THE HARMONIOUS GRID

The Northwest electric system and the embrace of customer-side resources

PART 2: EMERGING TECHNOLOGIES OF THE HARMONIOUS GRID

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NW Energy Coalition
for a clean and affordable energy future

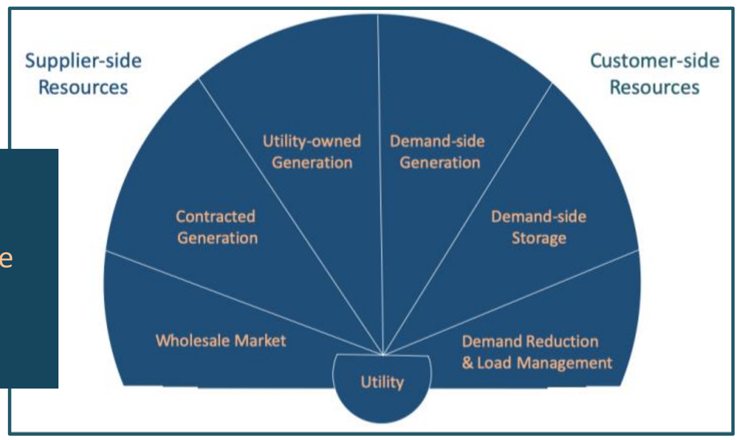
Emerging Technologies of The Harmonious Grid

Customer-side resources will fundamentally change our electric system

An electric system in which utilities and customers cooperate to manage and shape demand as well as supply represents a reinvention of "the grid" as we understand it. Rather than merely meeting customer needs for electricity cost-effectively, utilities can work in partnership with customers to modify and reduce electric demand when the cost of doing so is less than the cost of running more expensive power plants. Utilities will even be able to use customer-side assets to store energy for use at a later time.

The first installment in this series christened this dynamic, multi-faceted system, "the harmonious grid," because utilities will be able to choose among combinations of supply-side and demand-side resources to optimally meet customers' needs. How those choices will be made and the tools required for doing so are two of the questions we'll discuss below. But, first we need to understand the existing and emerging customer-side resources that will, if implemented aggressively and at scale, help ensure a reliable, clean, and affordable electric system.

Utilities will play the role of conductor calling on both supplier-side and customer-side resources to achieve optimum performance.



New instruments in the utility orchestra

Customer-side resources have been a vital part of our energy system for decades, although not on the scale and in the variety that's about to emerge. They include energy efficiency, distributed generation, demand response and storage.

Since the mid-1990s improved energy efficiency (EE) has greatly reduced per capita consumption of electricity and mostly flattened load growth in the Northwest. But, while utilities incorporate EE in resource planning and programs, customer energy use isn't currently managed dynamically in the same manner as supply-side resources such as power plants and wind farms. This represents untapped value for meeting customer electric needs in the most effective and affordable way.

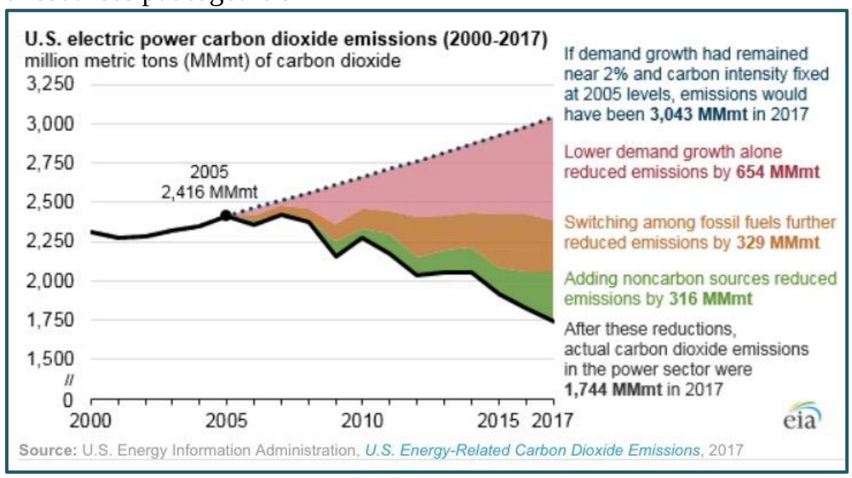
Distributed generation (DG) like rooftop solar is growing in popularity among customers, but so far it is less vital to the system as a resource because adoption rates remain relatively low. Demand response (DR) has played only a small role in system operations in the Northwest to date, and storage such as battery packs connected to the grid are just beginning to be installed.

Ongoing improvements in technologies and strategies suggest that cost-effective progress in EE is likely to expand and that DG, DR and storage are poised to emerge at a rapid pace if appropriate incentives are developed. Meanwhile, as electric vehicles come onto the grid, influencing the timing of vehicle charging will become crucially important to improving grid management.

At the same time, systems integration capabilities are being developed both "behind the meter" (on customer premises) and in the utility distribution system. This is a significant new development and in time will allow appliances and whole buildings to engage interactively with the grid. The following are a few examples of emerging resources and the contributions they can make to the harmonious grid.

Energy efficiency

Energy efficiency, combined with reductions in the prevalence of polluting industries, is our single greatest contributor to reducing greenhouse gas emissions. Between 2005 and 2017, reductions in per capita electricity consumption were responsible for more emission reductions than coal-to-gas power plant conversions and all new renewable resources put together.

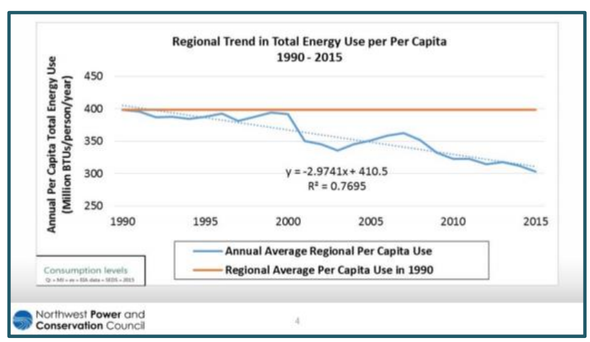


In the Northwest, per capita electricity intensity declined by 25% between 1990 and 2015, resulting in an annual savings of 12,364 aMW[1]. That's equivalent to 40% of all the electricity we currently consume.

The savings translate into reduced carbon emissions and significant avoided costs for generation. Energy savings also produce health and wellness benefits as a result of less pollution. And the economic activity associated with increased energy efficiency has proven to be a boon to the Northwest, which now has nearly 120,000 residents directly employed in energy efficiency occupations.[2]

	Actual 2015 Electricity Demand	2015 Electricity Demand with 1990 Energy intensities	Difference in Demand
Residential (WN)	6,862	8,308	1,613
Commercial (WN)	6,071	8,452	2,375
Industrial	4,934	12,668	8,376
Aggregated	17,867	29,428	12,364

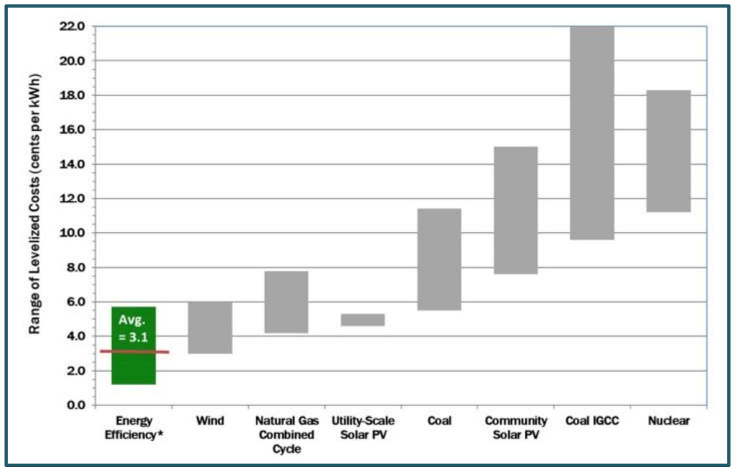
Northwest Power and Conservation Council 20



1 Jourabchi, M., Jayaweera, T., Smit, K., "Recent Trends in Energy Consumption and its Relationship to The Regional Economy," June 2018. https://www.nwcouncil.org/sites/default/files/2018_0612_p1.pdf

2 E2, "Clean Jobs America 2019: Clean Jobs Count," March 2019. https://www.e2.org/reports/clean-jobs-america-2019/

These benefits have come at a bargain price. The latest data from the American Council for an Energy Efficient Economy (ACEEE) show that utility-based EE programs across the nation acquire savings at an average cost of about 3 cents per kWh, making energy efficiency our most affordable resource.[3] The same has long been true in the Northwest.



Energy efficiency will continue to play an important role because, even though we have made great progress, many more opportunities remain and continuing innovations in technology are constantly creating new opportunities.

The U.S. Department of Energy's 2015 Quadrennial Technology Review found that, "By 2030, building energy use could be cut more than 20% using technologies known to be cost effective today and by more than 35% if research goals are met. Much higher savings are technically possible."[4]

We seem to be well on the road to realizing those savings. According to a 2017 analysis of 4,700 office buildings in the U.S., representing about 41% of commercial space, nearly 12% had an ENERGY STAR label and 5.2% were LEED certified.[5]

Appliances: More efficient and ready to become a grid resource

Since the National Appliance Energy Conservation Act was passed in 1987, American households have saved an average of more than $500 per year on utility bills.[6] That's in large part because the ENERGY STAR program has made consumers more aware of the savings associated with energy efficient appliances. Comparisons of ENERGY STAR-certified models with conventional ones are striking.

- ENERGY STAR-certified refrigerators are nearly 10% more efficient than models that meet the federal minimum energy standard and are up to 40% more efficient than conventional models sold in 2001.
- Certified dishwashers are 12% more efficient than non-certified models.
- Certified clothes washers use 40-55% less energy and 55% less water than standard models.
- Certified clothes dryers use 20% less electricity than conventional models.

Meanwhile, California, Washington, and a handful of other states have enacted state-level appliance efficiency standards, which will ensure that purchasers of new appliances will buy highly efficient ones.

3 Molina, M., "Growing and Supporting the Energy Efficiency Workforce," ACEEE, September 2018 http://www.ncsl.org/Portals/1/Documents/energy/webinar_efficiency_M_Molina_present_32693.pdf

4 U.S. Department of Energy, "Quadrennial Technology Review 2015" https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter5.pdf

5 CBRE Research, "U.S. Green Building Adoption Index 2019", cbre.us/research-and-reports/Green-Building-Adoption-Index

6 "About Energy Star," https://www.energystar.gov/about/about_energy_efficiency

The energy savings described above translate into hundreds of dollars in bill savings over the lifetimes of these appliances. And, because many conventional appliances are still in use, there are significant opportunities for continued energy efficiency in both the replacement and original equipment markets. Finally, many appliances and the homes and buildings that house them will soon be interactively connected to the grid, enabling utilities to manage their operation while meeting customer needs. This will create improved system value by reducing demand during high use periods or storing energy when electricity generation from renewable energy is plentiful.

Heating and cooling

Heating and cooling account for almost half of the energy use in homes and anywhere from 40% to 60% in commercial buildings, making HVAC (heating, ventilation and air conditioning) a primary target for technological innovation and increased energy efficiency. As a result, competition is emerging among multiple HVAC technologies that are reducing energy consumption in pilot testing by as much as 90%.

For example, ice-powered air conditioning uses ice as a battery, which can be both more energy efficient than some conventional HVAC systems while also making it possible to take advantage of price differentials. Blocks of ice are formed during the night when temperatures and energy consumption are low. The ice is then used to cool buildings during the day when temperatures and energy usage peak. The result is a 95% reduction in the energy required for cooling during the peak period. In an alternative approach, solar-powered air conditioning uses sunlight to directly power heating and cooling systems. And assorted detection systems are being developed to automatically adjust temperature in rooms based on occupancy.

Heat pumps are an increasingly popular option for heating and cooling. They draw heat from the outdoors to warm your home in cold weather and, when the weather is warm, they extract heat from inside your home and export it outdoors, to keep it cool inside. High efficiency heat pumps can reduce heating and air conditioning bills by as much as 30-50% depending on the pre-existing type of heating and air conditioning system.

Lighting

Home and building lighting is an area of vast efficiency improvement over the past decade and a half. Today's LED bulbs use as much as 85% less energy than traditional incandescent bulbs, they last up to 25 years, and they don't have the drawbacks of compact fluorescent bulbs, which are slow to brighten and produce a harsh light.

Structural improvements

Zero-energy buildings and homes are becoming increasingly common and, due in part to more demanding energy and building codes, conventional buildings built to code are starting to include at least some of the features of their zero-energy brethren. These include air sealing, enhanced insulation, and high efficiency doors and windows as well as improved designs that make use of passive properties such as sunlight and shade.

Enhancements that enable new construction to achieve net-zero emissions can sometimes be applied retroactively to existing homes and buildings. Many of these upgrades pay for themselves in ten years or less due to reduced utility bills.

Demand Response, Storage, and Distributed Generation

Demand response (DR) programs offer incentives to customers to shift some of their power use to times of lesser system-wide demand. By doing so, DR can help the Northwest meet capacity and balancing challenges and help integrate new renewable resources into the electric system. Traditionally, DR efforts have focused on heating, cooling, and water heating in the residential sector; on heating, cooling, and lighting in the commercial sector; on load aggregation programs and interruptible processes in the industrial sector; and on irrigation for agriculture.

Some DR resources are "firm" in that they can be planned ahead of time or are controllable by the utility. Also, customers may reduce energy consumption manually in response to a price signal sent by a utility or they may act based on a pre-determined schedule. Some residential, commercial and industrial customers rely on automated systems, liked timed sprinklers or car chargers.

As customer-side resources are integrated into the grid, some of the executional responsibility will shift to the utility. This shift will make DR programs more flexible and responsive to events. For example, time-based rates and peak pricing could become more fluid in response to variations in weather, market conditions, and other factors. Also, more sophisticated systems may increase the incentives for smaller customers to participate in DR efforts. And load aggregation programs in which groups of customers band together to package their consumption may be able to deliver greater savings as well.

The following graphic from the Brattle Group identifies current DR tools as well as new ones that will become available once buildings and appliances are integrated with the grid. This illustrates how grid integration and enhanced systems offer opportunities to improve the effectiveness of DR programs, .

1 Extend DR value streams

2 Broaden definition of DR

	Generation capacity avoidance	Reduced peak energy costs	System peak related T&D deferral	Targeted T&D capacity deferral	Load shifting/ building	Ancillary services
Direct load control	X	X	X	X		
Interruptible tariff	X	X	X			
Demand bidding	X	X	X		X	
Time-of-use (TOU) rates	X	X	X			
Dynamic pricing	X	X	X			
Behavioral DR	X	X	X			
EV managed charging	X	X	X	X	X	X
Smart water heating	X	X	X		X	X
Timed water heating	X	X	X		X	
Smart thermostat	X	X	X	X		
Ice-based thermal storage	X	X	X	X	X	
C&I Auto-DR	X	X	X	X	X	X

In the chart, existing demand response capabilities consist of direct load control, interruptible tariffs, demand bidding, and time-of-use rates. They provide three system benefits: less need for increased generation, reduced peak energy costs, and the deferral of peak-related transmission and distribution.

Grid integration will help defer costly additions to transmission and distribution. Grid integration will also enable the engagement of additional customer-side resources that can generate energy, store energy or reduce consumption in order to shape demand. These resources include home solar and batteries; appliances beginning with water heaters, smart thermostats, and EVs and their charging apparatus.

This potential was vividly demonstrated in a recent pilot program that tested the demand response value and customer acceptance of grid-integrated water heaters. The program, sponsored by the Bonneville

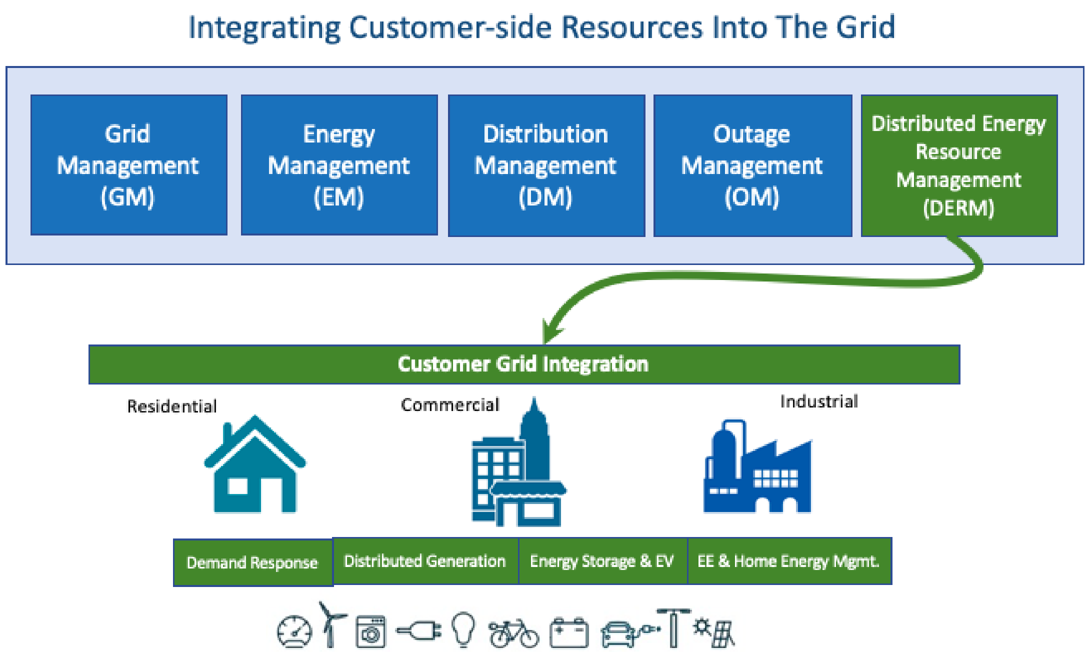
Power Administration (BPA), Portland General Electric (PGE) and seven other utilities, allowed the utilities to turn customers' water heaters on and off in response to numerous peak load events over the course of a year, with no measurable effect on hot water availability. The test revealed potential region-wide savings from this one measure of up to 1,000 megawatts annually.

Many more customer-side appliances have the potential to be integrated into the grid in order to manage load, decrease demand during peak periods, and store surplus renewable energy. The Northwest Power and Conservation Council estimates that total DR savings could amount to over 3,000 MW, obviating the need for several dozen gas-fired power plants.

Orchestrating new technologies and the grid

While the number and variety of customer-side distributed energy resources is growing rapidly, their potential value to the energy system can't be fully realized unless they're effectively integrated and coordinated with supply-side generation assets. They must be managed by expert systems that can monitor and forecast variables such as supply, loads, and prices. Then, as circumstances dictate, their engagement must be coordinated with generation resources to achieve optimum efficiency. In this section, we'll explore the new technologies on both the utility side and customer side that will help achieve this integration.

On the utility side, the introduction of customer-side resources adds a new function to the traditional functions they have long performed.



Managing and integrating customer-side distributed energy resources requires that utilities monitor and accurately forecast customer demand to match it with the capacity, availability, and prices for the many resources they have at their disposal. Also, because both customer demand and the capacity of some resources such as wind, solar, and hydro respond to external variables, such as the weather, utilities must be able to predict that as well.

Finally, the expert systems that manage the integrated grid must be able to dynamically control the various resources and have them reliably execute commands. All of these capabilities were the subjects of the Pacific Northwest Grid Demonstration Project, which, between 2010 and 2015, engaged 11 Northwest utilities across five states and 60,000 metered customers to assess the viability and potential value of an integrated grid. Using the Bonneville Power Administration's grid system and a platform designed by IBM that supported a variety of forecasting and modeling tools, the interactive system communicated the delivered cost of electricity and updated predictions of demand every five minutes while also monitoring resource capacity and transmission system traffic. Then, when circumstances dictated, the system sent price signals to grid-connected customer-side assets including smart thermostats, water heaters, and grid-responsive energy storage systems.

The project, which at the time was the largest grid integration test ever conducted, showed that interactive systems were able to accurately track demand, resource capacity, and price on a real-time basis and, in response, send the right incentive signals to the optimal resources. The weaknesses identified by the project mostly arose on the customer side and were due to occasional cases of insufficient data to adequately model and forecast customer needs and to effectively engage distributed resources.

Despite those difficulties, the project's results suggested that, with a 30 percent penetration of interactive control on the distribution side and 30 percent penetration of wind resources on the power side, an 8 percent reduction in peak load could be achieved. Happily, recent technological advances and the proliferation of smart devices and systems are making potential levels of penetration and, therefore, potential reductions in peak loads likely to be much larger. But, realization of that potential will depend on three major factors:

- The speed with which grid-capable systems and appliances are implemented by customers.
- The development of communication and interoperability standards to facilitate seamless transactions between the grid and customer-side distributed resources.
- The development of business models and incentives that make it easy and attractive for utilities and customers to embrace the opportunities offered by the harmonious grid.

Our ability to successfully meet these three challenges will be the subject of the next installment in this series.

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