and action proposals to be found in PGE's 2019 IRP. Similarly, transportation electrification has matured such that new administrative rules have been developed which require the filing of a transportation electrification plan. Energy storage has also developed through HB 2193 and dockets UM1751 and UM 1856. Lastly, through Dockets UM 2005 (distribution system planning) and UM 2001 (distributed generation interconnection) PGE believes the Smart Grid Report may become a redundant exercise.

Within the next two years, particularly, through distribution system planning, PGE's planning and investments in our Integrated Grid activity will be guided and overseen by the Commission through a Commission led planning process. As envisioned by Commission Staff at the UM 2005, May 4 workshop, DSP will at some time connect to the IRP process. Both processes are open processes with multiple stakeholders. Both IRP and DSP processes do or will require the submittal of a multi-year plan including assessment of near term and long-term investments.

Thus, PGE suggests that we revisit the purpose and need for the Smart Grid Report going forward.

Presently, the only activity recounted in the Smart Grid Report which will not have a process requiring either a formal plan, separate process and policy docket or regular reporting would be the Research and Development work conducted by PGE which is regularly reviewed in general rate cases.

Section 6. Status of Current Smart Grid Initiatives

6.1. Customer Engagement & Empowerment

6.1(a) Customer Engagement Transformation (CET): Customer Touchpoints Project

PGE's Smart Grid capabilities were enabled by this multiyear program which went live in 2018, comprehensively optimizing PGE business management systems and processes. CET involved streamlining business procedures, implementation of more efficient organizational and employee development practices and customer engagement strategies, and replacement of two large customer systems

- Customer Information System (CIS)
- Meter Data Management System (MDMS)

The CIS and MDMS went live in May of 2018, and the project was officially completed in Q2 2019. Replacing these systems has afforded PGE the opportunity and functionality to enhance the customer experience through use of automation and modernized billing practices data collection and management and customer care protocols.

The benefits of CET to smart grid engagement derive from more systematic data collection, tracking, and reporting, easier setup and configuration of programs, and making processes for setting up new rates and for billing more predictable and reliable, including billing under variable rates schedules like TOU pricing. Smart grid benefits also stem from more robust and automated validation, editing and estimation (VEE) for interval data and capabilities for self-service data access and more accurate identification and targeting of customer candidates for demand reduction initiatives.

Status: Deployed, Stabilization

6.1(b) Energy Expert

Energy Expert is an advanced energy monitoring platform available to PGE's large commercial and industrial customers for a fee. This is a PGE competitive operation. Energy Expert uses 15-minute interval meter data to give customers a highly accurate view of energy consumption over time.

PGE has offered energy monitoring services for over 10 years, and the current version of Energy Expert (version 6) has been available since June 2015. The platform features include:

- Display of advanced customer energy information data (consumption, historic trends, load profiles, cost savings opportunities, peak reports)
- Identification of abnormalities or areas for operational improvements
- Consolidation of weather data, time of day, day of week to predict energy usage
- Notifications and alerts
- Comparisons to historical data to track savings associated with energy conservation activities

To help ensure that PGE's business customers are aware of the Energy Expert tool, the program holds webinars, workshops and onsite demonstrations to help potential users understand the benefits of monitoring daily energy usage. Currently 105 customers are using Energy Expert to monitor over 500 meters.

Table 7: Number of Customers Utilizing Energy Expert by Year

Metric	2014	2015	2016	2017	2018
# Customer Utilizing Energy Expert	97	105	108	112	105

Status: Active Deployment

6.1(c) Energy Partner

PGE launched the Energy Partner automated demand response (ADR) pilot for commercial and industrial customers in 2013. The initial goal was to use automated controls to enable participants to respond to events with as little as 10-minute notice. The primary candidates were customers with 30kW of demand or higher. To manage the program and coordinate enrollments PGE contracted with EnerNoc to function as a demand response aggregator. At its peak, demand commitments of 13.1 MW were attained in the winter 2016-2017 season, since then, loss of customers to direct access and poor event realization rates caused nominated commitments to drop below 8.5 MW in subsequent months. EnerNOC, Inc. and PGE ended the aggregator contract in September 2017.

Table 8: Energy Partner Participation and Progress

Metric	2014	2015	2016	2017	2018
Participants	24	39	57	45	50
Maximum Available Winter Capacity (MW)	6.3	6.3	13.1	3.0	12.5
Maximum Available Summer Capacity (MW)	2.7	9.1	11.1	10.6	15.2

Status: Pilots & Evaluation

Using input from a third-party evaluator, PGE redesigned the Energy Partner program to create enrollment options for all non-residential customers regardless of size and provide more flexible participation options.

- A direct load control thermostat pilot, defined by Schedule 25, was created to allow small and medium sized non-residential customers to participate.
- Schedule 26 created an enhanced version of the program for larger non-residential customers. In the new program participants may choose their level of participation with options for seasonal availability, total hours of participation, hours of availability per day, and notification requirements.

To manage the new programs PGE contracted with CLEAResult Consulting Inc. to coordinate the customer enrollment and enablement process and with Enbala Power Networks, Inc. to provide the demand response management system (DRMS). Customers began transitioning to the new programs in Q4 of 2017. By the end of the summer 2018 DR season 95% of the customers in the previous program had transitioned to the new program.

6.1(d) Firm Load Reduction for Commercial & Industrial Customers

Through Schedule 77, PGE offered a demand response (DR) program to large non-residential customers who were able to commit to a >200 kW demand reduction for 4-hours from a single meter. The program was launched in 2010 and at its peak, there were three customers enrolled in the program who were able to reliably demonstrate load reductions of 18.3 MWs during events. These reductions were considered as a resource in PGE's integrated resource plan (IRP).

Though customers committed to a specific level of curtailable demand, additional load reductions above the commitment were often experienced. In the summer of 2015, program participants exceeded contract curtailment goals in all four events called.

Despite the success of the program in 2015, participation diminished in subsequent years. Of the three customers that were active in the program in 2015, one left the program to participate in the Energy Partner program (see below) and a second customer – which represented 87% of the demand reduction capacity – was purchased by a competitor and later closed. Service under Schedule 77 ended on November 30, 2017 and the final participant was transitioned to the Energy Partner program.

Table 9: Schedule 77 Program Progress

Metric	2014	2015	2016	2017	2018
Participants	3	3	1	1	0
Maximum Available Winter Capacity (MW)	18.3	18.3	1.8	1.8	0
Maximum Available Summer Capacity (MW)	18.3	18.3	1.8	1.8	0

Status: Program ended 11/30/2017. Included here instead of in Completed & Archived section for comparison purposes with the Energy Partner program.

6.1(e) Smart Water Heater Market Transformation

PGE is positioned for a major regional market transformation initiative that would create an estimated demand response (DR) capacity resource of about 90 MW in 2039. The initiative would cause a CTA-2045 communication interface built into all electric water heaters shipped into the Pacific Northwest. This cost-effective DR initiative is a critical component of PGE's residential sector DR strategy and strategy to address smart grid equity objectives in low income households.

A standard communication socket on all water heaters means that once a customer enrolls in the program, PGE would send the customer a communication device that the customer would plug into the water heater to enable remote management.

Status: PGE's launch of the initiative is contingent on a minimum of 4 larger utilities agreeing to fund the market transformation program over a 9-year period at an estimated cost of $40 million.

The present value of all PGE costs to create and operate the 90 MW DR resource (including PGE's share of the market transformation initiative) thru 2054 would be about $27 million. The net present value of avoided capacity costs would be $40 to $80 million depending on what fraction of a full combustion turbine cost is included as benefit. Revising state codes to require a CTA-2045 communication interface on all electric water heater standard prior to 2028 would substantially reduce the initiative's cost.

6.1(f) Low Income Customer Engagement

It is important that new program initiatives are accessible and meet the needs of all PGE customers. Though PGE does not collect income data from customers, we estimate that approximately 17% of our residential customers are low-income or otherwise in need of special attention to easily interact with PGE. PGE ensures that the needs of economically disadvantaged and other special attention customers are considered through a variety of efforts in research, program development, outreach, and OPUC engagement. The research and outreach process includes discussions with customers to learn what kind of challenges they are trying to overcome. We validate through interviews and outreach with Community Action Agencies including the biannual meetings PGE facilitates with Community Action Agencies to talk openly about challenges and creative solutions with key low-income community stakeholders. These insights collectively help inform how PGE markets and develops programs.

PGE provides Community Action Agencies(CAAs) with information and program marketing materials to distribute to customers that educate them about tools available to help manage energy use and bills such as Energy Tracker, mobile alerts, Preferred Due Date, and Equal Pay.

PGE is also working to develop programs that respond to the requests of this customer base. Recently, PGE conducted workshops with CAAs to discuss the fundamentals and benefits of electric vehicles. Recent focus groups involving lower income customer segments highlighted interest in peak time rebates as a risk-free, non-punitive pricing program. As a result, peak time rebates are being evaluated in the Flex Pricing Pilot.

Low-Income Customer Segments within the Special Attention Population:

- **Seniors** – Estimated 39% of Low-Income Customers
    - Low Income Seniors living solely on Social Security and the Energy Assistance process can be overwhelming to navigate
- **Single Family** – Estimated 23% of Low-Income Customers
    - Working Poor – Single parent with small children and a minimum wage job, struggles to pay household bills and is often late paying bills.
- **Newly Low Income** – Estimated 4% of all residential customers
    - Recent job loss or crisis and not familiar with low-income resources
- **English Not Spoken at Home** – Estimated 20% of all residential customers
    - Customers from other countries or cultures who have difficulty speaking English and navigating the energy assistance process
- **Living with Disability** – Estimated 10% of all residential customers
    - Customers with physical or cognitive challenges that may make daily tasks more difficult

6.1(g) Fire Station Microgrid

In 2016, PGE, ETO, and PUC Staff participated in the Rocky Mountain Institute's e-Lab Accelerator program to discuss opportunities for solar plus storage microgrids. Though not a participant in the program, the City of Portland is eager to demonstrate energy storage to support their resiliency efforts, to create a training tool for emergency response, and to reduce facility operating costs.

In October 2016, PGE's Renewable Development Fund (funded by voluntary contributions from PGE customers) awarded the City of Portland a $89,959 grant towards the cost of a solar plus storage single site microgrid at Fire Station #1 in downtown Portland. The RDF only funded the solar portion of the project; City of Portland is funding the storage portion. The City intends to use the funds to install a 30 kW solar array and 30 kW/60-120 kWh battery to create a microgrid at the fire station. PGE is working with the City to scope the project and plan for interconnection. PGE hopes to offer an incentive to the City for control of the battery to call demand response. The City will use the storage for back-up, demand charge optimization, and training.

Status: Planning Demonstration Project

Next Steps: The anticipated construction for the facility is Q2 or Q3 of 2019. The project has taken longer than expected due to changes in suppliers and permitting.

6.1(h) Multi-Family Water Heater

The 2016 Integrated Resource Plan identifies significant cost-effective demand response in the existing water heater market. In April 2017, PGE submitted a deferral request to implement water heater demand response pilot targeting multifamily residences. The program pilot would run through the end of 2019 and targets 8,000 water heaters over the 30-month pilot.

This program would work with property managers to target large multifamily complexes to enroll in direct load control of existing and new smart water heaters. Two-way communicating switches would be used for existing water heaters and, where appropriate, PGE would help buy down the cost to upgrade old water heaters to new, smart water heaters capable of connecting to a communications module.

Status: Phase 3 of Pilot

Next Steps: PGE has completed the first two phases of the pilot program and has installed Water Heater Demand Response switches on over 2800 water heaters. A deferral extension was requested to continue to test a 2nd and 3rd switch vendor along with testing Wi-Fi verse cell-enabled switches. We will be conducting an ongoing process and impact evaluation of the program and will share evaluation reports at the end of each program year season.

6.1(i) Residential and Small Commercial Time-of-Use Pricing (TOU)

PGE offers a voluntary program to customers with up to 30kW of demand available via Schedules 7 and 32. The program has approximately 2,300 residential customers enrolled. For the past decade, PGE has limited promotion of the program at the direction of the PUC's

Portfolio Options Committee for reasons of cost-effectiveness. It is actively promoted to EV drivers today. The Flex Pricing Research Pilot (see below) is designed to determine the future TOU rate or rates that will replace the existing TOU rate for residential customers and be actively promoted.

Status: Active Deployment. Met with OPUC staff May 2019 to revise a two-tier time of day pricing proposal. Aligning launch with Smart Thermostat and Smart Water Heater programs.

6.1(j) Smart Thermostat Demand Response Pilot (Rush Hour Rewards)

In 2015, PGE filed a request for deferred accounting (Docket No. UM 1708, Order No. 15-203) to launch a residential smart thermostat direct load control (DLC) pilot which leverages internet-connected smart thermostats as a demand response asset. The pilot launched with Nest in the winter of 2015 (Nest's first winter DR program). The pilot features a bring-your-own-thermostat (BYOT) design making it a great opportunity for our customers who have already taken steps to be more energy efficient, to also find a simple, easy way to shave their peak energy usage. Customers with heat pumps, electric resistance heat, or central air conditioners are eligible to participate. Participants receive $25 for signing up and $25 for each program season.

In 2017, PGE expanded its BYOT offerings to include Ecobee and Honeywell smart thermostats through its Connected Savings program, which is delivered by Whisker Labs. We believe this expansion will allow us to understand how other smart thermostats perform while expanding the same offer to customers owning other commonly used thermostats.

Status: Pilot & Evaluation

The program has now completed three impact and process evaluations with Cadmus and cost-effectiveness analysis, all of which indicate that the program has been successful at achieving cost-effective demand reductions.

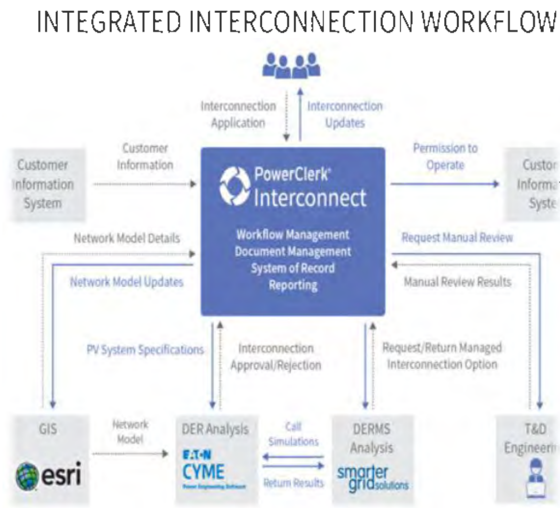
Table 10: Bring Your Own Thermostat (BYOT) Pilot Participation and Progress

Metric	2015	2016	2017	2018	2019 Q1
Participants	142	2,512	4651	13,027	15,501
Maximum Available Winter Capacity (MW)	0.1	0.3	.5	4.4	5.3
Maximum Available Summer Capacity (MW)	n/a	2.3	4.4	12	14.4

Starting in September 2018 PGE started a Residential Thermostat Direct Installation delivery channel. This delivery channel allows Customers who own a qualifying Ducted Heat Pump, Electric Forced Air Heating, and/or Central Air Conditioner but do not own a Qualified Thermostat to participate by receiving one from the Company for free or at a deep discount depending on their HVAC configuration. Thus far roughly 3,000 customers have taken advantage of this offer. This program channel will also be evaluated by Cadmus in 2019.

6.1(k) PowerClerk Software Implementation

Figure 12: PowerClerk Software Integration



PGE has experienced a dramatic increase in the volume of qualifying facility and net metering generation interconnection requests since 2017. In response, PGE has added additional resources including engineering personnel and field construction personnel, and implemented a number of internal process improvements to support the growing number of interconnection projects within PGE's service territory. One of the process improvements was deploying a queue management software package to more efficiently manage the growing number of interconnection requests. In the first quarter of 2019, PGE completed implementation of the PowerClerk queue management software platform. The benefits to our customers from this system include more efficient queue management, faster processing of applications, automated internal and external communication and workflows, and increased transparency for interconnection customers.

6.1(l) Energy Tracker

Energy Tracker is an online customer web portal that displays residential (Schedule 7) and business (Schedule 32, 38, 83, 85 & 89) energy usage & cost in interactive online over-time-dashboards along with personalized energy saving tips. The tool provides:

- Monthly, daily, hourly, and interval (i.e. 15-min) energy use charts
- Export of energy usage data to Excel
- Billing insights that compare one billing period to another
- Savings tips, goals, forecasts and tailored recommendations
- Direct links to ETO incentives for energy efficiency measures

Energy Tracker is central to PGE's strategy of actively engaging customers in using energy more efficiently and affordably. In Q1, 2018, PGE rolled out new energy tracker features further empowering the customer experience with energy tracker through a new user interface and mobile access. Outreach through community actions agencies on how to access and use energy tracker sources energy tracker as a tool for addressing PGE equity objectives.

Status: Active Deployment: More than 230,000 customers use the energy tracker tool and use of energy tracker is estimated to have helped customers reduce their annual energy consumption 3% faster (332 kWh) than customers not using energy tracker.

Next Steps: Future updates will allow for simplified enrollment in Time of Use, Demand Reduction, and other customer programs, provide more energy saving tips.

6.1(m) Flexible Residential Pricing Program (Flex 2.0)

In February 2019, in ADV 920 Advice No. 19-03, PGE filed the Flex 2.0 program with the Commission. To ensure overall program success, in 2019 PGE will focus on Peak Time Rebate (PTR) enrollment, specifically from April to July, to support a robust summer season. PGE aims at sufficient enrollment during the first summer season to gauge overall DR value of these participants. A second PTR marketing burst will take place later in the year to encourage enrollments prior to the winter season kick-off in October. For Time of Use (TOU), PGE will launch an awareness/education campaign in the fall of 2019 to support a broad scale TOU introduction in April 2019. PGE is also exploring a TOU+Smart Thermostat pilot opportunity in September 2019 that would inform marketing efforts for that product combination and would also provide data related to Demand Response value when TOD is combined with technology.

6.1(n) PGE Testbed

The Testbed is a development platform that enables demand response to be deployed at scale and under controlled conditions for experienced-based learning useful for understanding utility scale deployment of DR capacity. Phase I of the DR Testbed aims to generate insights using outreach, education, market research and surveys in attainment of the following goals:

- Identify, develop, and communicate the value proposition of DR to customers;
- Establish and retain a high level of customer participation in DR programs;
- Learn how to recruit and retain customers program participation and translate the lessons into cost-effective strategies for service territory-wide offerings;
- Collect information on DR potential to inform resource potential studies;
- Create new program offerings that can be quickly deployed;
- Coordinate on new program development with other demand-side measure providers such as the Energy Trust and NEEA; and
- Study and understand implications that high levels of flexible load has on system operations.

Differing messaging approaches and engagement models will be tested using technologies including but limited to, Peak-time Rebate, Time of Use, smart thermostats and smart water heaters.

Status: PGE received approval to implement Phase I of the Testbed and will begin implementation during summer 2019.

Next Steps: PGE will work with the Demand Response Review Committee (DRRC), established by the Commission, to inform activity in the Testbed. PGE will work with the DRRC and Staff to inform new activity and possible next steps for the Testbed. Where and when appropriate PGE will work with the DRRC on scoping a possible second phase of the Testbed focused on operations and resource development.

6.2. Data & Analytics

6.2(a) T&D Data Platform & Analytics

Data and analytics is foundational to operating the new Integrated Grid. PGE is building a T&D cloud data platform that will enable PGE to:

- Conduct advanced analytics and data science to better plan for and operate the system
- Share data bi-directionally with external stakeholders
- Test hypothesis in a data lab
- Glean insights and reports on the system

The platform will have the ability to ingest and integrate existing system data, new sources of unstructured data, and data from external partners. PGE is developing this capability incrementally, by prioritizing use cases that will add the most value to T&D.

Status: Phased Implementation, with the following planned for 2019:

- Data sharing capability for specific use cases
- Data science capability for specific use cases
- Data pipeline created to ingest and integrate data in near-real Time, real time, or batch mode for the following data sets:
    - Customer Data, Meter Usage, Alarms, Events, OMS, portions of GIS, and Maximo

6.2(b) Data Governance

To support the expanding data platform and analytics capabilities, and to ensure compliance, PGE is developing and implementing a Data Governance framework to ensure data security, data quality and metadata management.

Status: Planning phase

Next Steps: Implementation in 2020.

6.2(c) Remote Sensing Data Acquisition & Analytics

PGE is in the process of obtaining high-fidelity remote sensing information (e.g., LiDAR, hyperspectral imagery, high-resolution orthoimagery) across PGE's service territory. The program is intended to improve safety by enabling assessment of clearance discrepancies, improve system reliability by proactively identifying and mitigating vegetation outage risk, and improve productivity by streamlining work processes via desktop analysis of the T&D infrastructure. Acquisition of the high-fidelity geospatial data produced using remote sensing technologies will enable a data audit of PGE's GIS and streamline the reconciliation between land base and GPS coordinates collected during survey operations. Planning new infrastructure and improvements to the T&D system will become faster, easier, and more accurate as PGE operationalizes remotely sensed data and builds analytics on top of these data.

Status: Acquisition of PGE's T&D overhead lines in progress and schedule to be completed by September 2019.

Next Steps: In future years, PGE will build out capabilities leveraging the high-fidelity data captured by remote sensing technologies including enhanced predictive analytics, planning capabilities, and data reconciliation activities.

6.3. Connecting & Enabling Technology

6.3(a) Communications Upgrades

PGE is upgrading fiber and wireless communications networks to enable 2-way communications to the constantly evolving network of intelligent electronic devices (IEDs) and the data they create.

Fiber and Wireless Infrastructure

The Smart Grid depends on communications networks that allow data to be transmitted quickly and reliably. PGE's network of intelligent electronic devices (IED) is constantly growing in complexity and capabilities driving PGE to continually upgrade its fiber and wireless communications infrastructure. PGE facilities also require periodic communication upgrades to allow faster and more resilient communication between each other and PGE's data centers.

Status: Continuous Deployment

Communications Network Upgrades

PGE is upgrading its communications infrastructure to bring the technology current and allow a more flexible network. The upgrades began due to changes being undertaken by the telecommunications industry that will result in the phasing out of copper lines beginning in 2020. Ninety-two of PGE's substations are connected to SCADA via legacy copper lines leased from telecommunications companies. Modernization of the PGE network will begin in 2019 with the installation of a private MPLS (Multi-Protocol Label Switching) network. Full deployment of the MPLS and corresponding technology will enable high speed connectivity and real-time monitoring of thousands of data points at each substation.

Status: PGE will begin installing the core communications network infrastructure and replacing the legacy connections in 2019. Deployments are scheduled to begin at high priority stations and then be extended to other stations. Full deployment is expected to be completed in 2023.

Wireless Assets: 220 MHz and 700 MHz Spectrum

Enhanced wireless communication networks are fundamental to a fully functioning smart grid. PGE has acquired blocks of 220 MHz and 700 MHz spectrum to upgrade PGE's communications network capabilities.

The 220 MHz radio spectrum is being used to build a new LMR (Land-Mobile Radio) system that provides better service territory coverage, allowing PGE dispatchers to more quickly and reliably communicate with and coordinate the efforts of field crews, expediting outage repairs and enhancing worker safety.

The 700 MHz spectrum is being used to deploy a FAN (Field Area Network) that allows more rapid and less expensive wireless data monitoring, management and control of remote assets. The excellent propagation characteristics of 700 MHz signals allow for easy penetration of buildings and walls over larger geographic areas while optimizing infrastructure costs. Use of the FAN includes but is not limited to distribution automation assets, demand management programs, conservation voltage reduction, SCADA, synchrophasors, EV charging, storage, and customer smart devices.

Status: The 220 MHz spectrum has been deployed and is fully functioning as of June 1, 2019. The 700 MHz spectrum has also been deployed. The capabilities of the 700 MHz spectrum will be expanded as new automated assets that can be remotely managed are added to the PGE system.

6.3(b) Field Area Network (FAN)

Description of FAN technology

The FAN is a private PGE owned and operated high reliability, low latency wireless cloud that allows quick and inexpensive data connections to various devices that PGE uses to operate and manage the power grid. A subset of the FAN will allow lower reliability, higher latency connections to customer owned and operated devices like thermostats, EV chargers, garage storage etc. This will also enable PGE to respond to Smart City applications as they emerge.

How the FAN Supports PGE's Integrated Grid Strategy

A FAN is designed to efficiently connect technologies, such as:

- Distribution Automation (DA) such as reclosers for swift fault response and distribution reconfiguration
- Supervisory Control and Data Acquisition (SCADA)
- Demand Response Management System (DRMS). PGE currently employs Embala as its DRMS for visualization and control of all our demand response assets.
- Energy Storage integration
- Microgrid control
- Distributed Energy Resource (DER) management
- Solar integration
- Transportation Electrification (TE) integration
- Automated Metering Infrastructure (AMI)
- Street Lighting Control System Backhaul
- Field Data Communication

How the FAN will Support Integrated Grid Moving Forward

The integrated grid relies on connectivity, sensing and automation/control. PGE's distribution network system currently has limited visibility and communication capability through its SCADA system to existing distribution automation controls. This limited visibility prevents the distribution system from being utilized to enable the efficient deployment of technologies to achieve greater energy efficiency, energy network management and system reliability that customers are demanding.

The FAN will provide the fundamental backbone to allow for the communication and visibility within the power grid network architecture.

6.3(c) Supervisory Control and Data Acquisition (SCADA)

SCADA is control system architecture that uses networked computerized data communications systems to interface with and control the PGE transmission and distribution system (T&D). Deployment of SCADA to substations increases visibility of the grid to T&D operations and reduces the likelihood and duration of outages. Currently 80% of PGE substations are controlled and monitored by SCADA. The primary focus in 2018 was upgrading aging SCADA systems and planning for deployment to additional distribution substations. PGE is also strategically adding SCADA to reclosers and other intelligent electronic devices (IEDs) that will increase the visibility of the grid to T&D operators.

Status: Active Deployment

Next steps: PGE anticipates SCADA deployment at an additional 2-3 substations and replacing multiple aging systems in 2019. Multiple distribution stations will be outfitted with SCADA over the next five years as they are rebuilt to address aging assets. PGE is developing a plan for deploying SCADA to the remaining electronic reclosers and updating the standard recloser installation process to ensure all new devices are installed with SCADA.

Description of SCADA Technology

SCADA systems provide critical information and remote-control capability to system dispatchers and the Balancing Authority. Initially, SCADA was deployed at Transmission substations to ensure reliability and stability of the Bulk Electric System while balancing the utility's load with generation, negating the need for manned stations. Over time, the value of SCADA expanded to include safety and distribution reliability, increasing situational awareness and decreasing outage response times. Traditionally, SCADA transmitted limited information like circuit breaker status and transformer loading. The number of SCADA points per station has expanded to include equipment alarms, enabling proactive response to emerging issues. SCADA is now a critical component of an Integrated Grid, enabling safe, reliable two-way power flow and optimization of grid assets.

How SCADA Supports PGE's Integrated Grid Strategy

Deployment of SCADA to substations increases visibility of the grid to T&D operations and reduces the likelihood and duration of outages. Currently 80% of PGE substations are controlled and monitored by SCADA. In 2017 and 2018, PGE added SCADA to four distribution substations and one transmission substation while upgrading SCADA at three critical distribution substations. PGE is also strategically adding SCADA to reclosers and other intelligent electronic devices (IEDs) that will increase the visibility of the grid to T&D operators.

How SCADA will Support Integrated Grid Moving Forward

PGE is deploying SCADA at three distribution stations in 2019 and two distribution stations in 2020 as they are rebuilt to address aging assets. SCADA deployment to the remaining distribution substations will be planned in conjunction with the Distribution Management System implementation. Prioritization of the SCADA deployment plan will be based primarily upon reliability issues, wildfire risk mitigation, and DER interconnection requests. PGE is developing a plan for deploying SCADA to the remaining electronic reclosers and updating the standard recloser installation process to ensure all new devices are installed with SCADA.

6.3(d) Substation Remote Access Server

In 2014, PGE activated a substation remote access server which allows remote visibility to IEDs which speeds up restoration time and saves on operation & maintenance costs. Additionally, it provides access to data related to asset monitoring, disturbance monitoring, and real-time operations. Currently, 35% of substations and plants, plus our two control centers, are connected to the Substation Remote Access Server.

Status: Active Deployment

Next steps: PGE anticipates continued deployment of substation remote access to new and existing stations. Deployment will be accelerated by leveraging the private Transport Services network that the Communications group is implementing.

6.3(e) Advanced Distribution Management System (ADMS)

ADMS (Advanced Distribution Management System) is a PGE business imperative that will enable real-time management of the distribution system at a more granular level than what is capable today by leveraging use of automated technologies for system management, coordination and optimization. The result will be better reliability, improved power quality, increased operational efficiency, and enhanced system safety and security. These benefits will become more evident with migration to a dynamic distribution system integrating distributed resources.

System functions enhanced by ADMS include heightened situational awareness through SCADA, real-time network connectivity analysis, and faster and more accurate information on distribution network operating state and radial mode. ADMS will also facilitate Power Flow and State Estimation which provides insight into system voltages and power flows in areas which are not metered, enabling advanced applications and tools that can predict faults and allow proactive detection and mitigation of threats to system interruptions, failures and outages

Status: PGE is in the process of planning ADMS with core functions to be implemented and ready for operation by Q4 of 2020. Advanced application deployment will follow soon after that with full system deployment expected to be complete by the end of 2022.

Description of ADMS Technology

Advanced Distribution Management System (ADMS) is a centralized, advanced operations technology platform for System Operators to monitor, control, optimize, and safely operate PGE's distribution system. It is comprised of a suite of core functions such as DSCADA (dedicated distribution SCADA), an “as-operated” model of the distribution system, links to other applications (GIS, OMS, EMS), and uses the same types of analysis tools used for the transmission system to view and analyze the distribution system model (State Estimation and Power Flow). This increased complexity associated with operating a distribution system in the presence of emerging technologies like DERs, EVs, and DRs will result in uncertainty regarding system state, and is beyond the capability of the current EMS (Energy Management System) which is primarily designed to manage transmission and generation.

How ADMS Supports PGE's Integrated Grid Strategy

ADMS supports PGE's Integrated Grid Strategy's planned steps to a more flexible, resilient, and Integrated Grid by improving reliability through rapid fault location (FLISR Fault Location Isolation and Service Restoration), enhanced coordination across various programs (DR, DER, DA, etc.) impacting the distribution system, and optimize them to safely and efficiently provide customer and bulk power benefits. By planning now for the wave of DERs, developing a robust integrated ADMS will effectively manage the forecasted/market potential for DER and dynamic loads while addressing regulatory and customer expectations.

How ADMS will Support Integrated Grid Moving Forward

Going forward, as PGE drives for 80% reduced GHG emissions by 2050, ADMS creates a System Operator's "single pane of glass" system of advanced applications to manage the intricacies associated with clean energy alternatives. The VVO (Volt-VAR Optimization) application of ADMS will contribute to PGE's decarbonization goals by providing CVR (Conservation Voltage Reduction) or demand reduction mode that adjusts system operating voltage at peak intervals to effect demand reduction. Other technologies to be integrated are ES (Energy Storage), DR (Demand Response), QF (Qualifying Facilities), TE (Transportation Electrification), and eventually DERMS (Distributed Energy Resource Management System). These new tools, and the increased situational awareness ADMS provides to System Operators, will position PGE to respond effectively to dynamic future load conditions.

6.3(f) Conservation Voltage Reduction (CVR)

CVR is the strategic reduction of feeder voltage, deployed with phase balancing and distributed voltage- regulating devices to ensure end-customer voltage is within the low range of ANSI (American National Standards Institute) acceptable voltages (114V – 120V). PGE completed feasibility studies and two CVR pilot projects in 2014 at Hogan South substation in Beaverton and Denny substation in Gresham. By reducing voltage 1.5% - 2.5% in the pilot project, PGE was able to reduce customer demand (MW) and energy consumption (MWh) by 1.4% - 2.5%. The pilots yielded customer energy savings of 768 MWh in 2014. A preliminary evaluation has identified 94 transformers as potential CVR candidates with a customer energy savings potential of 142,934 MWh/yr. (16 MWa).

Status: With completion of pilots and evaluation, CVR is on hold. Competing peak demand objectives have led to a focus on distribution automation (DA), field area network (FAN), and advanced distribution management system (ADMS). Attention to CVR can resume when optimized by deployment of ADMS, the availability of more granular interval-level AMI data and enhanced communications network capabilities.

6.3(g) Dispatchable Standby Generation (DSG)

Dispatchable Standby Generation (DSG) is a valuable way to help the transition to totally renewable resources; it allows PGE to share in the benefit of customer generation at times when it is most valuable to the grid. In addition, we are researching a method to use renewable fuels in the diesel generators, thus limiting greenhouse gases from the generation. The customer sites are interconnected with PGE to allow the remote dispatch of the generators by PGE.

DSG is a program that is now 20 years old and provides generally all of PGE's non-spin reserve requirements at a very low cost. The program utilizes customer owned emergency generators as a resource for PGE – the generators can be remotely dispatched by PGE when there is a need for reserve capacity, and in return, PGE helps with O&M expenses of the customer's generator. In addition, PGE contributes some capital to the customer to offset the sophisticated controls required to parallel the generators to PGE's grid.

Currently the program has 127.9MW of capacity online from 38 customers at 63 sites using 90 machines. The program is continuing planning to expand with additional generators as PGE's need for increased reserve capacity occurs, (typically just a few MW per year). The capital requirements for the program are variable as new sites enter the program, and average about $0.75M per year. Operating expenses for the program are roughly $2.5M per year. The program provides the lowest cost capacity resource available to PGE.

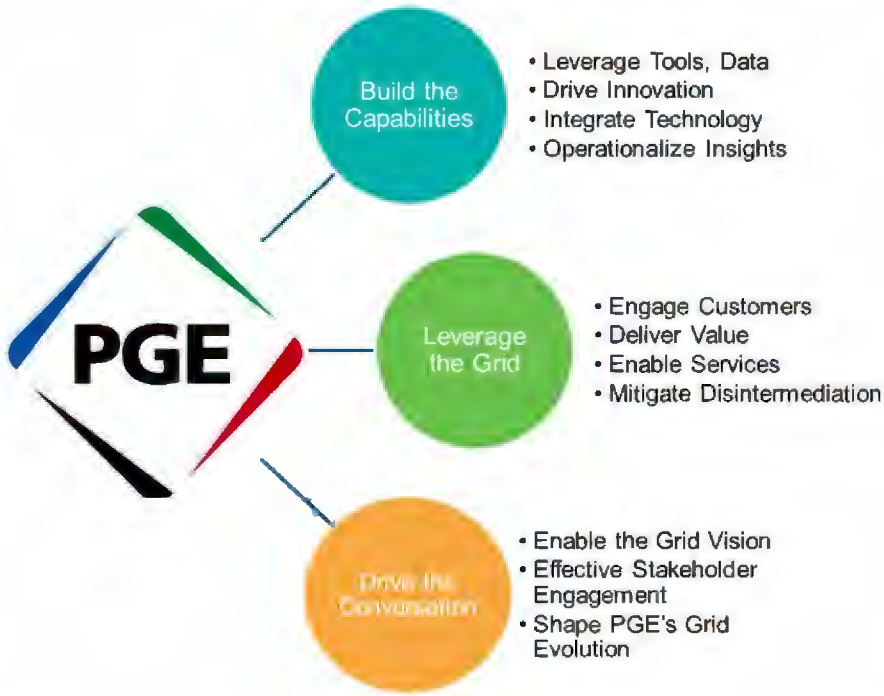
6.3(h) Distribution System Planning

Robust distribution system planning is required to achieve our goals around equitable, affordable, and sustainable decarbonization of the energy economy. For this reason, PGE has formally kicked off a distribution system planning team and process in support of our own operational needs and to support the regulatory process underway.

The Distribution System Plan (DSP) is a proposed T&D-led plan to develop advanced distribution system planning capabilities to harness distributed resources and help enable PGE to realize key customer, corporate and regulatory objectives. Foundational steps to the DSP have already been made in the normal course of business.

The DSP will build new capabilities in PGE's core business of planning the electric system. These new capabilities will be fundamental in enabling the Company to leverage the grid as a platform integrating localized energy resources, and in putting PGE in a position to lead the conversation on integrating new technologies in a responsible, measured, and optimal way. This initiative has been designed to proceed flexibly, with a minimal investment required to meet immediate needs and the optionality to accelerate activities if required.

Figure 13: DSP Outcomes



The DSP will allow PGE to directly serve several high-priority customer and market needs.

Table 11: DSP Customer and Market Needs

Customer and Market Needs	
Safety, power quality, reliability, and resilience	Maintaining system safety, power quality, reliability, and resilience is a foundational requirement for delivering exceptional service to our customers. The distribution system planning capabilities needed to meet these requirements will need to reflect the continuing evolution of the system and the changing mix of resources on PGE's grid.
Renewable energy and the reduction in greenhouse gas emissions	Oregonians strongly support cleaner options in energy supply and are willing to purchase it, with over 178,000 PGE customers voluntarily participating in the nation's top renewable energy program, Green Future.27 Moreover, our customers expect PGE to meet future energy and capacity needs through the development of renewable generation and enabling technologies, such as energy storage.28 Both the City of Portland and Multnomah

[27] Green Future is PGE's voluntary renewable energy program, launched in the Fall of 2015. More information can be found at this webpage: https://www.portlandgeneral.com/business/power-choices-pricing/renewable-power/green-future-solar

[28] IRP public workshops on January 24, 2017 and February 16, 2017. For more information please see: https://www.portlandgeneral.com/our-company/energy-strategy/resource-planning/integrated-resource-planning

	County have each announced a resolution to achieve 100 percent economy-wide clean and renewable energy by 2050 through electrification, energy efficiency, and electricity decarbonization.29 PGE can play an active role in enabling electrification, energy efficiency, and deep decarbonization pathways in order to achieve these goals.
Affordability in electricity supply	Part of our vision of being our customers' most trusted energy partner relies on continuing to deliver affordable service through prudent investments, operational efficiency and asset optimization. Recent Oregon Public Utilities Commission ("OPUC" or "Commission") collaboratives with SB 978 stakeholders have further underscored that this is a top tier issue for our customers.30 Pursuing the innovations that drive customer value will enable PGE to continue delivering energy that is safe, clean, reliable, affordable, and secure.

PGE has an opportunity to serve each of these needs by initiating the proposed DSP, which will build the capabilities to continue meeting T&D planning needs in a changing electric power ecosystem, enable accelerated GHG reductions, and maintain affordability for customers.

The DSP initiative includes a broad set of initiatives related to enhanced capabilities in forecasting, data integration, interconnection, hosting capacity, and locational value that enables these outcomes.

DSP will support PGE to do the following

1. Enable PGE to continue delivering safe, reliable and secure energy as the mix of resources on the system continues to evolve;
2. Accelerate greenhouse gas reductions by enabling the integration of low carbon resources; and
3. Facilitate system efficiency and cost reductions by better reflecting the value of distributed energy resources.

Safe, Reliable and Resilient

The growth of distributed resources creates a more dynamic environment in which greater levels of data and analysis are needed in order for PGE to continue delivering safe, reliable and secure energy for customers.

In addition, the growing adoption of distributed solar, energy storage, electric vehicles, smart thermostats, and other distributed resources presents opportunities for those distributed resources themselves to become part of the Company's T&D Planning toolkit. By incorporating these resources into distribution planning, PGE has an opportunity to also enhance system resiliency.

New capabilities to integrate and utilize distributed resources in a way that maintains and potentially enhances reliability, power quality, and resiliency will be developed along with new

[29] For more information please see https://multco.us/sustainability/news/journey-100-renewable-introduction-deep-decarbonization

[30] See SB 978 – Actively Adapting to the Changing Electricity Sector, Page 2.

processes for distributed resources to provide grid services and meets customers' evolving expectations. This includes creating more detailed forecasts for electricity demand and explicitly representing distributed resources in T&D planning models.

Through DSP, PGE will continue delivering exceptional service to its customers even as the system changes, resources on the system evolve, and as new resiliency needs arise.

Accelerating Decarbonization

Building a smarter, more flexible grid is essential to integrating new low-carbon resources on the distribution grid.

In the near term, increasing visibility in distributed resource potential by analyzing where, what kind, and how many distributed resources can interconnect with the grid, can help guide the effective integration of resources.

In the medium term, a clear view into the abilities of the grid to host new resources can inform standards and distribution planning criteria such that system upgrades consider distributed resources growth.

In the longer term, utility management of distributed resources on the system (or aggregations thereof) can create value by enhancing grid flexibility in coordination with the intermittency of renewables at all levels of the grid.

DSP activities will improve data quality and acquisition in the distribution planning environment to produce more accurate results from hosting capacity studies and proactive integration of low carbon resources. This not only accelerates PGE's path toward deep decarbonization, but it also helps PGE leverage the grid to create distributed resource services and solutions that help meet our customers evolving expectations.

Affordable Service

The integration of distributed resources as part of the T&D Planning toolkit begins with the identification of opportunities that enable additional grid flexibility to more effectively integrate low-carbon resources with the grid. Most immediately, new capabilities for analyzing hosting capacity can be used to communicate locations where new distributed resources can be interconnected with least impact to the grid. Initial efforts under the DSP will also introduce new frameworks and analytical capabilities that will provide the foundations for future processes that will drive distributed resource grid value.

These prospective activities could include competitive procurement of distributed resources such as virtual power plants, or it may also include active network management and coordination of customer-interconnected devices. In either case, distributed resource and intermittent renewable dispatch can be coordinated and optimized to deliver grid needs at the lowest cost to consumers. The DSP, and the foundational analytical capabilities that it operationalizes, will be fundamental to developing effective long-term plans for the system. These plans will realize the full potential of future utility visibility and coordination of distributed resources. The DSP will allow PGE and its customers to benefit from an enhancement in overall system efficiency and value from effective and prudent planning that includes a view to these future possibilities.

DSP Regulatory Background

As a condition of PGE's 2016 Smart Grid Report, the OPUC requested that "PGE identify and discuss the system and Company resources necessary to begin evaluation of DER value to customers and the additional resources needed to commence distribution system planning." In response to that request, PGE discussed the likely elements of a Distribution Resource Plan in the 2017 Smart Grid Report.

Additionally, in LC66, as a part of its acknowledgement of PGE's 2016 IRP staff made the following comment:

"The description of PGE's thorough DSP's activities in the IRP update is helpful, but is not focused on getting to Staff's main issue of the need for improved transparency and creation of an overall plan for distribution system investments. PGE's four priority elements may be the best four areas for focus from a ratepayer perspective but the reasoning behind these selections and the ultimate goal these activities are intended to achieve was not provided, so Staff and stakeholders are unable to provide review of PGE's roadmap and plan."

These comments, along with various comments provided motivation for the opening of UM 2005, staff's investigation into distribution system planning.

UM 2005

In response to growing consensus that a common framework was necessary for discussing distribution system planning (DSP), staff opened an investigation on March 13th, 2019. This process is still relatively new, but has already been good catalyst for formalizing processes internally at PGE. It has helped to better understand important drivers and insights desired by staff and stakeholders.

In staff's white paper on the DSP, staff that their visions for the DSP docket is to establish a regulatory planning process that provides adequate distribution system insight. Additionally, they note that a process should have the following characteristics:

- Robust
- Aligned
- Strategic
- Adaptive
- Inclusive
- Regular

PGE appreciates these guiding principles and is embracing them as we organize ourselves and the work. Many of these characteristics have been emphasized in our approach to the latest IRP process and we're excited to apply them as we dive into the DSP process.

PGE's Approach to DSP

While UM 2005 is still new, PGE has already begun working on many of the elements of distribution system planning in a variety of venues. Staff notes in their white paper that there are a multitude of dockets that touch on elements of distribution system planning across many areas of the business, including RVOS, the IRP, transportation dockets, and the various DR pilots underway.

PGE is focusing its approach to DSP specifically in four core areas:

- Data integration and forecasting
- Hosting capacity analysis
- Interconnection process improvement
- Locational value analysis

The following sections outlines the elements of each

Data Integration and Forecasting

This aspect of DSP focuses on integrating new data sources into the T&D Planning environment and on developing new forecasting processes for distributed resources and flexible loads. Together, these activities will allow for increased technical transparency into the operation of the distribution system. The level of data integration and forecasting capability will gradually be increased such that PGE will have a highly granular view of distributed resources in the current period and under future probabilistic forecasting methods. This view will help PGE reflect the system impacts and market values of distributed resources.

Data integration is critical for many of our strategic initiatives and much of this work is already underway. GIS integration to our future ADMS will provide a clear, single system of record that will be critical for power flow analysis not just for operations but in planning for differing scenarios.

Additionally, PGE has begun to engage with vendors to test using AMI data to conduct bottom up forecasting of load on the distribution system. Working with leading vendors such as Innowatts and TROVE, we have begun to use AMI data to develop customer-specific forecast models and load prototypes to better understand where we expect peaks to develop in the near- and medium term. These complement our top-down methods used for bulk system planning to work toward a hybrid approach that derives value from each method.

Another example of data integration and forecasting at work is in the Distributed Resource and Flexible Load Study conducted by Navigant as a part of our 2019 IRP. This study, managed jointly between IRP, T&D planning, and Customer Energy Solutions, developed forecasted adoption and load impacts of DERs across our service territory under several scenarios. By forecasting these resources together, we were able to capture interactions between programs and resources (for instance, how do TOU rates impact adoption of electric vehicles). Using granular customer data, the study also developed feeder-level outputs, which will be an important early input as we look to refine forecast for capacity constraints on our system.

Hosting Capacity Analysis

PGE will develop the capability to identify where, when, and how the distribution system can accommodate, or "host," distributed resources. Hosting capacity analysis advance through iterative stages and benefit from improved inputs provided through the Data Integration and Forecasting activities and through continually improved methodologies and tools. An initial baseline analysis and subsequent refinements of hosting capacity analysis for distributed solar resources will take place in the initial stages of the DSP. Later stages of the DSP expand the analysis to additional distributed resource technologies and asset types and will better reflect system operational flexibility and the impacts of smart inverter functionality.

We have already begun this work both internally and with partners. Using EPRI's DRIVE model, distribution engineers have begun to model DER hosting capacity for solar resources on our feeders under business as usual conditions. We have also done proof-of-concept work with Opus One Solutions to dynamically model power flows for a select set of feeders to better understand how we might do scenario analysis for new DERs coming onto the system. As a part of the Smart Grid Testbed project, we have engaged with Kevala Analytics to understand how we can rapidly model changes in power flows for not just solar, but other resources such as DR, EE, and EVs.

Interconnection

Continuously improving PGE's interconnection processes is important to enhancing customer experience, reducing operating costs, and ultimately achieving a distribution system platform that seamless and efficiently incorporates new customer technologies. Advancement in hosting capacity analysis, introduction of smart inverter standards, and identification of accurate value signals for distributed resources will all be leveraged, as appropriate, to continue to enhance interconnection processes.

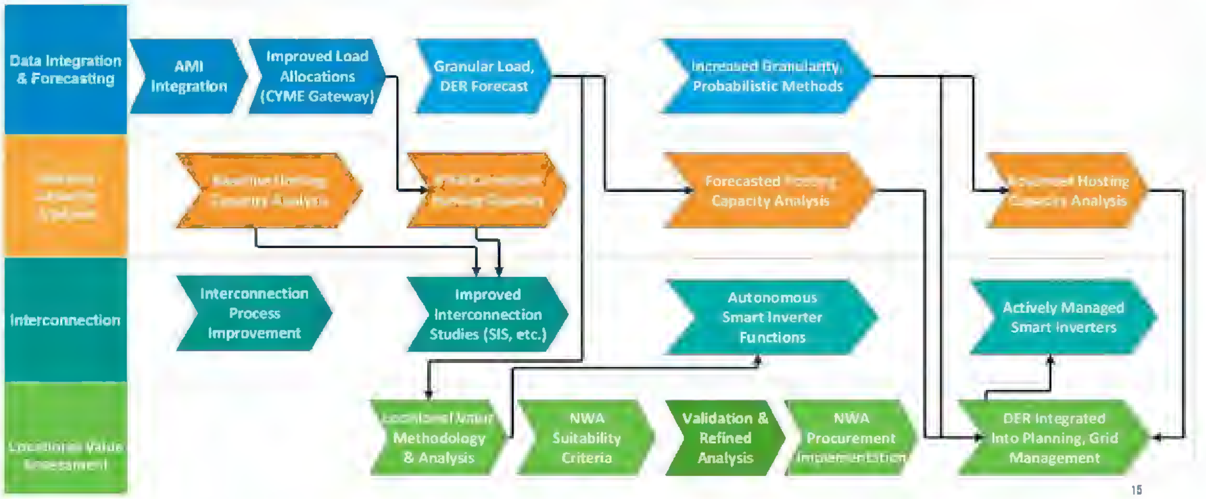
We have already started work to improve the interconnection process using PowerClerk for our small generating facility interconnections. We're exploring how an expansion of this tool may better help coordinate with stakeholders such as ETO and internally with the customer programs teams.

Locational Value Assessment

Assessing the locational, temporal, and scenario-based (e.g. resiliency) values of distributed resources is foundational to reflecting distributed resources in planning and enabling them to provide grid services. Initial DSP efforts on locational value will focus on gaining agreement on frameworks for valuing distributed resources. These frameworks will seek to leverage existing studies and models (RVOS, SAM, Storage Potential study, etc.) to establish frameworks for resource valuation and to start developing aspects of market-based sourcing mechanisms such as Non-Wires Suitability Criteria. The DSP will seek to validate these frameworks through learnings from the Smart Grid Testbed and other initiatives. Later stages of the DSP will introduce and refine methods, tools and processes for continuously identifying and effectively signaling locational values.

The four initiatives and their interdependencies are depicted in the following roadmap figure:

Figure 14: DSP Implementation Roadmap



6.3(i) Distribution Automation (DA)

Expansion of SCADA-integrated switching devices throughout the PGE's service territory is at the core of enabling other PGE smart grid initiatives (e.g. Advanced Distribution Management System (ADMS).

Distribution Automation (DA) expands SCADA capabilities by reducing the frequency and duration of sustained outages; reducing system asset and non-asset risk; improving O&M efficiency; increasing system visibility and awareness; and implementing schemes which are adaptable to future system changes.

Implementation consists of installing automatable, SCADA-integrated switching devices on PGE's distribution feeders. Typically, these devices will communicate over PGE's 700 MHz spectrum to the System Control Center (SCC). When integrated with a DA controller, the devices are capable of automatic fault location, isolation, and service restoration (FLISR). In all instances, these devices can be remotely controlled by System Operators.

Status: Active Deployment

Next Steps: Deployment planned to roughly 25 percent of PGE feeders over the next several years. Standard equipment has been selected, and prospective feeders have been identified for DA implementation. PGE is in the process of developing a dedicated engineering team whose responsibilities will include process development and executing on the capital plan to enable DA on 15% of feeders by the end of 2023. Finally, PGE is developing a change strategy which will outline how PGE will prepare its workforce to safely operate and maintain DA implementations.

6.3(j) Distribution Temperature Sensing (DTS)

PGE has installed real-time line sensors on ten feeders in the company's service territory at locations that could signal a pending underground cable failure. Four of these feeders are producing data. Additional setup will be needed to receive data from the remaining six. These linear sensors give visibility to temperatures of subterranean cables at 2 second intervals.

Because temperature affects capacity, insight into the temperature better informs PGE of the timing and need for future system upgrades.

Status: Deployment to substations where high reliability is necessary for sensitive loads being served

Next Steps: PGE will deploy DTS in a new substation expected to be energized in late Q1, 2019. In addition, PGE will deploy DTS in new substations deemed as high reliability in the future.

6.3(k) Fault Detection (Distribution)

This pilot involves installation of Faulted Circuit Indicators (FCIs) on one PGE feeder line. Data generated by the FCIs are integrated into SCADA via AMI communications infrastructure. PGE is monitoring the pilot as a test case for performance of the FCIs and use of AMI communications infrastructure and will evaluate the cost-benefit of the communication enabled FCI deployment as well as use of AMI infrastructure for fault data transfer and determine whether to invest in this method of fault detection. The Company anticipates the pilot should result in improved reliability metrics that would bolster Smart Grid reliability.

Status: Pilots & Evaluation in progress.

Next Steps: The single feeder pilot alone will not provide sufficient data to validate the use case and technology. As resources become available FCIs will be installed on additional feeders and data will be integrated via. SCADA system and additional evaluation will be performed.

6.3(l) Geospatial Information System (GIS)

PGE's GIS capabilities are intrinsic to the Smart Grid value proposition throughout the business enterprise. GIS provides a digital, spatial picture of PGE's electric system and models "normal state" connectivity of its various components based on as-built information. The GIS data model informs the outage management system (OMS) and will soon be updated to inform the advanced distribution management system (ADMS), introducing new capabilities for interactive and automated control of the grid.

Integrations between the GIS infrastructure and customer- and project sourced information create a robust visualization and information gateway for users across the PGE business enterprise to create, configure, and deploy web-based maps and tools for visualization of assets and asset information. Future state of field mapping and data collection solutions will be built upon a platform that can function both online and offline while enhanced capabilities resulting from future integration with OMS will enhance show near real-time changes on the system. Analytical capabilities inherent in GIS facilitate assessment of sites for energy infrastructure development suitability, and analysis results can be consumed and visualized in maps and applications.

Status: Active Deployment

6.3(m) OSU Microgrid Synchrophasor

This is a collaboration with Oregon State University (OSU) modeling how a composite dynamic load model can be estimated in real-time to provide insight into the design of microgrid protection schemes. Challenges being addressed include reverse power flows, reactive power adequacy, automatic device reclosing, and delayed relay tripping.

The research involves development of a program, using the programming interface of Python, that will automate calls to a time-domain power system simulator (compatible with PSS/e, PowerWorld, PSLF). The simulator will run an equivalent synthesized model of PGE subareas (potential microgrids) to inform functionality under normal and anomalous grid operating conditions. Anomalous grid conditions will be sampled from both natural events and adversarial events such as cyber-attacks. To reduce the computational complexity associated with real-time analysis, and make it appropriate for distribution level networks, we partition the system into Voltage Control Areas (VCA), which allow system operators to manage active and reactive system power reserves in an efficient and effective manner.

Benefits: Investing in Synchrophasor research at OSU will inform PGE planning and operations in transitioning from a mono-directional hierarchical power delivery model to an integrated Smart Grid incorporating distribution resource assets. This transition will optimize PGE's capabilities to meet customer expectations for electrical system efficiency, reliability and resilience and to optimize peak shaving and seamless grid integration of renewable generation.

6.3(n) Remedial Action Schemes (RAS)/Special Protection Scheme (SPS)

A RAS is an automatic protection system designed to detect abnormal or predetermined system conditions and take corrective actions other than and/or in addition to the isolation of faulted components to maintain system reliability. RAS enables Smart Grid reliability and functionality by leveraging the Energy Management System (EMS) State Estimator and Real Time Contingency Analysis tool to help maximize transmission and distribution infrastructure and defer need for additional capital investments at a time when transmission lines are becoming increasingly difficult to site, permit, and construct.

PGE has two RAS deployed, one at Grand Ronde and one at Round Butte. The Grand Ronde RAS has been approved for removal in about 5 years because there will be a 57kV Conversation Project in the area, eliminating the need for the RAS. The 57kV Conversions are being done to modernize the transmission systems.

Status: Limited Deployment: RAS may be considered as a mitigation option when evaluating transmission reliability concerns/constraints at other locations in the future.

6.3(o) Connected Communities

Connected Communities establishes PGE as a conduit between customer, local government and business stakeholders for advancing long term goals that lie at the nexus between a customer experience defined by choice and improving the availability and of urban services. Current Smart Cities efforts are directed towards establishing public-private partnerships within the PGE service territory to determine the appropriate scope for utility functions as informed by a better understanding of customer needs and how PGE can best enable or provide grid assets such as distributed energy resources (DERs) (including demand response, distributed generation, battery storage, microgrids, and ETO energy efficiency programs). The goal is to establish a framework through which PGE can support accelerated deployment of technology, business operations, policies and practices needed to support a collaborative Connected Communities vision as consistent with objectives set forth in OPUC policy, PGE strategic goals and community expectations.

PGE serves 51 cities in 7 counties and many municipal entities within its service area. Although our municipalities are evolving at different paces with different priorities, we are seeing a growing interest in:

- ‘Smart’ infrastructure (lighting controls, environmental sensors, traffic monitoring, high-speed internet service)
- Improved resiliency (business continuity, emergency management, disaster preparedness)
- Reduced carbon footprint (renewables, electric vehicles)

PGE is current evaluating several near-term opportunities with municipal customers that include a variety of technologies: smart street lights, energy storage/microgrids, and EV charging infrastructure.

To effectively partner with our municipalities, PGE is assessing their community needs, technology viability, and resource requirements:

- **Market Assessment:** Some information is available, but in most cases a more detailed assessment of smart infrastructure plans, resiliency needs and sustainability initiatives should be conducted.
- **Technology Assessment:** Need to develop an organized approach to identifying and screening relevant technologies, establishing priorities for future pilot projects.
- **Staffing Requirements:** Additional resources will be required to coordinate and bolster city and community engagement. In addition to dedicated FTEs there exists an opportunity to support the evolution of city services via the provisioning of data, analytics and reporting.

6.3(p) Solar - Smart Inverters

PGE owns or operates 24 smart inverters at 12 PV solar installations totaling 5.3 MW (DC) of nameplate capacity.

Table 12: PGE Smart Inverter Count[31]

Year Installed	Total installations in PGE territory	Installations with advanced inverters	% of annual total
2002 - 2008	301	-	0%
2009	240	4	2%
2010	674	26	4%
2011	864	93	11%
2012	822	215	26%

[31] *Energy Trust 2018 Annual Report*, Available at https://www.energytrust.org/wp-content/uploads/2019/04/2018.Annual.Report.OPUC_.pdf.

2013	524	95	18%
2014	893	128	14%
2015	1,264	283	22%
2016	1,051	299	28%
2017	1,054	461	44%
2018	1,179	830	70%
Total	**8,866**	**2,434**	**27%**

Through efforts under SEGIS grants, PGE has demonstrated the ability to control inverters to:

- remotely connect/disconnect systems
- adjust power factor
- provide curtailment control
- adjust ramp rate

In addition to PV use cases, the 20 smart inverters at SSPC enable functionality such as transactional control and frequency regulation.

For PGE to realize the benefits of smart inverters at a utility scale, broad-scale enablement and adoption of smart inverter technology is required. Fortunately, IEEE1547-2018 has been adopted and CA Rule 21 for interconnection have begun to encourage the adoption of such standards industry-wide.

PGE's planned efforts around smart inverters are to encourage broader adoption of the technology:

- Continued involvement in the development of industry inverter standards, particularly UL-1741 and IEEE-1547
- Engagement with EPRI working groups on smart inverter integration and enablement
- Involvement in OPUC workshops on smart inverters
- Explore opportunities to programmatically enable existing smart inverters and/or encourage new installs
- Look for opportunities to integrate smart inverters into our enterprise systems, either through our ADMS or DERMS platforms once they're fully online

6.3(q) Synchrophasors on Transmission System

Synchrophasors provide enhanced system situational awareness for transmission operators and planners by providing real-time system information. Phasor measurement units (PMUs) capture data at a higher resolution than typical grid monitoring devices and include more depth of information beyond voltage and frequency, including GPS, and time stamped phasor quantities. A wide deployment of PMUs and phasor data concentrators (PDCs: IEDs that collect and aggregate data from PMUs), communications infrastructure, and analytics software can provide:

- Enhanced situational awareness

- Improved visibility into interconnection points with adjacent utilities and regional flowgates[32]
- Detailed post-event analysis
- Generation model validation and test avoidance (reduced down time of generation facilities)
- System state model validation

Status: Pilots & Evaluation. PGE is strategically deploying PMUs and PDCs at critical transmission facilities to realize these benefits. To date, PGE has deployed Synchrophasor technology at 1 transmission substation (Rosemont). In addition to PMU and PDC installation in the field, PGE has invested in critical server infrastructure and software that will enable the Company to realize the maximum benefits of this technology.

Next steps: Proof of concept successfully completed. Presently no drivers for expanded deployment of data retrieval infrastructure

6.3(r) T&D Asset Monitoring

By installing IEDs on many large capital assets, PGE is promoting a more reliable grid and increased asset utilization. Dissolved Gas Analyzers (DGAs) monitor dissolved gas in system transformers. Changes in dissolved gas characteristics could indicate a deterioration of device health and imminent asset failure. This type of proactive monitoring allows PGE to practice condition-based maintenance as opposed to time-based maintenance, optimizing Company resources.

PGE has installed advanced transformer sensors to monitor dissolved-gas on 38 of 45 critical transformers. The Company is also installing DGAs on non-critical transformers on a case-by-case basis.

Status: Active Deployment

Next steps: PGE plans to upgrade the remaining critical transformers in 2021. In the next couple of years PGE intends to evaluate installing similar sensors on other system assets such as circuit breakers and substation batteries. Real-time sensor information from these devices could result in optimized maintenance schedules and prevented device failures and outages.

6.3(s) Travelling Wave Fault Location Protective Relays

PGE has completed the installation of Travelling Wave Fault Location Protective Relays on the Bethel- Round Butte (230kV), Shute-Sunset (115kV), and Grassland-Slatt, BPA (500kV) circuits. The relays enable greater precision in pinpointing the location of transmission faults, greatly reducing the duration of transmission outages. Historically, the Bethel-Round Butte 230kV line has been PGE's least reliable 230kV circuit. Sustained outages to this circuit averaged three-four days for restoration due to difficulty in locating the faulted section. This

[32] PGE is evaluating participation in WISP (Western Interconnection Synchrophasor Program) which works to increase grid operators' visibility into bulk power system conditions, allow earlier detection of grid stability threats, and facilitate PMU data transfer with neighboring control areas: https://www.smartgrid.gov/project/western_electricity_coordinating_council_western_interconnection_synchrophasor_program

technology will enable PGE to accurately locate faulted sections without helicopter dispatch, saving $24,000 per event.

Status: All transmission line terminals receiving new relays are being furnished with relays having Traveling Wave Fault Location capabilities. The manufacturer has improved the analysis capabilities that allow greatly improved capabilities with relays on just one end of the line.

Next Steps: Continued deployment at all new and revised transmission line terminals.

6.3(t) Ultra-Capacitor Generator Starting Power

This project investigates performance advantages offered by capacitor technology over traditional lead acid starting batteries in terms of reliability, lifespan, cranking amps, wider operating condition tolerances and cost savings in solving the number one cause of backup reciprocating generator failures, the starting battery system.

PGE's Dispatchable Standby Generation group works with 90 customer owned emergency generators at 63 sites to provide a key service for critical backup emergency systems. The failure of any of these systems to start significantly impacts customer operations and consequently their perception of the DSG program

The project protocol involves determining the best technical solution, procuring the equipment and modifying the starting power system of a single backup emergency generator to utilize ultra-Capacitors in place of lead-acid batteries. The installation will then be monitored in conjunction with other DSG generators to observe its operation and verify the benefits for the possible retrofit of future starting systems.

Compared to the traditional lead-acid starting batteries, ultra-capacitors offer 6 times the lifespan, 3 times the cranking amps and are less susceptible to temperature fluctuations. Ultra-capacitors are also more energy efficient as they use less energy to float charge and have faster recharge between cranking attempts.

Benefits: Project success could pave the way for changeover to ultra-capacitors from lead-acid technology. There would be a direct benefit to DSG customers served by a successful ultra-capacitor test and indirect benefits to other customers from making DSG more cost effective and resilient. Future benefits to customers could include energy savings if the technology could replace less efficient battery systems for other applications.

6.3(u) Voltage Disturbance Detection (i-Grid)

Voltage disturbances (including sags, swells, interruptions, and outages) are the most common power quality problems. PGE has installed i-Grid detection devices that capture and record voltage disturbances, as well as long-term voltage trends. Voltage reporting allows engineers to perform post- event analysis and diagnose system issues which could result in proactive equipment replacement. To date, PGE has installed 112 i-Grid detection devices on 107 feeders.

Status: Limited Deployment

Next steps: PGE will continue limited, strategic deployment of voltage disturbance detection devices. Additionally, PGE will evaluate additional ways how to leverage voltage reports such as enhancing asset monitoring capabilities.

6.4. Transportation Electrification

6.4(a) I-5 Charging Initiative

In October 2018, PGE entered into a collaboration agreement with ten electric utilities on the west coast to evaluate opportunities and challenges for medium and heavy-duty transit along the I-5 corridor from Mexico to Canada. The study has five main components:

- **Zero-Emission Medium- and Heavy-Duty Truck Current Market and Needs Assessment:** evaluation of current and forthcoming vehicle & charging options, market needs assessment (regulatory, financial, and technological), and industry disruptions;
- **Current Trucking Market Landscape and Use Cases:** review of existing trucking patterns along i5, including duty cycles, vehicle use cases, major sectors, key market players, typical fleet characteristics, tonnage of cargo moved, etc.
- **Coordinated Assessment of Current Utility Infrastructure:** evaluation of the major transmission and distribution assets (e.g., substations) that are likely to be affected by the mass deployment of zero emission trucking infrastructure
- **Zero Emission Solutions and Recommendation:** identification of priority deployment locations of charging trucking charging infrastructure, T&D system upgrades, etc.
- **Utility Recommendations** on where and how to accelerate deployments of zero emission trucking deployments along the i5 corridor.

By collaborating with 10 other utilities, we will get more value than we could get alone, limit our costs, and create a core team for future inter utility collaboration. Though the study will cost approximately $500,000, by partnering with other utilities, PGE's share will not exceed $27,000.

HDR has been selected to conduct the study (in partnership with CALSTART, S Curve Strategies, and Ross Strategic). They study will be completed by EOY.

Collaborating Utilities:

- Los Angeles Department of Water & Power
- Northern California Power Agency
- Pacific Gas and Electric Company
- Pacific Power
- Portland General Electric
- Puget Sound Energy
- Sacramento Municipal Utility District
- San Diego Gas & Electric Company
- Seattle City Light
- Southern California Edison Company ("SCE")
- Southern California Public Power Authority

6.4(b) Electric Avenue Vehicle Expansion

PGE is expanding on the success of Electric Avenue, a group of five electric vehicle stations located at World Trade Center in downtown Portland, by building six additional Electric Avenue sites. The sites will each include up to four dual-head fast chargers and one level 2 charger for accessibility. Similar to a gas station, this model co-locates several chargers, increasing the chance that drivers in need will be able to find a functional and available charger, thereby effectively improving the availability and reliability of public charging infrastructure. Our vision is to have these sites – geographically dispersed throughout the service area – serve as a harbinger of the availability of electricity as a transportation fuel. The sites will increase the visibility of electricity as a transportation fuel and empower the many customers who need to see convenient public charging infrastructure in order to consider an EV. An exciting feature of this pilot will be to examine the impact of community charging infrastructure on increasing the adoption of electric vehicles by transportation network companies (e.g., Uber and Lyft), car-sharing companies (e.g., Reach Now), and the home-charging challenged (i.e. those who live in multifamily buildings or do not have off-street parking with electric service). The pilot will allow us to test price signals to encourage off-peak charging, promote charging when excess renewables are available, and (in the future) enable (and reward) customers to discharge their vehicle batteries to the grid. Prices for charging at these stations will be in line with existing market rates and may employ time-variant pricing to promote charging at times aligned with the needs of today's electric system.

Status: Approved in March 2018 (Order No. 18-054) https://apps.puc.state.or.us/orders/2018ords/18-054.pdf. Currently under construction.

6.4(c) Electric Avenue Outreach and Technical Assistance

The largest barrier to electric vehicle adoption is lack of consumer awareness. To raise awareness of the benefits of driving electric, we are conducting a 3-yr outreach, education, and technical assistance pilot. The pilot will provide technical assistance for commercial and industrial customers (including non-profits that support low-income communities), specialized trainings for key industry stakeholders (e.g. dealers and builders), market transformation, ride and drive events, and education on whole-house time-of-use rates to residential customers who drive electric vehicles.

Status: The pilot is ongoing (2018-2020).

6.4(d) Electric Vehicle Operations

PGE has a history of and will continue to utilize our own operations to test and learn about emerging electric vehicle technologies. Through the electrification of our fleet we are testing smart charging control, vehicle to grid, and fleet electrification planning. Further, as EV ambassadors, we work with our employees to test the impacts of TOU rates, learn about EV buying processes, and better understand needs for workplace and public charging infrastructure.

Status: Ongoing Deployment

6.4(e) Trimet Electric Mass Transit Pilot

PGE has installed and manages 3 electric bus charging stations (2 depot chargers and 1 en-route charger) for use by TriMet. PGE's involvement in the pilot allowed TriMet to use grant funding from the Federal Transit Administration (FTA) to purchase an additional electric bus, thus enabling the electrification of an entire bus route. By owning and managing the charging infrastructure, PGE will be able to obtain key learnings that will allow us to most advantageously integrate the considerable demand that may emerge from future electric bus charging infrastructure. The pilot will evaluate distribution system impacts and customer service considerations by studying coincident peak, non-coincident peak, feeder voltage dynamics, charging behaviors, and load profiles. PGE would procure and own the chargers, while TriMet would bear the cost of their installation and maintenance. TriMet will pay the applicable tariffed rate for electricity from the charging stations.

Status: As of this filing, TriMet's buses and these chargers will be operational.

6.4(f) Workplace Smart Charging Pilot

PGE has commenced an employee workplace smart charging pilot at its own workplace sites. Currently PGE has 69 workplace charging spots at 18 sites; 20 of those chargers are DR-enabled. We anticipate piloting this concept with some of our customers, but it is important that we expand this pilot carefully and strategically as curtailment of EVSEs has unique customer impacts not fully comparable to other direct load control (DLC) programs (i.e. heating, cooling, and hot water):

- **Utility of vehicle:** unlikely heating and cooling, EVs are often on the move and not connected to PGE's grid. If a customer does not get a full charge while at work or while patronizing a business, it is conceivable that they may not have enough charge to reach their next destination. We must start slowly with expanding this pilot to ensure a positive customer experience.
- **Impact on our customers' customers:** It is one thing to curtail charging on our own employees at our facilities, however, when we begin curtailing customers' charging stations, we will also likely impact their customers and employees. This creates two-tiers of customer service, again adding to the emphasis that we must start slow to ensure a positive experience for all.
- **Lack of consistent load profiles/use cases:** Unlike many technologies/customer classes, there are no clear load profiles associated with workplace/business charging infrastructure. This raises questions of (1) how much potential value there is with workplace smart charging, (2) how to standardize program design such that programs are still relevant to most, and (3) how do we ensure positive customer experience despite likely different charging experiences at different sites.

The pilot will evaluate: achievable coincident demand reductions, reliability of demand reductions, customer experience (both facilities and end-use vehicle owners). The pilot should yield results that inform future program designs, such as program costs, achievable curtailment, and attribution.

Status: Research

Next Steps: In 2018, PGE intends to collaborate with 1-2 business customers who intend to install 5-20 electric vehicle charging stations at their site(s). We plan to offer those customers incentives to procure charging infrastructure that is DR-enabled and for committing to up to 10 curtailments per year. If the pilot proves successful, PGE may expand the pilot to additional customers in the service area.

6.4(g) Clean Fuels Program

The 2009 Oregon Legislature passed HB 2186128 authorizing the Oregon Environmental Quality Commission to adopt rules to reduce the average carbon intensity of Oregon's transportation fuels by 10% over a 10-year period. The 2015 Oregon Legislature passed SB 324129 allowing DEQ to fully implement the Clean Fuels Program in 2016. The rules for the program are adopted in Oregon Administrative Rules Chapter 340 Division 253 – as filed with the Secretary of State. The rule allows electric utilities to register as a credit aggregator for electricity used as a transportation fuel. Utilities must register by October 1, to generate credits for the subsequent year. Through Docket Um 1826 the OPUC found it to be in the public interest for the utilities to aggregate the Clean Fuels Credits.[33]

Status: In 2019, after consulting with stakeholders, PGE filed a plan for the initial deployment of Clean Fuels Program activities. Within that plan, PGE identified 4 key areas for deploying funds in 2019-2020:

- **Drive Change Fund:** grant program to support non-residential customers in a variety of project types to advance transpo1iation electrification to the benefit of residential customers;
- **School bus electrification:** work with up to 5 school districts to help them acquire an electric school bus and install charging infrastructure;
- **Public charging access:** we will offer free two-year subscriptions to its Electric Avenue network of charging stations to any Oregonian who receives the state's income-qualified rebate for the purchase or lease of a new or used EV;
- **Public outreach for Transportation Electrification:** PGE will educate residential customers and raise awareness about the benefits of EVs; these activities include a total cost of ownership tool on PGE's website; engagement with dealers and at public events; and a ride and drive event with a national vendor.[34]

As detailed in the table below, PGE received 49,667 residential EV charging credits for 2016 and 2017. As of March 5, 2019, the company has sold these credits, resulting in funds of $5,473,374.[35]

Table 13: Clean Fuels Credit Activity

Date	Action	Credits	Funds
2018	Credits adjusted (for 2016 – 2017)	49,677	

[33] Oregon Public Utility Commission Order 17-250. Available at https://apps.puc.state.or.us/orders/2017ords/17-250.pdf

[34] *See* PGE March 29, 2019 Report pursuant to Order No. 18-376, Docket UM 1826. Available at https://edocs.puc.state.or.us/efdocs/HAH/um1826hah162118.pdf

[35] Id.

2018	Credits transferred	(31,320)	$3,286,611
2019	Credits transferred	(18,347)	$2,186,763
As of 3/5/19	**Credit Activity Total**	**0**	**$5,473,374**

Per Order No. 17-250, PGE will separately file an annual report that includes more detail about individual credit sales.

As detailed in Table 14 below, the company has also incurred cost of $65,483 in 2018 and the first part of 2019 for credit monetization, portfolio planning, and regulatory process.

Table 14: Clean Fuels Expenditures to Date

Date	Action	Funds
2018-2019	Funds from Credit Sales	$5,473,374
2018	Expenditures	$(12,187)
2019 (to 3/5/19)	Expenditures	$(53,296)
As of 3/5/19	**Balance**	**$5,407,891**

6.5. Research & Development

PGE has included our research and development activity here though the activity has historically also been reported through separate filings and updates to Commission Staff. As PGE makes continued advancements on Integrated Grid development our research and development work continues to have importance as this work will move closer to the distribution system planning (DSP) space.

6.5(a) Microgrid Resiliency Feasibility Assessment

This project evaluates the feasibility of utilizing existing customer-owned generating resources to form a microgrid within PGE's service territory. A first phase will determine equipment and infrastructure needs to allow selected areas on a customer site to form independent electrical islands to identify the capability and limitations of meeting energy requirements via existing onsite generation. A second phase will identify limitations of onsite generation and medium voltage assets for each island and review the capabilities and benefits of adding energy storage devices.

Benefits: This R&D project will provide PGE and stakeholders information needed to determine when, where and how self-sufficient microgrids can be implemented within the PGE service with seamless integration as a distributed resource asset in combination with battery storage and other distributed energy resources.

6.5(b) Bigelow Canyon Wake Effects

In the observation of wind turbine arrays, it is known that wake-to-wake interactions in a wind farm play a large role in the decrease of its efficiency and thus power extraction suffers from these non-linear interactions. The following hypothesis is posed: Derating upstream turbines enables further flow passage, allotting increased resources to turbines within the wind farm, and therefore, possibly increasing the overall performance of the farm. In the Biglow Canyon wind farm, specifically, Siemens 2.3MW turbines (or otherwise phase 3) could be improved by manipulating the Vestas V82 (1.65MW) turbines (phase 1). Wind tunnel experiments at Portland State University will be conducted to validate the conjecture as brought by the two posed questions in the Learning Objective. The experiments will have an installation of a single turbine as well as a 4x3 wind farm for which resistances (loads) will be varied for the upstream rows and voltages will be measured on the downstream turbine (Note: variable loads equate to the proposed derating). All will be scaled to be consistent with prior experiments. The voltages will be recorded at a sufficiently high frequency as well as its record length will be long enough to arrive at converged statistics for the differences due to derating. This is a continuation of a 2016 R&D project – evaluating means of decreasing wake effects at Biglow Canyon.

Benefits: Decreasing the wake effect on Biglow Canyon Phase 3 wind turbines could increase the total annual energy production (AEP) at Biglow Canyon – increasing the value and lowering the cost of renewable energy.

6.5(c) Biomass – Complete Activities

Complete remaining activities to close out Biomass R&D – including air permit modeling and monitoring of fields used for growing Arundo per Morrow County bond.

Benefits: The Arundo fields need to be monitored to minimize risk/liability to PGE customers.

6.5(d) BPA Collaboration - Coordinated Voltage Control

The objective of this research is to develop, simulate and validate a coordinated voltage control scheme for increasing Dynamic Transfer Capability on California-Oregon Intertie and Pacific HVDC Intertie. This project will develop algorithms for coordinated voltage control and optimization of reactive power resources to increase DTC limits on the interties and internal flowgates. BPA will provide joint funding of $150,000

Benefits: Optimizing the use of PGE transmission will reduce energy costs for PGE customers.

6.5(e) Cascadia Lifelines Program

The Cascadia Lifelines Program is a targeted research consortium aimed at improving Oregon's infrastructure resilience in a cost-effective and value informed manner. PGE is joined by ODOT, Northwest Natural Gas, the Bonneville Power Administration, and the city of Portland as regular members that contribute $50,000 a year to fund the program. Participating at this level provides PGE a seat on the Joint Management Committee, which determines the research projects that are undertaken.

Benefits: Co-funding Cascadia Lifelines' R&D projects provides PGE information used to design and operate a more resilient and reliable grid and to more effectively and efficiently respond to customer needs during emergency events.

6.5(f) Data and Analytics Visualization POC

This POC will deliver a three vendor (mPrest, OpusOne and innowatts) POC that will demonstrate the vendors ability to provide high value to PGE's Integrated Grid initiative. The

POC will focus on specific use cases, including improved load forecasting capability, identification of under- and over-loaded transformers and the ability to wrap multiple systems into a system-of-systems.

This POC, if successful, will deliver high-value analytics and visualization capabilities that are not currently core competencies for PGE and will greatly accelerate PGE's corporate strategic goals, support a reliable a clean energy future, build and operate a smarter more resilient grid and pursue excellence in our work through a leap forward in PGE's data analytics and data visualization capabilities.

Benefits: This POC will provide multiple planning and operational value streams to PGE and its customers. These include:

- The ability to rapidly integrate multiple systems provides high value by reducing O&M costs and operational miscues that result in poor data used to make capital and O&M decisions.
- Improved load forecasting would result in the ability for PGE to better manage its operational business during both peak and non-peak events.
- Improved load forecasting may provide PGE the ability to inject additional energy into the EIM or other markets that may emerge over the next several years.
- The capability of identifying overloaded and under loaded transformers will reduce the risk of an outage, thereby improving outage metrics and improving the customer experience of PGE's customers.
- Implementing a data bus approach will reduce human error, lag time between manual updates of multiple systems, facilitate data governance, data analytics and provide a higher-level of confidence in data quality and decision making thereby enhancing decision quality and speed of decision making in multiple areas.
- Begin to move the needle on PGE's data analytics and visualization in a manner that directly supports the Integrated Grid Strategy.
- The speed of integration, if realized, will accelerate PGE's development and delivery of an energy exchange platform necessary to support SB978 and corporate goals.

6.5(g) Development of Distributed Battery Control Methods and Business Case at PSU

The 2016-2017 academic year project installed a battery/inverter system (BIS), 8kW/30kWh, at an employee home based on the laboratory prototype designed and demonstrated by PSU in June 2016. This BIS connects at the residential meter base to simplify and reduce cost of installation. The project tested end-to-end controls and equipment specifications required to utilize a BIS to provide backup power for an entire home during a grid outage. In normal conditions the system would serve numerous utility use cases such as a resource to serve peak demand, storing excess wind energy at night, and aiding renewables integration in general.

In the 2017-2018 academic year, PGE and PSU designed a meter base adapter to simplify the system installed in June of 2017. The PSU work also built a control system that could aggregate not one, but 1000s of batteries and water heaters through a method based on open standards.

The demonstrations prove installation of a BIS “at-the-meter” with cloud-based control can be implemented.

Next Steps: Field test of aggregation system for small battery systems which is part of PREPHub - Distributed Storage for Community Resiliency.

6.5(h) Employee EV Incentive & Data Collection for Charging Behavior Research

This project seeks a partial extension of the PGE Employee EV Research program. The proposed extension would only apply to eligible PGE employees that receive pre-approval for vehicle purchases before the end of 2017. Extending this program would allow PGE to gain valuable insight into the driving and charging habits of three new vehicle models that are not well represented in the 2016 and 2017 program year cohorts: the Tesla Model 3 (220 miles of range per charge, first deliveries in Q1 2018), Gen 2 Nissan Leaf (potentially >200 miles with upgraded battery, arrival date TBD) and Chevy Bolt (238 miles of range per charge, out now). These are the first moderately priced EVs (all retail in the mid $30,000 range before federal and state tax incentives) with driving ranges of over 200 miles. Vehicles of this type will likely represent the majority of new vehicles purchased in our service area in the coming years as battery prices decline and vehicle ranges increase. This project extension will only fund employee vehicle purchase incentives ($2,000 per vehicle). Funding for project evaluation is already included in the current program budget. Depending on the availability of shareholder dollars, a budget of $50,000 will cover either 25 or 50 vehicle purchases. PGE currently has 9 unfunded pre-approvals for 2018 purchase (all Tesla Model 3s).

Benefits: Gathering data on electric vehicle driving and charging habits will enhance customer service by ensuring that future transportation electrification programs are designed to meet the needs of electric vehicles with longer driving ranges. Only 2 of our 124 program participants currently own vehicles with ranges in excess of 200 miles and purchase prices in the mid $30,000 range.

Learning Objectives:

- Do the charging and driving habits of electric vehicles with 200+ miles of range differ from those with less than 100 miles of range?
- What kinds of charging infrastructure do drivers of EVs with 200+ miles of range most rely on?
- What programs might best support the adoption of EVs within PGE’s service area?

6.5(i) Distributed Storage for Community Resiliency - PREPHub

PREPHub demonstrates the potential for Smart Grid technology to yield community resiliency benefits during major emergencies such as an earthquake. Pioneered by MIT’s Urban Risk Lab, PREPHub modules contain equipment for charging small load electronics such as cell phones and radio communications, laptops, tablets and other cached goods, and lighting devices. The modules contain battery storage and incorporate small solar arrays to extend limited duration power availability during an emergency event when they run off-grid. When not operating in emergency mode, the modules all distributed resourced small capacity electricity storage to the PGE system.

PGE will support deployment, research and evaluation of at least one PREPHub installation in conjunction with the City of Portland. The City seeks to demonstrate PREPHub as a visible/tangible face for its BEECN network. During a catastrophic event that disrupts telephone service, BEECN would offer temporary radio communications for reporting damage and coordinating emergency response. There are 49 BEECN locations sited throughout Portland. During regular operations, the PREPHub modules will provide grid services which help PGE progress toward a clean energy future.

Benefits: By providing charging for small plug load devices during emergencies, PREPHub modules will strengthen community resilience during catastrophic events. They will also offer small unit distributed energy storage capacity on the PGE system and provide experience optimizing future distributed energy resource aggregation, control, storage and dispatch.

6.5(j) EPRI CTA-2045 EPRI Demo of “Smart” Water Heaters and EVSE

Building on the EPRI employee pilot in 2015, PGE co-led a 3-year, BPA-funded regional pilot with 8 participating utilities that finished in late 2018. The pilot engaged 90 PGE residential customers, and 190 from other utilities using CTA-2045 enabled-water heaters. The pilot implemented control strategies to quantify peak load reductions, and quantify load shifting capability per tank (i.e. reduce load in evening to shift consumption to night to store wind). The pilot demonstrated a reduction in system peak of about 0.35 kW and the ability to regularly shift about 1 kWh of energy a couple times per day. Survey data showed high customer satisfaction despite more than 600 control events completed in 220 days.

Status: The national award-winning project produced a strong business case that justifies a market transformation plan to pay for the cost to manufacture most water heaters shipped to the region with the CTA-2045 socket. With conservative enrollment assumptions, the plan yields a regional benefit of 425 MW (90 MW for PGE) by 2039, and a net benefit to the regional of $230 million. See also the full report at: www.bpa.gov/goto/smartwaterheaterreport

Next Steps: See Water Heater Market Transformation Project.

6.5(k) EPRI CTA-2045 EPRI Demo of “Smart” Water Heaters and EVSE: Demo of “Smart” EVSE (EV 240V chargers): CTA-2045 EPRI

EPRI convened (2013 thru 2016) a group of utilities, e.g. Duke, Southern Company, PGE, and appliance manufacturers to create demand responsive appliances using CTA-2405. The project demonstrated end-to-end demand response (DR) capability using the CTA-2045 communication interface. CTA-2045 defines a standard socket for appliances (picture a USB socket designed for appliances to support DR).

PGE: installed nine prototype electric vehicle supply equipment (EVSEs), i.e. the Siemens VersiCharge in employee homes. The pilot used the e-Radio CTA-2045 communication module to communicate to the EVSE.

PGE quantified the peak demand reduction using the shed command during summer peak demand periods. The result was a 0.2 kW demand reduction. (56% reduction.) The research also showed that being on a TOU rate was effective in regularly shifting load away from the 2pm to 8p hours. See research report completed by Research into Action, Inc. in December 2018. Status: Project completed.

Next Steps: Awaiting greater adoption of CTA-2045 by manufactures.

6.5(l) EPRI P1 Power Quality

This program encompasses three separate modules. PS1A which is improving power quality (PQ) in the transmission and distribution system, PS1B which is integrating PQ monitoring and intelligent applications to maximize system performance, and PS1C which is achieving cost-effective PQ compatibility between the electrical system and future loads. These three modules will help PGE with the increased grid complexity by testing new grid components such as smart inverter, smart meters, photovoltaic (PV), etc. This will also help PGE move PQ from merely reacting to understanding, managing, and preventing tomorrow's PQ issues. The goal would be to maximize the value from PQ data streams to better deploy advanced, low cost PQ techniques to improve the grid reliability. The entirety of the P1 program is to solve real, valuable utility issues through PQ expertise and research. Some examples include advanced diagnostics using PQ data to help anticipate equipment failure, advanced data visualization and validation, and PQ assessments of distributed energy resources (DER) technology.

Benefits: Taken together advanced diagnostics using PQ data will help devise low cost solutions for anticipating equipment failure, providing advanced data visualization and validation, and conducting PQ assessments of distributed energy resource (DER) technology, and improving grid reliability and compatibility with tomorrow's technology. Assessment of program results can help optimize grid integration of cleaner sources of energy while bolstering grid resilience and robustness and improving PGE's ability to diminish adverse PQ impacts on customers in the future.

6.5(m) Energy Storage

House Bill (HB) 2193 mandates that PGE procure at least 5 MWh of new energy storage by January 1, 2020. PGE has created an inter-departmental team responsible for developing a plan for meeting this mandate. The team has developed a project vision which is to optimize PGE's opportunities to learn about contracting for and operating different applications of energy storage by creating a diversified storage portfolio (in location and storage type). Key principles include utilizing storage as an integration resource, providing system benefit to all customers, balancing cost & risk while maximizing reliability, integrating T&D with Power Ops, and enabling resource diversification/de-carbonization. The team has identified five types of projects with the potential to optimize fulfillment of the storage mandate:

- **Substation:** A 17-20 MW, PGE-owned, operated, and controlled energy storage project that connects to the distribution system and is integrated with PGE's power operations.
- **Mid-feeder:** One 2 MW PGE-owned, operated, and controlled energy storage that provides added resilience and distribution support for high penetration solar.

- **Customer Programs:** PGE-owned and customer-owned (with Demand Response) energy storage systems that examine the potential for residential customer program offerings.
- **Customer Microgrid:** Customer sited, PGE-owned energy storage systems to provide support for disaster resilience at critical facilities.
- **Generation at Port Westward II:** PGE-owned energy storage system paired with generation to leverage support for ancillary services/spinning reserves & load following.

Status: Planning

Next Steps: PGE is evaluating options over the next 2 years with the intent to begin procurement in 2019 and system integration around 2020. PGE is planning the release of an RFP for a substation battery by June 2019.

6.5(n) EPRI P161 Information & Communications Technology and Security Architecture for Distributed Energy Resources Integration

This investment supports PGE's increasing reliance on technology, data networks and IT communications systems through research and development that promotes grid reliability, flexibility, resiliency and data management, transport and security. The research program involves a diverse grouping of protocols that involve assessment and potential commercialization of emerging technologies for use in Transmission and Distribution and customer engagement.

Benefits: Embracing best practices for the application of technology the electric utility sector is essential to PGE's continued success in serving its customers more effectively and efficiently. Anticipated applications of this research include ICT/Security Architecture for distributed energy resources (DER), data management & analytics, GIS best practices, centralized vs decentralized control, augmented reality, business efficiency, telecommunications management, Field Area Network (FAN) technologies, DER management systems Distributed Energy Resources (DER), Demand Response (DR), Advanced Metering System (AMI)s, and telecommunications and enterprise architecture & systems integration

6.5(o) EPRI P174 Integration of Distributed Energy Resources

This program offers insights into current and future utility interconnection practices and strategies in the face of economic and technical challenges associated with increasing grid deployment of Distributed Energy Resources (DERs). Technologies and techniques addressed include feeder voltage regulation, hosting capacity limits, and inverter grid support options to maintain reliable service. Also addressed are feeder impact assessments, inverter interface electronics, interconnection and communication standards, and integration analytics and the economic implications associated with DER integration. Finally, the program includes laboratory and field evaluations and demonstrations of improved DER power management and communications. A primary objective of the work in the field is to expand utility hands-on knowledge for managing distributed energy resources while enhancing asset safety, reliability, and effectiveness of utilization.

Benefits: Economic modeling and technical insights into integrating DERs as grid resource in support of a more decarbonized resource portfolio, and as a T&D resource to support a more flexible and more reliable grid. Integration of DERs supports a more streamlined interconnection process, and identification/evaluation of system constraints.

6.5(p) EPRI P180 Distribution Systems

EPRI's Distribution Systems Program 180 has been structured to provide members with research and application knowledge to support planning and management of the grid today and the transition to a modern Integrated Grid. The Program delivers a portfolio of tools and technologies to increase overall distribution reliability and resiliency; understand the expected performance for specific components throughout its life cycle; assess methods for evaluating the condition of system components; and develop and test new technologies. The program delivers a blend of short-term tools such reference guides and industry practices as well as longer-term research such as component-aging characteristics and the development of new inspection technologies. Overall, the Program includes research that supports grid modernization and provides tools for planning, design, construction, maintenance, operation, and analysis of the distribution system.

Benefits: The research areas provide us with the information to plan, develop, and operate the new T&D grid reliably and efficiently.

Learning Objectives:

- Identify and apply new approaches and strategies for managing aging assets
- Apply advanced diagnostics, inspection and assessment methods, tools, and techniques, and Integrate advanced distributed sensor technologies
- Optimize component procurement specifications and equipment application guidelines to improve investment decisions

6.5(q) EPRI P199 Electrification Program

Business enterprises are constantly striving to increase productivity and enhance their competitiveness in the global marketplace. In many cases, electrification – i.e., the application of novel, energy-efficient electric technologies as alternatives to fossil-fueled or non-energized processes – can boost utility productivity and enhance the quality of service to the enterprise and the customers it serves. Electricity offers inherent advantages of controllability, precision, versatility, efficiency, and environmental benefits compared to fossil-fueled alternatives in many applications. A lack of familiarity and experience with emerging technologies, however, impedes many enterprises, particularly small- to medium-sized businesses and civil institutions, from pursuing electrification measures that can improve the productivity and efficiency of operations. Such enterprises would benefit from information and support from their electric utility. However, electric utilities themselves face obstacles to serving as effective partners in this regard. Identifying and measuring the prime opportunities for electrification in a given service territory can be difficult. Utilities must also reconcile electrification strategies with mandated energy efficiency goals that are usually narrowly defined in terms of kilowatt-hour reductions. Moreover, the lack of an analytical framework for quantifying the net benefits of electrification strategies – from the customer, utility and societal perspectives – hinders the development of utility-business partnerships to facilitate beneficial electrification. This research program aims to address these gaps by developing and refining analytical tools and a knowledge base of technologies, applications, and markets and facilitating stakeholder networks to help utilities evaluate and pursue electrification opportunities.

Benefits: This program enables customers to improve productivity, efficiency and competitiveness through electrification.

6.5(r) EPRI P200 PDU – Distribution and Utilization

The distribution system is changing at an ever-rapid pace, much more so than any other area in the power system. Much of this has been driven by changes in customer behaviors (low load growth), customer adoption of distributed energy resources (DER), prosumers, as well as recent technological advancements newly available distribution planners and operators. Tools and methods for planning and operating the distribution system were not designed to meet this changing landscape.

Distribution systems have been designed for one purpose: reliably serve all customers in a safe and cost-effective manner. However, in this new era additional objectives must be considered as well, including accommodating high levels of DER, increasing resiliency, improving operational efficiency, and actively using distribution systems to provide bulk system services. Traditional planning methods utilizing rules-of-thumb are no longer sufficient and methods and tools for truly optimizing distribution planning and operational functions are necessary.

Tools and technologies, such as distribution management systems, automation systems, protection systems, and planning tools must adapt to facilitate the needs of this new distribution system. New technologies and their integration will be critical to allow distribution planners and operators to meet these goals and realize this concept of an “Integrated Grid."

P200 has been structured to provide research and application knowledge to support planning and management of today’s grid as well as tomorrow’s. The Program includes research that supports grid modernization and provides tools for planners, operators, and analysis experts of the modern distribution system. This program will serve as the hub for all activities related to distribution planning and operations.

Benefits: P200 focuses on T&D Planning for the new distribution grid. This research will help us make our system reliable, smart, and efficient, which in turn helps us deliver on our customer’s expectations. The research provided also helps us develop the next generation of utility engineers and provides them with the tools needed to plan and operate the new T&D grid.

6.5(s) EPRI Program P60: Electric & Magnetic Fields (EMF)/Radio Frequency (RF) Health Assessment and Safety Program

EPRI Program 60 is the largest and most comprehensive EMF research program in the United States. It provides a balanced research approach that addresses health & safety issues with regard to both the community and workers. In 2017, the focus will remain on experimental and epidemiologic research to help address issues such as childhood leukemia, neurodegenerative diseases, pregnancy outcomes, and EMF interference with implanted medical devices. EPRI’s EMF research and expertise can augment and build in-house EMF issue management capabilities – gained from EPRI meetings, technical updates, webcasts and reports. In addition, it is planned to have EPRI lead workshops for PGE Engineers to understand how to build EMF reductions into our designs and proceduralize the process.

Benefits: Both EMF and RF have been classified by the International Agency for Research on Cancer as possible human carcinogens. As our infrastructure ages, the grid expands to address electric vehicles, renewable integration, and new technologies (T&D construction, smart meters); we need to understand the latest in EMF research. PGE's support of P60 demonstrates our leadership and proactive approach to addressing potential community and regulatory concerns. Without this participation, PGE would be unable to access experts and the benefits of EMF and RF research geared toward the electric utility industry.

Ultimately, the EPRI EMF/RF Program provides research, analyses, and expertise to better inform public dialogue and regulatory oversight on EMF and RF health and safety issues that is based on sound science.

6.5(t) EPRI Program P62: Occupational Safety and Health

EPRI's Program 62 provides members with research relative to current and anticipated occupational health and safety (OH&S) issues. Deliverables derived from PGE's engagement are on-going and will be used to build, update and sustain our occupational health program. Deliverables relate directly to influence worker protective clothing (heat/cold stress) economic evaluation of ergonomic interventions, economic safety metrics/indicators and the development of an exposure database. Additional deliverables include monthly webcasts (recorded), a technical workshop and access to EPRI technical staff. By utilizing EPRI, PGE has an information resource that will allow for better short and long-term safety planning and strategizing. The program is designed to address both current issues and anticipate those of tomorrow.

Benefits: Participation in Program 62 will provide PGE with past, current and future research designed to address safety and health issues facing PGE. Implementing these research findings will lead to enhanced customer service and operational efficiency through the development of improved safety practices and procedures.

6.5(u) EPRI Program 88-Combined Cycle Heat Recovery Steam Generator (HRSG) and Balance of Plant (BOP)

PGE expects increasing challenges associated with flexible operation of its thermal generation assets upon joining the Energy Imbalance Market (EIM) on October 1st, 2017. Participation in EPRI Program 88 would better prepare PGE for the challenges expected from cycling base loaded plants by providing guidance on how to mitigate potential impacts. Program 88 covers best practices for HRSG operation, maintenance, and optimization and includes design guidance for new plant construction to better accommodate fast start and cycling operations. PGE has 4 combined cycle power plants and a total of 9 HRSGs.

Items covered by Program 88 that can be utilized by different teams at PGE include the following:

- Mitigation of thermal transients on critical components during plant start up, shut down and ramping operations
- Non-Destructive Examination (NDE) methods and guidance to find areas damaged by Flow Accelerated Corrosion (FAC)
- Plant modifications to reduce cycling impact to baseload plants (ultrasonic detection for draining)
- Specifications for new plant construction (Carty 2/3)
- Covered Piping Program Documentation (ASME B31.1 Power Piping code requirement for Carty)
- New HRSG cleaning methods for gas-side fouling (bang and clean technology)
- Boiler tube leak detection using acoustic and eddy current devices
- End of life calculations and modeling for different components (damage tracking)
- Dissimilar metal welds procedures and repairs in collaboration with Program 87

All research will help mitigate the impacts from thermal fatigue on critical components and reduce or eliminate forced outage down time, ensuring PGE's generating assets are reliable to operate when requested.

6.5(v) Investigating Use of Ductile Iron Poles for T&D Infrastructure

Evaluate the use of ductile iron as a viable support structure material in PGE's system, PGE is soliciting the research capabilities of Oregon State University's College of Civil Engineering. This work will support a graduate research assistant for general investigations into the long-term performance of ductile iron poles. This will include a thorough literature review as well as accelerated testing of ductile iron pole sections conducted under three types of degradation scenarios. Those scenarios include: 1) Corrosive environment using OSU's Qfog system 2) Sulfate rich soil environment using either OSU's Qfog or MCMEC system 3) Placement and initial measurements at OSU's long-term outdoor exposure site. During and after the accelerated aging, OSU will do electrochemical surface measurements (Eis) and scanning electron microscopy (SEM). Additionally, after accelerated aging, all specimens will be placed on OSU's outdoor long-term exposure site for continued monitoring. This will provide PGE with a repository of samples that can be measured periodically and will allow them continual updates, ahead of time, as to the long-term performance of ductile iron pipes. PGE has provided sections of ductile iron pipe and "comparison" pole material samples.

Benefits: Ductile iron poles have the potential to improve reliability and resiliency by eliminating woodpecker damage as one of the leading causes of premature wood pole failure. Additionally, the use of ductile iron poles addresses the growing concern around use of treated wood poles in environmentally sensitive areas.

6.5(w) Northwest Energy Efficiency Alliance (NEEA) End Use Load Research

This project involves participating in the End Use Load Research (EULR) Project being managed by NEEA. The purpose of the EULR project is to obtain a representative sample of electric end use load shapes, as this data has not been collected since the 1980s. This data will be collected continuously over a five-year period and will be accessible through an online database to participating parties. Detailed end use data has many important uses for PGE, including informing our deep decarbonization planning, demand response planning, bottom-up forecasting, and rate design.

Benefits: Research from this project will help PGE better plan and develop programs that fit customer lifestyles and meet their desire for clean, reliable energy.

6.5(x) OIT Energy Storage - Second Life Battery

This project will inform PGE planning and operations on the ability to implement Second Life Battery Energy Storage Systems (SLBESS) removed from vehicles to facilitate the integration of renewables and to minimize fossil-fueled generation. The project involves construction of a 250kW/1000kWh test pack for real world testing at the Oregon Renewable Energy Center (OREC) at Oregon Tech. Four battery packs will be prepared with different State of Charge (SOC), varying from 40% to 80%. Two packs will be used for determining battery cycle life and two packs will be used for system management development. Analysis will be performed on the SOC%, capacity, life cycle, efficiency, charge-discharge, and reaction time. The tabulated data will be used to determine the cycle life of different battery types. After simulation, the battery management system hardware will be developed.

Benefit: Development of a battery management system will allow PGE to effectively deploy second life batteries for renewable energy integration and grid resiliency.

Next Steps: PGE is in the process of planning a partnership with a technology provider, vehicle manufacturer to use battery packs from their vehicles for 2nd life applications.

6.5(y) Smart Streetlights Phase 2

In 2017, PGE engaged Portland State University in a research project to investigate and demonstrate 'smart' streetlights. A market assessment of technologies conducted by PSU supported pursuit of a demonstration pilot project with Sensus, PGE's AMI vendor. A two-phase demonstration project was initiated with 100 PGE- owned streetlights in Fairview and parts of Clackamas County. The focus of Phase 1 was primarily the deployment of the Sensus VantagePoint System and demonstration of its ability to reliably monitor streetlight fixtures, measure electricity usage of such fixtures and control them remotely. Phase 2 will demonstrate the system's ability to remotely brighten, dim and flash the lights, and to support secure user roles (e.g. shared control) for PGE and municipalities. Phase 2 will require replacement of PGE's existing 3-pin lighting fixtures with 7-pin fixtures capable of dimming and flashing.

Benefits: Smart streetlights will use less energy. Outages will be detected near real-time, improving the PGE's responsiveness to maintenance needs (and improving safety). Municipalities will be able to program streetlights to address specific needs and use cases (e.g. emergencies and traffic conditions). Billing will be done on actual, as opposed to deemed, usage (an interest expressed by a number of municipalities).

6.5(z) Salem Smart Power Center (SSPC) - Use Case Optimization

Over the four years that the Salem Smart Power Center (SSPC) has been in operation, we have tested and proven several use cases including frequency response, feeder voltage control, solar integration, demand response and non-spinning reserve. These use cases have been implemented, but only in a way that an operator must manually turn on each application one at a time. In 2017, Pacific Northwest National Laboratory (PNNL), in partnership with PGE, performed a comprehensive study of the economics of the various use cases and how they could be optimized to gain maximum value from this resource. This report found that in addition to SSPC's value in providing frequency response to comply with NERC requirements, there is an additional $170,000 annual benefit that is not being realized because the various applications currently cannot run in an optimized fashion. This project would design and install software enhancements that allow the use cases to operate automatically, switching from one to another according to a set of defined business rules.

Benefits: PGE has an obligation under Oregon HB2193 to build an additional 5MWh of energy storage. Several projects are being proposed and these projects face unknown challenges regarding controls, use cases, financial justification, interconnection strategies and business rules. Given that PGE has a utility scale energy storage plant in place we have an excellent opportunity to pave the way for future projects. Everything that is learned and produced by this project will be transferable to future projects, not just in storage but in distributed resources in general.

In addition, there is an opportunity to realize a $170,000 annual return from this work based on PNNL projections for the SSPC and current market conditions.

6.5(aa) Transformer Thermal Model Validation

At PGE's request, Portland State University conducted a thermal modeling study of single-phase subterranean vaulted transformers in Summer 2017. The purpose of the study was to identify potential thermal limit violations within transformers and on vault lids, given a variety of weather, loading and vault conditions. A final report was delivered to PGE in September 2017. Ideally, models are validated against measurements of in-service equipment. Model results should be compared to measurements taken from the object being modeled, and if discrepancies are noted, then the model must be adjusted such that the discrepancies are eliminated. The thermal modeling results have not been validated against field measurements of in-service transformers. PSU and PGE propose to conduct validation studies to provide validity to the modeling results.   The team will monitor temperatures and loading of several subterranean vaulted single-phase transformers, then use measurement data to tune model conditions and provide validation of the modeling results.

PGE installs transformers below grade in vaults in downtown Portland and at the request of customers within other areas of its distribution system. When a transformer is under electrical load, its temperature tends to rise due to thermal losses caused by the circulation of electric current and magnetic ux. When installed in a vault, a lack of sufficient ventilation may cause the transformer temperature to rise above the transformer's rated operating temperature. Extended operation beyond this limit could lead to thermal damage, shortened asset lifetime, and possibly interruption in service. Vault lid temperatures may also become excessive, which would directly affect customers who encounter these lids. A thorough, validated study of the thermal behavior of vaulted transformers would provide PGE engineers with confidence in their engineering decisions regarding transformer vault design, thereby improving safety, reliability and operational efficiency.

Benefits: This project will enhance customer benefits through improved safety, both for PGE employees and PGE customers. Benefits will also accrue through improved reliability and operational efficiency.

6.5(bb) OSU Wave Energy

The R&D funding will be used to advance Wave Energy and Modeling Research at OSU. This project would provide support for the continued expansion of wave energy research & modeling, prototype linear test-bed testing, and resource evaluations being used to assess renewable energy potential in the Pacific Northwest.

Benefits: Advancing wave energy research will provide the benefit of encouraging new project development in Oregon. This would allow increased diversity in PGE's renewable resources portfolio.

6.5(cc) E-Mobility Research Analytics

The Smart Grid will unleash the potential for large scale electrification of transportation. By 2025, PGE projects ten-fold growth in electric vehicle (EV) adoption in its service territory with charging loads for passenger vehicles exceeding 200 kWa/hr and heavy-duty vehicles at 1-2 MWa/hr.

This research project aims to better understand the impacts of growth in demand for EV charging on the PGE system so as to be prepared to accommodate demand as it materializes. Specific issues to be addressed include load profiles of high powered charging equipment, utilization/diversity of factors of different types of charging deployments, integrity of vehicle to grid energy flows, quality of on-charger and on-vehicle metering equipment, and the ability to integrate charging with power operations.

Benefits: This research supports PGE's low-cost decarbonization efforts (the transportation sector accounts for about 40% of Oregon's GHG emission). It will also enhance PGE's ability to evaluate future investments that support EV adoption, better understand how to improve the interconnection process in the face of growing installation of EV charging infrastructure, and Inform business strategies aimed at reducing operation costs such as sub-metered EV charging.

6.5(dd) Energy Systems Innovation Center (ESIC) Partnership

As part of PGE's on-going research and development efforts, we have renewed our participation in the Energy Systems Innovation Center (ESIC), a consortium of investor-owned and public utilities, Pacific Northwest National Laboratory, and Washington State University. ESIC is a leading center of excellence both nationally and internationally for research, education, technological innovation, and technology transfer in energy systems, including smart grids. With an exceptional team of faculty in power, energy, and computer science, and more than 20 faculty in allied fields (including economics, public policy, and sociology), ESIC provides a strong synergistic environment for conducting major multi-disciplinary studies on electric energy and its social and economic impacts, facilitating the development of public policy at the state and national levels.

6.6. Physical & Cyber Security

6.6(a) EPRI P183 Cyber Security

The Cyber Security and Privacy Program of the Electric Power Research Institute (EPRI) focuses on addressing the emerging threats to an interconnected electric sector through multidisciplinary, collaborative research on cyber security technologies, standards, and business processes.

Benefits: This project will provide research in the support pf providing safe, reliable power by identifying digital threats to and remediating vulnerabilities to PGE technology infrastructure. Customers will benefit from increased safety and reliability of the electrical grid.

Learning Objectives:

- Technologies which support the management of cyber incidents and increase the cyber security and resiliency of the grid
- Guidance on developing cyber security strategies and requirements for selecting effective technologies;
- Techniques for assessing and monitoring risk; Understand security threats of smart grid assets

6.6(b) Smart Grid Cybersecurity

PGE is committed to providing effective security controls based on a risk-based approach to ensure we are investing wisely. Security and flexibility that meet the needs of our customers and keep pace with our fast-changing environment that includes smart grid as well as traditional electric grid assets. These controls include the following:

Cyber Security and Management Practices

- **Access controls:** Electronic and physical access controls large facilities to smart grid edge devices are evaluated for appropriate security and functionality.
- **Risk assessment:** Defined Risk assessments (delivery of power, malicious code, unauthorized use, etc.) are developed and evaluated for the changing smart grid landscape.
- **Threat management:** Defined practices policies and procedures are being developed and evaluated for the Smart Grid environment.
- **Encryption:** Secures communications a data storage where assessments have identified the need to mitigate and lower risk.
- **User access authorization management:** Procedures to secure electronic access, grant and remove individual access.
- **Configuration management:** Procedures to change, maintain and back up critical configurations of devices to support incident response, business continuity and disaster recovery.

Coordination with Smart Grid and Future State

- Third party provider contact language for security requirements and controls.
- Integrated Security Operations Center (ISOC) network and physical security monitoring and response coordination.

- Incident response planning and exercises to support business continuity and disaster recovery.
- Increase network visibility for situational awareness, cyber security and business continuity.

6.6(c) Smart Grid Physical Security

PGE has enacted and maintains effective controls, protocols and measures based on a risk-based approach to ensure security and privacy for customers and for PGE Smart Grid assets and traditional electric grid assets. Controls, protocols and measures in place include the following:

- **Elocks:** Programmable electronic locks and keys to secure physical access and grant and prevent individual access that is scalable from large facilities to smart grid edge devices. Audit and historical logs are maintained and available for review.
- **Card readers:** Programmable network connected electronic badge readers are required for physical access to facilities that require higher levels of real time alerting and monitoring. This technology authenticate authorization to access a facility, grants and removes individual access authorization, and provides real time alerts. Audit and historical logs are maintained and available.
- **Fencing:** Mini mesh anti-climb, anti-cut material and construction fencing is installed at PGE sites requiring perimeter fencing. Fence fiber provides alarms when climbing motion is detected while larger riprap stones under fence deter digging.
- **Car Barriers:** Bollards, gates, access road approaches, boulders, vehicle parking and other barriers are installed to provide for assessment of and possible interdiction of vehicular threat vectors based on site vulnerabilities.
- **Lighting and Video:** Motion detection lighting and video cameras are being installed as warranted for monitoring, to deter entry and generate visual evidence of violations and help guide incident response efforts.
- **Law enforcement coordination** for incident response contacts help expedite response times and coordinate deterrents to entry.
- **Third Party threat risk assessments** are conducted
- **Ballistic protection** is installed for CIP-014 Bulk (high risk) Transformers

6.7. Completed & Archived

6.7(a) EV-only (sub-metered) TOU Rate

Through Schedule 7, PGE offers a TOU rate for separately metered service used exclusively for EV charging. To participate in this option, the customer must (at his or her own expense) install all necessary equipment (including the revenue-grade meter). The sub-metered rate is cost prohibitive for customers and has ultimately yielded no participation to date.

As an alternative to reduce costs, PGE has considered using “smart” residential charging units with internal metering capabilities; however, there are no industry standards or best practices on utilities measuring, verifying, and performing on-going testing of the metering in these devices to ensure they are consistently revenue grade.

Status: Complete. PGE is currently developing a new TOU rate.

6.7(b) Employee EV Research Project

PGE has more than 150 employees who own or lease an electric vehicle. In 2016, we launched an employee research project to study charging behavior (home, public, and workplace), TOU rates, and demand response/smart charging. The project ended mid-2018.

The project provided PGE better understanding on where and when people charge, how TOU rates impact home charging habits (and use of other appliances in the home), and the impacts of curtailing charging loads at home and work. Key elements of the study included:

- Time of Use: On average, more than 80% of EV charging happened at drivers' homes—as a result we understand the importance of looking for pricing and control strategies at the premises. As such, half of the participating employees were randomly selected to be put on Schedule 7's whole-home TOU rate which offers savings of greater than 40% for shifting energy consumption to off-peak hours. The study compared TOU participants versus non-participants and evaluated impacts on charging behavior as well as energy use for all devices in the home.
- Note: this is PGE's historic rate schedule and not the pricing options offered in PGE's current TOU program, Flex.
- Smart Charging: 35 employees in the pilot utilized a DR-enabled home charging station; additionally, all employees are eligible for free workplace charging (some of which is DR-enabled). PGE is collaborating with EPRI in studying the interoperability of smart appliances. The centrally-managed charging process allows PGE to signal cars or charging stations to adjust demand in real-time to optimize resource and system utilization. The study aims to evaluate practical feasibility, customer experience, and achievable curtailment from smart charging. Additionally, we directly engaged with several employees to program their vehicles to charge on a schedule.
- Public Charging Behavior: all participating employees were responsible for keeping a vehicle charging log to track public charging events. These logs were evaluated to better understand what drives people to charge outside of the home and workplace, how often they publicly charged, where they charged, and for how long they charged.
- Survey Data: Additionally, PGE used the employee group to periodically survey for EV-related insights.

We anticipate that the learnings from this study will inform future program design to help efficiently integrate customer EVs into PGE's grid.

Status: Complete

6.7(c) Commercial and Industrial Time-of-Day Pricing (TOD)

PGE offers TOD pricing via Schedules 83, 85, and 89. All customers with monthly demand in excess of 30 kW are on a time-varying pricing program.

Status: Active Deployment

6.7(d) Energy Management System (EMS) State Estimator (SE)

PGE has developed our energy management system state estimator system model to optimize operation and reliability of the transmission system. The SE is one of several tools used by Transmission Operations Engineering to optimize coordination with the Reliability Coordinator on bulk electric system operational concerns. The model provides insight into the state of the grid by reading system data from the SCADA system (voltage, line flows, etc.) and performing power flow simulations. EMS SE is also an enabler for the Real Time Contingency Analysis, another EMS application that simulates the impact of pre-defined contingencies on the transmission system.

Status: Fully deployed April 1, 2017

6.7(e) Firm Load Reduction for Commercial & Industrial Customers

Through Schedule 77, PGE offered a demand response (DR) program to large non-residential customers who were able to commit to a >200 kW demand reduction for 4-hours from a single meter. The program was launched in 2010 and at its peak, there were three customers enrolled in the program who were able to reliably demonstrate load reductions of 18.3 MWs during events. These reductions were considered as a resource in PGE's integrated resource plan (IRP).

Though customers committed to a specific level of curtailable demand, additional load reductions above the commitment were often experienced. In the summer of 2015, program participants exceeded contract curtailment goals in all four events called.

Despite the success of the program in 2015, participation diminished in subsequent years. Of the three customers that were active in the program in 2015, one left the program to participate in the Energy Partner program (see below) and a second customer – which represented 87% of the demand reduction capacity – was purchased by a competitor and later closed. Service under Schedule 77 ended on November 30, 2017 and the final participant was transitioned to the Energy Partner program.

Table 15: Schedule 77 Program Progress

Metric	2014	2015	2016	2017	2018
Participants	3	3	1	1	0
Maximum Available Winter Capacity (MW)	18.3	18.3	1.8	1.8	0
Maximum Available Summer Capacity (MW)	18.3	18.3	1.8	1.8	0

Status: Program ended 11/30/2017

6.7(f) Bulk Thermal Storage

In 2016 PGE successful tested in a PSU laboratory, a prototype of a residential heating and cooling system where the customer's energy needs are decoupled from when PGE delivers energy by using a thermal storage system. This allows PGE to use the lowest cost and/or cleanest generation sources. Generally, low-cost wholesale energy costs coincide with periods of wind and solar generation. The prototype validated modeling that demonstrates substantial savings in energy and on-peak demand. If commercialization challenges can be addressed, the economic benefit is very large. At a mature implementation level, 40% of all residential energy could be limited to 8 hours, at times chosen by the utility to minimize cost and maximize use of wind and solar generation.

Status: Project completed 2016. Next step must include a partnership with HVAC manufacturer who will commercialize the technology.

6.7(g) Advanced Metering Infrastructure (AMI) Deployment

Smart meters are a foundation upon which smart grids are built. In response to OPUC order No. 08-245, PGE has installed digital smart meters at more than 825,000 customer locations along with dozens of communication towers. Virtually all PGE customers have been using smart meters since 2010.

The smart meters collect electricity usage data in one-hour increments for residential customers and in 15-minute increments for most business customers. Customers can use the data to understand their electricity use patterns and make modifications to use electricity more efficiently and affordably.

The smart meters allow rapid and accurate identification, diagnosis and deployment of restoration crews in cases of outages, excessive line losses, under- or overutilized transformers and instances of possible energy theft or diversion.

Smart meters also make a substantial contribution to decarbonization. PGE estimates that the installation of smart meters has resulted in 1.2 million fewer miles driven for meter reading, reducing CO2 emissions by 1.5 million pounds annually. Eliminating the need to for meter reading has helped manage labor costs, translating into more affordable electricity for customers.

Status: Fully Deployed

6.7(h) Energy Management System (EMS) & Automated Generation Control (AGC)

EMS-AGC is one of several interfaces that play a critical role in ensuring smart grid functionality and reliability. In coordination with CAISO (California Independent System Operator), EMS-AGC controls PGE’s generation fleet and ensures bulk electric system reliability and market dispatch through participation in the Western Energy Imbalance Market (EIM). EMS-AGC also provides advanced analytics on historic data used to optimize system performance.

Status: Actively Deployed and Fully Functional

6.7(i) Outage Management System (OMS)

OMS value to the Smart Grid lies in its optimization of field crew deployment to restore outages. Deployed in 2015, OMS imports information from AMI, SCADA, and phone calls from customers to identify interrupted circuits and model the extent of an outage. Logic within the OMS allows outage managers to selectively ping meters, or groups of meters, to confirm outages and outage restoration as well as filter out unwanted alarms and limit the number of alarms for the OMS to analyze.

Status: Active Deployment

6.7(j) Real-time Contingency Analysis (RTCA)

RTCA is a situational awareness tool that runs contingency on the State Estimator. The model runs power flow for defined contingency scenarios (loss of line, transformer, or any other element in the system). The model then ranks the overall impact of potential system operating limit concerns (thermal overloads, voltage issues). This enables pre-contingency mitigation strategies to be employed to address the potential impact of a particular outage scenario. Contingency models for 230kV, 115kV and 57kV lines are evaluated

Status: Complete - Fully deployed April 1, 2017

6.7(k) Flex: Pricing Research Pilot

In 2014, PGE began a strategic effort to evaluate pricing program types and barriers to customer participation. PGE completed market research that included surveys and focus groups to help inform a pilot offering. PGE also leveraged AMI data to conduct load segmentation research, identifying 5 load profiles that can be targeted for demand response and pricing initiatives. A pilot to test various pricing program types was approved with deferred accounting on June 15, 2015 (Docket No. UM 1708, Order No. 15-203).[1]

The Flex pricing pilot tests various pricing program types to identify which ones offer the best customer experience and the greatest system benefit:

- Behavioral Demand Response (BDR)
- Day/Night TOU
- Peak-Only TOU
- Three-tier TOU
- Peak Time Rebates (PTR)

Recruitment strategies were shared with stakeholders at the 2/9/16 customer engagement workshop. Recruitment for the pilot began in February 2016. As of April 2017, PGE had enrolled roughly 8,000 participants (assigning half to treatment and half to control groups). An additional 7,000 were included in opt-out peak time rebate or behavioral demand response programs.

Table 16: Flex Pilot Participation and Progress

Metric	2016
Participants	13,897
Maximum Available Winter Capacity (MW)	1.1
Maximum Available Summer Capacity (MW)	3.5

Next Steps: Cadmus completed its pilot evaluation and presented its final report in June 2018. Based on those findings, PGE proposed a PTR program modeled after the PTR scenario that received the highest levels of customers satisfaction and load shift in the pilot. An updated Schedule 7 tariff to include that offering was approved in April 2019, and customer enrollment began that same month. As of May 2019, PGE had enrolled 12,000 customers into the program. PGE plans to file an additional update to the Schedule 7 tariff in June 2019 to include a new Time of Use pricing plan that will go into effect Q4 2019.

Section 7. Research & Development

7.1. Research Expenditures

Table 17 summarizes R&D expenses by project for 2017 and 2018.

Table 17: R&D Expenses (2017-2018)

R&D Project Name	2017	2018
Agronomy, Acceptability & Potential for Growing Giant Cane (Arundo donax) in E. Oregon	$36,000	-
Behind the Meter Use of Energy Storage and a PV System	$47,153	-
Biglow Wake Effect - PSU	$35,000	-
Biomass - Complete Activities	$538,902	-
BPA Collaboration - Coordinated Voltage Control	-	-
Cascadia Lifelines Project	$50,000	$50,000
Computer Based Modules for Sulfur Hexafluoride SF6	$234	-
Data Analytics and Visualization POC	$31,630	$350,000
Development of Distributed Battery Control Methods and Business Case at PSU	$47,930	$58,101
Distributed Storage for Community Resiliency-PREPHub	-	$36,000
Employee EV Incentive & Data Collection for Charging Behavior Research	$94,893	$99,350
EPRI CTA-2045 EPRI demo of “Smart” water heaters & EVSE	$70,995	-
EPRI DRIVE Tool	$10,000	-
EPRI Optimizing Heat Recovery Steam Generator Drains	$10,906	-
EPRI PQ Knowledge Development and Transfer	-	$20,000
EPRI P1 Power Quality	-	$123,447
EPRI P94: Energy Storage & Distributed Generations	$92,404	-
EPRI P161 Information & Communication Technology	$80,000	$174,630
EPRI P173: Bulk Power System Integration of Variable Generation	$67,977	-
EPRI P174 Integration of Distributed Energy Resources	$35,916	$71,258
EPRI P180 Distribution Systems	$112,295	$122,325
EPRI P183 Cyber Security	$91,694	$91,691
EPRI P199 Electrification Program	-	$68,278
EPRI P200 PDU - Distribution and Utilization	$43,038	$55,679
EPRI P60 EMF-RF Health Assessment and Safety	-	$144,588
EPRI P62 Occupational Safety and Health	-	$42,882
EPRI P64 - Boiler and Steam Turbine Cycle	-	$33,043
EPRI Program 88-HSRG and BOP	-	$77,235
Fire Station One Commercial Solar + Storage Grid Integration	-	$25,080
Inspection & Correction Program for Below Grade Corrosion	$54,661	-
Investigating Ductile Iron Poles for T-D Structures	-	$20,000
Maxisys / BPA R&D Project (T&D Node/Breaker Modelling)	$50,000	$50,000
NEEA End Use Load Research	-	$130,000

NuScale Modular Reactor Study Group	$5,000	-
OIT Energy Storage-2nd Life Battery	$25,000	-
OSU Microgrid Synchrophasor	$60,000	$30,000
Seismic Analysis and Post Event Transmission Studies	$33,944	-
Smart Streetlights Phase 2	-	$31,567
Solar & Meteorological Data Collection/Evaluation	$10,000	-
SSPC Use Case Optimization	-	$71,858
SSPC Voltage Control	$11,275	-
Transformer Thermal Model Validation	-	$15,000
Via Pickup Truck & Exportable Power Demonstration	$2,874	-
Wave Energy - OSU	$25,000	-
WSU Power Engineering Energy Innovation Center Data Access	$15,000	-
Yamhill County Landfill Gas Potential for Renewable Power Generation	$5,000	$10,000
Grand Total	**$1,794,721**	**$2,002,012**

Appendices

Appendix 1. Smart Grid Metrics

Table 18: Asset Optimization Metrics

Metric	2015	2016	2017	2018	2019
% Substations with SCADA	77%	78%	78.2%	80.1%	81.9%
% Critical Transformers w/ DGA	68%	85%	84%	83%	84%
Efficiencies realized through CVR (MWh)	-	356	768	-[36]	

Table 19: Reliability Metrics, Corporate Summary

Metric		2015	2016	2017	2018	3-yr Avg.
Including Major Event Days[37]	SAIDI	175	169	350	88	203
	SAIFI	0.78	0.79	1.04	0.51	0.78
	MAIFI	1.2	1.1	1.35	1.26	1.25
	CAIDI	222	214	336	172	240
Excluding Major Event Days	SAIDI	75	97	113	88	99
	SAIFI	0.48	0.59	0.62	0.52	0.58
	MAIFI	1.2	1.1	1.35	1.26	1.25
	CAIDI	156	163	181	172	172

[36] CVR has been disabled on pilot feeders while communications/analytics pilots are underway

[37] A Major Event Day is a day in which the daily system SAIDI exceeds a threshold value that is computed via the IEEE Standard 1366 (IEEE Guide for Electric Power Distribution Reliability Indices) methodology. This methodology is used by PGE to calculate distribution system performance indices and utilizes the Major Event Day (MED) designation as a basis for evaluation of system performance. The purpose of MED designation is to allow major events to be studied separately from daily operation, and in the process, to better reveal trends in daily operation that would be hidden by the large statistical effect of major events. As a result, PGE captures and reports system performance metrics both including and excluding Major Event Days.

Table 20: Reliability Metrics by Region, Eastern

Metric		2015	2016	2017	2018	3-yr Avg.
Including Major Event Days	SAIDI	237	196	274	98	189
	SAIFI	1.03	0.88	1.04	0.53	0.81
	MAIFI	1.58	1.4	1.94	1.74	1.69
	CAIDI	230	223	264	185	224
Excluding Major Event Days	SAIDI	76	92	115	98	102
	SAIFI	0.55	0.60	0.65	0.53	.60
	MAIFI	1.58	1.40	1.94	1.74	1.69
	CAIDI	139	152	176	185	171

Table 21: Reliability Metrics by Region, Southern

Metric		2015	2016	2017	2018	3-yr Avg.
Including Major Event Days	SAIDI	155	183	395	100	226
	SAIFI	0.70	0.85	1.07	0.56	0.83
	MAIFI	0.9	0.8	0.87	0.77	0.83
	CAIDI	223	215	368	177	253
Excluding Major Event Days	SAIDI	91	132	135	100	122
	SAIFI	0.51	0.68	0.67	0.56	0.64
	MAIFI	0.9	0.8	0.87	0.77	0.83
	CAIDI	178	193	202	177	191

Table 22: Reliability Metrics by Region, Western

Metric		2015	2016	2017	2018	3-yr Avg.
Including Major Event Days	SAIDI	97	124	432	69	208
	SAIFI	0.49	0.64	1.03	0.47	0.71
	MAIFI	0.74	0.9	0.79	0.87	0.87
	CAIDI	200	194	419	147	253
Excluding Major Event Days	SAIDI	64	83	97	69	83
	SAIFI	0.37	0.52	0.55	0.47	0.51
	MAIFI	0.74	0.9	0.79	0.87	0.87
	CAIDI	178	159	174	147	160

Table 23: Energy Storage Metrics

Metric	2019	2020	2021	2022	2023
Available Storage Capacity (MW)	5.01	5.76	33.76	34.76	36.50
Available Storage Energy (MWh)	1.28	4.28	96.28	100.28	105.29
# of Energy Storage Locations	2	5	8	508	520

Table 24: Electric Vehicle Metrics

Metric	2014	2015	2016	2017	2018
Est. Number of Electric Vehicles in Service Area[38]	5,500	6,300	8,091	10,756	13,894

Table 25: Customer Engagement Metrics

Metric		2014	2015	2016	2017	2018[39]
Total # Customers that have utilized Energy Tracker	Residential	165,004	201,375	231,777	84,624	89,877
	Commercial	2,462	3,388	4,138	1,585	1,217
	Total	**167,466**	**204,763**	**235,915**	**86,209**	**91,094**
Energy Tracker Realized Savings[40]		3%				
# Customer Utilizing Energy Expert		97	105	108	112	105
# of Customer Accounts of TOU Rate Schedule[41]	Residential[42]	2341	2355	3835	5082	4443
	Commercial	305	304	319	331	314
	Industrial	393	420	427	421	386
	Total	**3039**	**3079**	**4581**	**5834**	**5143**
# Customers participating in DSG		34	35	38	39	38
Dispatchable capacity of DSG (MW)		94.0	106.8	116.9	122.7	127.9

[38] Estimated based on ODOT and Navigant estimates of EVs in Oregon with about 80% in PGE service area

[39] In April of 2018, Aclara was replaced by Opower/FirstFuel, and therefore values for April, May, June of 2018 are not available. Additionally, all visitors in July 2018 are considered first time visitors, as it is not easily possible to compare Opower/FirstFuel visitor IDs against Aclara's visit IDs.

[40] Energy Tracker savings data is based on program evaluation in 2013

[41] The 2018 data is not curtailed to those enrolled in their respective TOU rate before 12/31/2018. The counts in this table represent service points that have chosen optional time-of-use rates. The 2012-2016 counts (particularly for commercial service points) are lower than those presented in the 2017 smart grid report because previous counts included some larger commercial customers who had not opted into a time-of-use rate, but rather whose default rate schedule included a time-varying component.

[42] 2012-2016 counts are from December ICE datasets; 2018 counts are from the Customer Research database

Capacity of customer-owned DER (MW)[43]	44.5	54.2	73.2	112.14	136.6
Number of customer programs[44]	6	6	6	6	6

Table 26: Demand Response Metrics[45]

	Metric		**2014**	**2015**	**2016**	**2017**	**2018**
	# Customers participating in DR	Residential	0	142	16,409	16370	26552
		Business	24	39	42	18	43
		Total	27	184	16,467	16388	26595
Winter	Maximum available capacity of DR (MW)	Residential	0.0	0.1	1.4	0.5	5.3
		Business	24.6	24.6	14.9	3.0	15.2
		Total	**24.6**	**24.7**	**16.3**	**3.5**	**20.5**
	Season Peak (MW)		3,646	3,914	3716	3,727	3,399
	Available capacity of DR (% of season system peak)		0.67%	0.63%	0.44%	0.10%	0.60%
Summer	Maximum available capacity of DR (MW)	Residential	0.0	0.0	5.8	4.5	13.0
		Business	21.0	27.4	12.9	3.0	15.2
		Total	**21.0**	**27.4**	**18.7**	**7.5**	**28.2**
	Season Peak (MW)		3646	3914	3726	3,976	3,816
	Available capacity of DR (% of season system peak)		0.58%	0.70%	0.50%	0.19%	0.74%

Table 27: Customer Engagement Metrics
(% Participation in Each Program Type by Segment, 2018)

Segment	**Residential**	**Business**
% Participation in each program type		
Avg. # of Retail Customers[46]	772,389	109,377
Energy Information Services	41.5%	5.2%

[43] Includes solar, wind, hydro, fuel cell, and methane gas. Capacity is reported in MW-AC. Inverter-based technologies (solar and wind) include an 85% DC-to-AC derate factor.

[44] Includes energy information services (Energy Tracker & Energy Expert), demand response (Schedule 77), pricing programs (TOU and TOD), and distributed generation (DSG, Net Metering, Volumetric Incentive Rate and Qualified Facilities); Note: Does not include pilots

[45] Programs covered in the table below include: Critical Peak Pricing, Schedule 77, Energy Partner, Smart Thermostats, and the smart water heater direct load control pilot.

[46] PGE 2016 Annual Report: http://investors.portlandgeneral.com/annuals-proxies.cfm

Demand Response	3.4%	0.05%
Pricing Program	0.0%	0.0%
Distributed Generation	1.0%	0.6%