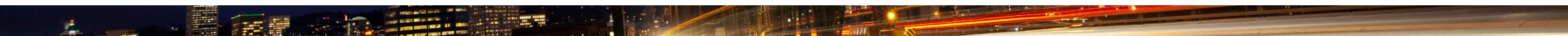




A MODERNIZED grid platform for a clean energy future



The modern electric grid is the platform to enable a lower-carbon future for all sectors of the economy, from utilities to transportation to industry.



Our world is changing — and so is how we create and use power. Until recently, electricity has flowed pretty much as it had for more than a century — in a one-way stream from where it’s generated to where it’s used. But new smart grid technologies create a two-way exchange of electric power and information that helps us make our system more efficient and more reliable for customers. The modern grid will empower customers to take advantage of the cleanest energy sources, lower their overall household energy spending and partner with their utility to help decarbonize our economy.

The smart grid allows us to work in collaboration with customers to integrate renewable energy and other technologies that improve efficiency and drive decarbonization. These efforts can be something as simple as customers installing solar panels to reduce their electric bills, which also play an integral part in addressing climate change. In essence, the modern electric grid is the platform to enable a lower-carbon future for all sectors of the economy, from utilities to transportation to industry.

At Portland General Electric, our mission is to connect customers with what matters most, and our imperatives are to address climate change and ensure equity in the transition to a clean energy future. We are enhancing our grid to enable a seamless platform that launches our economy into an affordable, equitable, resilient, safe and clean energy future. These enhancements include:

- The increasing availability of clean, renewable sources like wind and solar.
- The use of electricity for more things like electric vehicles and heat pumps.
- The integration of new, geographically diverse energy markets.
- The deployment of new technologies like storage, communications networks, automation and control systems for flexible loads and distributed generation.
- The development of connected neighborhood microgrids and smart communities.
- The use of data and analytics to better predict demand and support energy-saving customer programs.

Building on our foundational infrastructure, nearly 130 years in the making, PGE is creating an electric grid that’s more flexible, resilient and integrated — in a word, smarter. The modernized grid complements our transmission and distribution system operations as we continue to harness new technologies and move toward our clean energy future.

Preparing for the future

Between now and 2050, we estimate that our service area will need about 10 to 15 gigawatts of new renewable resources to transition to a clean energy economy. While this amount is within the total renewable resource potential of our region, it represents a ten-fold increase in our current renewables. Expanding our use of energy storage will also help integrate new renewable resources while supporting grid operations. Furthermore, by updating our communications and control systems, we’ll support new customer technologies, smart cities and more efficient grid operations.

Integrating our grid and markets

As we look forward, building the smart grid on our distribution system foundation requires the integration of multiple levels of our generation, transmission, distribution and customer systems. Grid stability has traditionally been managed on the transmission system, but this must expand to include the distribution system. Ultimately, an integrated grid will accelerate our deployment of renewable energy, create better experiences for customers, support system-wide optimization and lower energy costs for everyone.

This integration is also key to obtaining the lowest cost renewables for customers. With more renewables being added to the system, there are times when their variable output outstrips customers’ need for power. As a result, that low cost renewable energy is often curtailed. Because PGE is part of an integrated Western grid, we’re able to take advantage of that low-cost resource for our customers whenever possible. We support enabling customers who want to install distributed resources like rooftop solar. Though when it comes to the lowest cost renewable energy available, that usually isn’t coming from your neighbor’s roof — it’s grid-scale wind projects or the excess renewable energy generated elsewhere on the Western grid.

RAPID ADOPTION OF NEW TECHNOLOGIES

From now to 2030, we estimate:



We’ll need about **2.5 times the wind and solar we have today** to meet customer demands with renewable energy.



We’ll see a **ten-fold increase** of energy storage capabilities on the grid.



Demand response programs will **increase ten-fold**.



Electric vehicles charging on the grid will **increase twenty-fold**.

STRATEGY IN ACTION

Meeting demand on the hottest day of the year

On August 3, 2017, our service area reached a record 105 degrees Fahrenheit — and PGE reached an all-time record summer energy peak at 3,974 MW.

Prior to the heat wave, we had integrated data from our smart meters with our outage management system to identify transformers that needed to be upgraded or replaced. We had also implemented 13 MW of demand response and other dispatchable resources. Finally, we had upgraded substations with advance communications and control systems. All our work kept customers comfortable on the hottest day of the year.

Energy for everyone

As the state’s largest electric utility, our social compact has been to keep energy affordable and accessible to all customers. We have worked over the years with partners to create programs and policies to help customers who have historically experienced systemic and social barriers to affordable and reliable energy because of economics, geographical location or language barriers. For example, working with Community Action Partnership Agencies and counties, we have a system that makes available low-income bill payment assistance, low-income weatherization, time payment assistance and other ways to help customers pay their bills.

In the future, maintaining a just and equitable energy system means recognizing that energy is an integral part of the fabric of our society that is growing in importance. It also means thinking creatively about how communities benefit from the clean energy future, from access to clean technologies to jobs at PGE and elsewhere. Maintaining a just and equitable energy system means embracing the role we play as conveners of access to healthier, more equitable resources. When the community bands together to do their part to lower costs and support for cleaner alternatives, the benefits are far reaching.

IN THE FUTURE, MAINTAINING A JUST AND EQUITABLE ENERGY SYSTEM MEANS RECOGNIZING THAT ENERGY IS AN INTEGRAL PART OF THE FABRIC OF OUR SOCIETY THAT IS GROWING IN IMPORTANCE

CREATING AVAILABLE, FLEXIBLE ENERGY

In this new era of dynamic electricity use, PGE is integrating flexible electricity use and generating resources while driving affordability and accessibility. This paper outlines a number of focus areas, projects and plans designed to help us meet our goals. We are working to apply an equity and inclusion lens to all we do, acknowledging that we are learning more and trying to get better at this as we move forward.

STRATEGY IN ACTION

Salem Smart Power Center: Energy storage and grid frequency stabilization

The Salem Smart Power Center was developed by PGE and our partners as part of the largest regional smart grid demonstration at the time — the Pacific Northwest Smart Grid Demonstration Project.

The project used state-of-the-art storage batteries to show how variable renewable sources, such as solar and wind, may be stored for later use. When power sagged briefly on the regional transmission system in February 2015, the batteries immediately fed 5 MW back onto the grid to help stabilize grid frequency.

Greater flexibility with energy storage

Historically, utilities have been able to alter generation to balance energy supply with demand, which fluctuates throughout the day. To maximize the use of renewable resources like wind and solar, which generate variable amounts of power during the day, flexibility must increase. Energy storage systems like batteries and electric vehicles, store electricity during periods of high generation and provide it back to the grid during peak usage times. PGE is turning to energy storage as a way to leverage more renewable resources and maintain reliability, while helping regulate the grid. Looking to the future, when used in conjunction with microgrids, energy storage can also supply power to customers during outages. These local microgrids can meet the needs of customers in a particular area during wide-area events impacting the grid.

More efficiency through automation and control

By automating and optimizing our operations, we can make our transmission and distribution (T&D) system smarter than ever. We’re deploying advanced sensing equipment and automation across our system. We’ll further enhance grid efficiency through voltage optimization, which improves energy efficiency and reduces energy usage.

Imagine a grid that can automatically identify outages, diagnose problems and restore power to customers. Distribution Automation (DA) uses digital sensors and switches to manage the flow of power without manual intervention. This can shorten the duration of outages and reduce the number of impacted customers by two-thirds, leading to greater reliability and cost savings.

IMAGINE A GRID THAT CAN AUTOMATICALLY IDENTIFY OUTAGES, DIAGNOSE PROBLEMS AND RESTORE POWER TO CUSTOMERS

Lower costs through flexible loads

When we can reduce the demand on our grid during peak times, we can deliver power at lower costs. Flexible load strategies, such as demand response, include customer programs like flexible pricing, building management systems, smart thermostats and smart water heaters — all of which help us balance power supply with power use by shifting load to non-peak times. From 2016 to 2021, PGE will increase demand response capacity in our service area by more than 500 percent. Our approach places PGE as a leader among utilities in the Pacific Northwest.

Demand response strategies also empower customers to control their power costs while keeping long-term prices low for our entire community. For example, as part of our smart thermostat program, customers save money by telling their thermostats to make decisions based on the cost of energy, the weather and comfort.

Smarter decisions with analytics and forecasting

Data, when coupled with analytics, are powerful. PGE is learning more about the demands on our grid and how to bring energy to customers more effectively by analyzing data from smart meters and other sources, including distributed energy resources.

Smart meters are fundamental to our smart grid, and we've been using them across our system for a decade. These meters, along with advanced weather forecasts, help predict how much electricity customers use on hot summer days or how much energy is being produced from sources like rooftop solar. PGE will monitor voltage in near-real-time to help identify abnormal conditions and analyze outage data to determine the cause, so we can shorten restoration times or avoid the outage altogether.

Better protection with physical and cyber security

As systems become more sophisticated, it's critical that we continue to protect our energy delivery, data and employees against both physical and cyber threats. Our Integrated Security Program focuses on the safety, protection and reliability of our operations and information. This means anticipating business needs and maintaining our security expertise so we can respond quickly to threats and be responsible stewards of customer information.

A reliable, resilient foundation

By strengthening the safety and reliability of our grid, we can ensure the best experiences and opportunities for customers. We're focusing our efforts where they'll make the most impact. This involves replacing aging equipment, redesigning parts of our T&D system and targeting areas prone to

weather-related outages. To prepare for a grid with two-way power flow, we are proactively integrating modern equipment that includes enhanced monitoring and control. These enhancements will allow us to partner with customers to build resilient microgrids, limiting widespread outages during major storms or earthquakes.

STRATEGY IN ACTION

Operational technology enables market access

Energy market participation requires the control of generation resources and significant data about the grid to ensure effective dispatch of resources. To support participation in the Western EIM, PGE deployed new operational technology.

- Telecommunications infrastructure allows data exchange with market operators.
- High-accuracy meters measure energy exchange.
- Supervisory Control and Data Acquisition (SCADA) systems allow real-time monitoring and detailed system modeling.
- Automatic Generation Control (AGC) systems enable remote, efficient dispatch of energy resources in conjunction with market and system needs.

INTEGRATION: BETTER TOGETHER

In the deeply decarbonized energy future we envision, electricity systems will efficiently integrate vast amounts, sizes and types of renewable sources, as well as new technologies. From modernizing our communications to determining where distributed energy resources will offer the most value, integration is a key theme in our modernized smart grid.

Fast, secure data with upgraded communications

For our grid to be truly integrated, all equipment, devices and systems — including those at customer premises — must communicate with each other and PGE quickly and securely. PGE is developing new capabilities for data and systems interoperability that will enable us to ingest large volumes of data from generation, transmission, distribution, meter and home appliances to drive even more efficiencies in how we manage energy. Visibility into, and integration of, this data is critical in our path to create the smartest and cleanest energy for customers. We're also continually investing in our fiber optic network, and in 2016, PGE purchased wireless communication spectrum that covers our service area as part of a long-term strategy to support our smart grid.

STRATEGY IN ACTION

Rush Hour Rewards: Smart thermostats save money

In 2015, PGE launched a smart thermostat program. The Rush Hour Rewards program achieved large demand reductions, averaging about 0.8 kW per customer in the summer — the equivalent total savings of about 17 kWh.

Today, about 4,800 PGE customers are enrolled in Rush Hour Rewards, with a capacity of 3.8 MW. Our goal is to reach enrollment of 15,500 thermostats for 5.44 MW of demand response.

More value with Distribution Resource Planning

Customers are bringing more distributed generation resources, like rooftop solar, onto the grid. These will play a key role in our clean energy future. PGE is working to ensure that all customers can benefit from distributed energy resources, which can lower energy costs for the community as a whole, especially when paired with energy storage and flexible loads. PGE is developing a Distribution Resource Planning (DRP) process in conjunction with our Integrated Resource Planning (IRP) and Transmission Planning processes. As customers add new

WE WANT TO WORK WITH CUSTOMERS TO DEPLOY DIVERSE ENERGY SOLUTIONS, ENABLING THEM TO CONTRIBUTE TO OUR DECARBONIZED ENERGY FUTURE

technologies — like EVs, heat pumps and rooftop solar — we will continue to model, customize and optimize the system. This involves forecasting where distributed energy resources will be installed on the system, planning and prioritizing locational modernization, and engaging in public and regulatory processes. We want to work with customers to deploy diverse energy solutions, enabling them to contribute to our decarbonized energy future. Together, we will increase efficiency and decarbonize.

A strong core with integrated operations

Our modernized grid must have a strong center of operations that fully monitors and integrates new energy resources and flexible loads, along with traditional utility operations and community resiliency initiatives.

As generation sources are added to our distribution system, we'll need to evolve our conventional way of balancing load and generation on the grid. In 2017, PGE joined the Western Energy Imbalance Market (EIM) — a real-time energy wholesale market that automatically dispatches the lowest-cost electricity generating resources available to customer needs within the hour, while optimizing use of renewable energy over a seven-state region (plus a Canadian province). Our participation in the EIM is managed through our operations center, where we will also soon house our Advanced Distribution Management System (ADMS). This will integrate our smart grid with distributed energy resources and demand response systems. In effect, our operations center will soon be the brain that processes signals from our modern smart grid, enabling optimal system operations.

Extending market access

The evolution of our grid and technology investments positions PGE to partner with customers on the selection, integration and operation of energy resources. We have a unique ability to support customers' specific goals while maintaining the lowest-cost solutions for reliable grid operations. We already realize value in aggregating customer generators, which fills an important role in providing reliability services during grid disturbances, while also serving the needs of their owners as localized back-up power.

Additionally, we have demonstrated our ability to achieve value in multiple energy markets and have already implemented the systems that allow for real-time trading in the Western EIM. Our demonstrated competency in leveraging market opportunities is a great fit for customers who seek value from their energy assets by accessing those markets.

SUMMARY

PGE's proactive investments in an integrated smart grid platform are enabling the clean energy future that we, together with customers, envision. With a modernized grid, we will:

- Accelerate the path to clean, renewable energy sources while maintaining equity, efficiency and reliability.

- Foster the adoption of distributed energy resources, and ensure that they are fully integrated and backed by system-wide resiliency and security.
- Improve automation throughout the grid to create further efficiencies, increasing reliability for customers.
- Integrate customer technologies to enable transportation electrification, smart communities and customer choice.
- Ensure customers can participate in the smart grid, help address climate change and reduce their overall spending on energy.
- Provide great family-wage clean energy jobs with a diverse workforce that reflects the communities we serve.
- Welcome partnerships with other utilities, industries and customers. Initiatives like the Western Energy Imbalance Market prove utility collaboration and benefits across the region are possible, both in the form of more efficient operation of the system and the potential for better utilization of renewable energy resources.

As we move toward our modernized grid, we are prioritizing our investments based on what customers want today, as well as their expectations for tomorrow.

ADDITIONAL RESOURCES

PGE Clean Energy Vision
portlandgeneral.com/energyvisionpdf

PGE energy storage proposal
portlandgeneral.com/2018storageplan

PGE Green Future™ program
portlandgeneral.com/greenfuture

PGE Decarbonization Study report
portlandgeneral.com/deepdecarbstudy

PGE energy strategy
portlandgeneral.com/energystrategy

Electric vehicles and charging stations
portlandgeneral.com/ev

PGE green tariff program
portlandgeneral.com/greentarriff

PGE Integrated Resource Plan
portlandgeneral.com/resourceplanning

PGE strategy paper
The path to a decarbonized energy economy



portlandgeneral.com/cleanvision