Innovative Utility Offerings at the Distribution Edge: Case Studies from Around the Globe

Travis Lowder, Jeffrey Logan, and Emily Chen

National Renewable Energy Laboratory

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List of Acronyms

BEE	behavioral energy efficiency
BRPL	BSES Rajdhani Power Limited
CIE	Compagnie Ivoirienne d'Electricité
DER	distributed energy resource
DSM	demand-side management
EDP	Energias de Portugal
EV	electric vehicle
EE	energy efficiency
HER	home energy report
HPS	high-pressure sodium
IOV	internet of vehicles
LED	light-emitting diode
LVCT	line voltage communicating thermostat
PEPT	Programme Electricité Pour Tous
SGCC	State Grid Corporation of China
TEPCO	Tokyo Electric Power Company

Foreword

At the 10th Clean Energy Ministerial (CEM), government leaders from around the world will share national clean energy strategies and identify new opportunities for collaboration. Year after year, the CEM continues to provide a unique and valuable forum for combining political, technical, and multistakeholder dialogue, and its 10th anniversary is a testament to the durability of international support for a cleaner and more environmentally sustainable energy future.

This commitment is shared across the global electric power industry, as companies transform the way they do business to deliver the clean energy future that customers want and expect. Different regulatory environments and unique circumstances will lead countries to pursue separate pathways in developing clean energy solutions that are safe, reliable, and affordable. However, on every continent, companies are bringing a similar vision to their work—a vision that puts the customer at the center of what they do.

As architects and owners of critical energy infrastructure and critical elements of the economy of the future, electric companies have a position of responsibility to act as cooperative partners to government and all stakeholders in creating innovative clean energy solutions. Each day, I see examples around the globe of this in action as our industry evolves to meet new customer demands. That means developing new services and solutions for newly engaged customers who need and want more information than ever about their energy use. It means transforming generation fleets to provide reliable energy from a balanced, diverse mix of sources while moving toward a future of carbon-free electricity. And it means reimagining and rethinking how to create and deliver value for customers.

These are exciting and dynamic times for our industry, and the case studies contained within this report are illustrative of the broad evolution that is underway. In homes, new technologies are giving customers more control over their energy use and unlocking new opportunities for energy savings. In commerce and industry, new services and rate designs are allowing businesses to implement renewable energy commitments and better optimize and manage complex energy systems. In transportation, electric cars, buses, and ferries are the key to dramatically reducing local pollutants and carbon emissions.

Over the past 10 years, the electric power industry has made significant progress both in deploying clean energy and in reducing carbon emissions and will continue to do so. With a combination of smart technology, effective regulation, sustained leadership, and innovative business models, I am optimistic the next 10 years will bring even more progress toward a clean energy future for this and future generations.

Lawrence Jones
Vice President for International Programs, Edison Electric Institute
Chair, Public-Private Leadership Forum for 21CPP

Table of Contents

1 Introduction **1**
1.1 The Changing Energy Landscape 1
1.2 The Utility-Customer Relationship 2
2 Utility Innovations **5**
2.1 North America 5
2.1.1 Canada—Hydro-Québec's Line Voltage Communicating Thermostat Pilot 5
2.1.2 Canada—ATCO's Intelligent Street Lighting Pilot 7
2.1.3 United States—Puget Sound Energy's Green Direct Program 9
2.2 South America 11
2.2.1 Peru—Enel X and Hydro-Québec's Electric Bus Pilot Project 11
2.3 Africa 13
2.3.1 Cote d'Ivoire—Compagnie Ivoirienne d'Electricite's Electricity for All Program 13
2.4 Oceania 15
2.4.1 New Zealand—Vector Energy's Hot Water Load Management Trial 15
2.5 Europe 18
2.5.1 Portugal—Energias de Portugal's EV.X Mobile Application 18
2.6 Asia 20
2.6.1 Japan—Tokyo Electric Power Company's "Elderly Care Plan" 20
2.6.2 China–State Grid's Internet of Vehicles: A Smart Electric Vehicle Sharing Management System and Port Electrification 21
2.6.3 India—BSES Rajdhani Power Limited's Home Energy Report Program 24
3 Conclusion **27**
References **28**

List of Figures

Figure 1. Global new investment in clean energy by sector. 2
Figure 2. Average house demand profiles. 7
Figure 3. ATCO employee replacing a high-pressure sodium bulb 9
Figure 4. Route for electric bus through downtown Lima 13
Figure 5. New Zealand peak loads by region 16
Figure 6. Average load control day versus average non-load control day during Vector pilot 17
Figure 7. Screenshots from EV.X app 19
Figure 8. Disaggregation visualization 20
Figure 9. State Grid Corporation of China electric vehicle charging network 22
Figure 10. Excerpts from behavioral EE customer bill 26

List of Tables

Table 1. Countries and Solutions Profiled in this Report 3
Table 2. Characteristics of the Two Experimental Groups 6

1 Introduction

1.1 The Changing Energy Landscape

In September 1882, the opening of Pearl Street station in New York created a commercial alternative to gas-powered lighting and marked the beginning of the modern electric power industry. In the decades that followed, industrial, commercial, and residential applications for electricity continued to multiply and expand across the United States and other developed economies. Today, more than a century later, electricity has become a predominant form of energy delivery, is a touchstone of industrialized society, and continues to be the fastest growing source of energy end-use consumption (the U.S. Energy Information Administration forecasts world net electricity generation to increase by 45% by 2040) (EIA 2017).

As electricity became a critical commodity in modern economies, most countries organized the electric power industry along a similar paradigm, establishing vertically-integrated and regulated monopolies with exclusive jurisdiction over service within specified geographic territories. This allowed these monopolies—utilities—to leverage economies of scale, reduce transaction costs along the supply chain, and achieve high efficiencies in electric transmission to deliver low-cost, safe, and reliable electricity to end users.

The vertically integrated, regulated utility model persisted during most of the 20th century. However, changes in regulation, economics, and technology during the past several decades have ushered in a period of significant—and accelerating—industry transformation.[1] Notably, throughout the 1990s and early 2000s, the restructuring movement that affected many industries (e.g., airlines, railroads, telecommunications, etc.) led some jurisdictions to unbundle the electricity supply chain and introduce customer choice among electricity providers. Results of these efforts were mixed, and today, a diverse mosaic of regulatory paradigms exists across the world as policymakers continue to consider how best to adapt to rapidly shifting dynamics in economics and technology.

Another significant shift has come with the changing economics of electricity supply. Although mature technologies for conventional thermal generation have continued to experience modest cost and efficiency improvements, the cost of other new generation technologies have declined precipitously since the early 2000s. In particular, large-scale land-based wind and solar—buoyed by government support policies such as feed-in tariffs, renewable portfolio standards, tax incentives, and other mechanisms—have emerged as the preferred option for new generation in many locations. The resulting boom in investment for new renewable generation capacity (see Figure 1) has created a more heterogeneous and complex landscape of diverse supply options, bringing new entrants into the market for power generation while also creating new challenges for wholesale power markets and grid operations. In particular, solar generation has proven so successful in some service territories that it has affected peak management at the transmission

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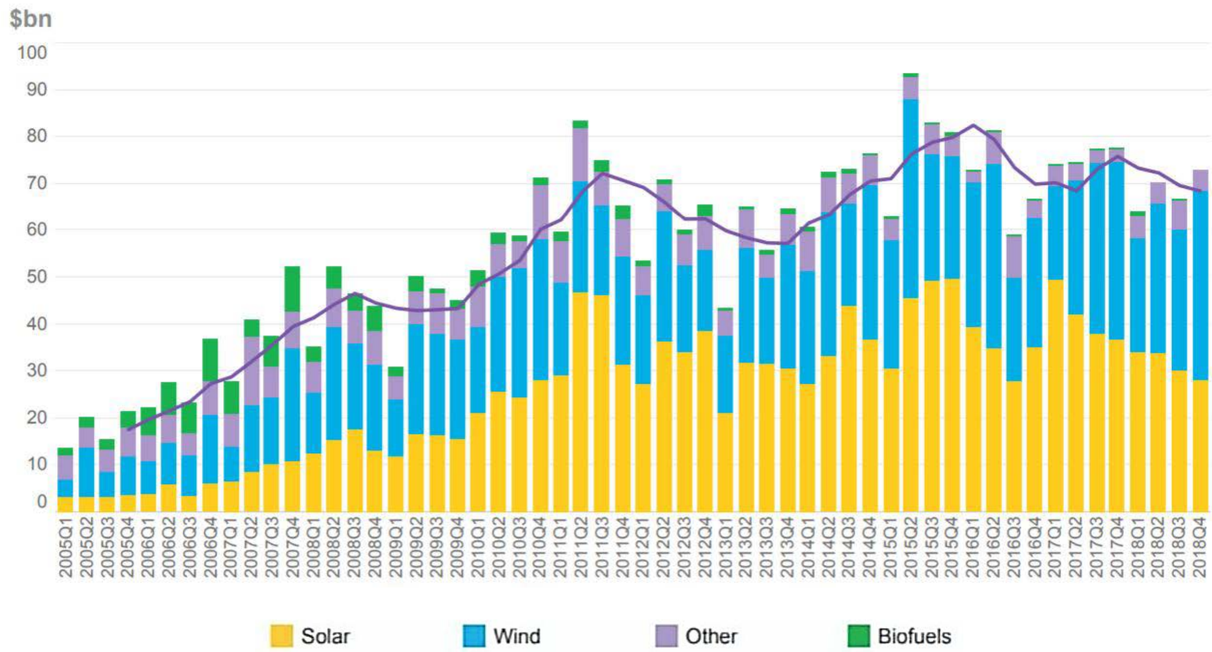
[1] The 21st Century Power Partnership (21CPP) has authored numerous reports dedicated to understanding and characterizing power system transformation. For a deep dive on the forces impacting the electric power industry, consider 21CPP the *Status of Power System Transformation* reports for 2015 and 2017.

level (e.g., California) and challenged standard practices of grid operations and design at the distribution level.



Source: BNEF 2019

Figure 1. Global new investment in clean energy by sector.

Note: “Other” category includes hydro, geothermal, and marine (tidal) technologies.

Thirdly, the proliferation of distributed energy technologies (DERs) is creating opportunities for the electric power system to operate in new and dynamic ways. Battery storage, electric vehicles (EVs), and demand-side management (DSM) devices (e.g., smart thermostats and building energy management systems) provide utilities and customers with new levels of visibility and control of their energy use. Moreover, the location of some technologies behind the meter creates the conditions for consumers to more actively participate in an entirely new model for dynamic, multidirectional electricity transactions. The application of new technology extends also to the grid itself, where utilities are deploying a layer of enabling smart technologies, communication systems, and sensors that create the information and data infrastructure upon which a new set of electricity and energy services can be built.

1.2 The Utility-Customer Relationship

How each of these trends will impact electric service delivery in any jurisdiction will depend heavily on the specific, localized characteristics of regulation, economics, and technology. As a result, pathways for power system transformation are unlikely to follow a single uniform trajectory. However, customer expectations for the services and opportunities that electricity can provide *are* universally evolving. As electricity becomes more deeply embedded in commercial and personal daily life, there is growing demand for services that provide customers more information, choice, and control. In turn, innovative utilities worldwide have begun redefining their relationship with their customers, allowing more customer agency as well as providing data, tools, and special programs and services that can meet consumer demand for emerging platforms, technologies, and capabilities.

This report catalogues several innovative approaches utilities are taking to meet these consumer preferences in a fast-changing world. It comprises a series of case studies for products and programs that enhance the consumer experience, provide greater access to DERs, and generally respond to the changing realities of the utility/customer relationship. The utilities and their subsidiaries featured in this report represent 10 countries on six continents, emphasizing that this movement is global. To highlight the diversity of solutions at hand, the report breaks these innovations out into seven categories—energy supply, energy efficiency (EE), lighting, transport, data, heating and cooling, and rural/off-grid solutions. See Table 1 below.

Table 1. Countries and Solutions Profiled in this Report

	Asia			North America			South America	Europe	Africa	Oceania
	Japan	**China**	**India**	**Canada**		**U.S.**	**Peru**	**Portugal**	**Cote d'Ivoire**	**New Zealand**
Energy Supply						Puget Sound Energy				
Energy Efficiency			BRLP		Hydro-Québec					
Lighting				ATCO						
Transport		State Grid					Enel X/ Hydro-Québec			
Data	TEPCO							EDP		
Heating and Cooling										Vector
Rural/Off-Grid									CIE	

Note: ATCO is a utility in Alberta, Canada; BRLP=BSES Rajdhani Power Limited in India; TEPCO=Tokyo Electric Power Company; EDP=Energias de Portugal; CIE=Compagnie Ivoirienne d'Electricité

This report is based on a series of conversations the authors held with utilities from 2018–2019 and supplemented with independent research. All the utilities have been given the opportunity to review the material and provide feedback.

In almost all conversations, the utilities expressed common goals that underpinned their product offerings. These include:

- Empowering customers to make informed energy decisions and to contribute to distribution system-wide goals (such as peak demand reduction or avoided infrastructure)
- Addressing the unique conditions of their market, such as population growth or contraction, energy access, or lack of infrastructure
- Reducing emissions

- Innovating in nascent products and markets.

Perhaps the most evident example of this last bullet is in the movement of utilities across the world to capitalize on the emergence of EVs. Although EVs can represent load growth, and thus revenue from a regulated standpoint, utilities are exploring additional and nonconventional entry points into the EV space. The three examples in this report of alternative means of investing in an EV business line include developing behavioral analysis mobile applications to inform consumer decision making (Energias de Portugal), making capital investments in the vehicles themselves outside of the regulated business (Enel X and Hydro-Québec), and building out charging infrastructure and connecting it all via an "internet of things" network (State Grid).

2 Utility Innovations

2.1 North America

2.1.1 Canada—Hydro-Québec's Line Voltage Communicating Thermostat Pilot

Hydro-Québec is a state-owned utility that manages generation, transmission and distribution assets across Québec. Although the utility operates a nearly carbon-free portfolio of generation assets (99% of its electricity is derived from hydropower resources), it remains active in driving the deployment of clean energy technology within its service territory. With heavy investments in electric mobility both at home and abroad (see Section 2.2.1), advanced battery materials, wind energy, demand response and other ventures, Hydro-Québec serves as a model for utilities worldwide for transitioning to a next-generation grid architecture.

Although Hydro-Québec has a portfolio of innovations on which this report could draw, the authors have chosen to focus on one of the utility's micro-pilot programs centered on line-voltage communicating thermostats (LVCTs) that was conducted among a group of 30 employees from November 2016 to March 2017.

LVCTs are electric thermostats used for heating applications, namely electric baseboard heaters. Unlike low-voltage thermostats for most household heating and cooling equipment, LVCTs operate at line voltage (120 or 240 volts) because of the high energy requirements to convert electricity to heat. The thermostat's "communicating" aspect means that it is "smart," i.e., cloud-connected and programmable, like a Nest system, only for electric baseboard heaters. As such, LVCTs can provide a suite of capabilities, such as remote control, occupancy sensing, energy use reporting, self-learning, data security and other functions (Penney 2017). LVCTs first arrived on the consumer market in 2015 (Fournier, Leduc, and Sansregret 2017) and about a year later, Hydro-Québec launched a pilot around them.

Hydro-Québec is a winter-peaking utility, owing largely to the fact that a significant portion of its customers use electric baseboard heating as their main heating source (66% of households in the entire province of Québec) (Fournier, Leduc, and Sansregret 2017; Fournier et al. 2018). This makes it an ideal testbed for the effectiveness of LCVTs for a variety of use cases, including peak load reduction, energy efficiency (EE) and customer savings.

In August 2016, Hydro-Québec sent out a recruitment email to 1,000 of its employees in the Trois-Rivières area. The email contained a survey and a prospective offer of participation in the pilot, which would provide LVCTs and installation at no cost. Some 140 applicants responded, although 72 were rejected because they did not meet the utility's criteria for participation (including having a smart meter, an internet connection, and a predominance of electric baseboard heating, among other things).

From the remaining applicants, the utility selected 30 at random to enroll in the pilot, referred to as the treatment group, and another 30 were selected to participate as a control group. Characteristics of both groups are outlined in Table 2 below.

Table 2. Characteristics of the Two Experimental Groups

Characteristics	Treatment Group	Control Group
Number of participants	30	30
Average annual consumption (kilowatt hours)	26,280	25,333
Household size (average number of people)	3.3	3.3
House built before 1970	33.3%	33.3%
Floor area less than 1,500 sq. ft.	53%	50%
Wall-mounted heat pump presence	27%	43%
Constant setpoint (no setback)	47%	43%
Household occupancy follows a regular pattern/schedule	97%	83%

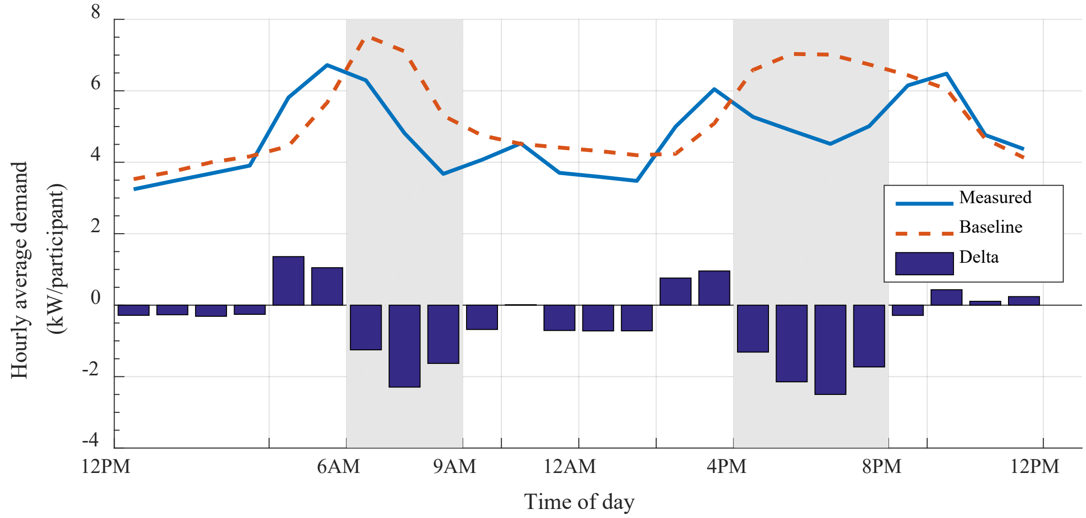
Source: Fournier et al. 2018

All the non-communicating line-voltage thermostats of the 30 participants in the treatment group (average of 10 per home) were replaced by LVCTs manufactured by Sinope Technology. Participants could link each to a cloud platform through their home Internet connection and thereby use Web and mobile interfaces to control settings, view consumption data and access other features.

The pilot's two primary investigations were into whether LVCT users would realize savings relative to the control group[2], and how effective the thermostats were as a source of demand response. For the second investigation, Hydro-Québec designated eight event days during the winter of 2016–2017 and ran two setpoint modulation routines to reduce demand during morning (6 a.m. to 9 a.m.) and evening (4 p.m. to 8 p.m.) peak periods. These modulations were geared to preheat rooms two hours before a peak period, and then reduce heating (and therefore electricity draws from the grid) at the time of the peak. Although the baseboard heaters' overall energy consumption was not affected by this strategy, their contribution to peak load was reduced. In fact, the pilot found that households using set point modulation strategies on all their installed LVCTs could be relied on to reduce their peak load contribution by an average of 2 kilowatts (kW) for both morning and evening events.

Figure 2 illustrates this load shifting strategy with a chart showing a reference case demand (red dotted line) as well as a demand curve where the setpoints were modulated for preheating (blue solid line). The valleys in the bars during the morning and evening peaks illustrate the effectiveness of the demand response strategy.

[2] Specifically, the energy savings would arise from the ease of programming setpoints offered by LVCTs.



Source: Fournier et al. 2018

Figure 2. Average house demand profiles.

Note: In this figure, 12 p.m. refers to midnight and 12 a.m. to noon.

The implications of these findings could impact Hydro-Québec's system planning, allowing the utility to resort to non-wire alternative strategies such as smart thermostats to reduce system peaks instead of potentially more expensive infrastructural upgrades. This, of course, would have obvious implications for ratepayers, although it is notable that this pilot *did not* in fact demonstrate, to a statistically significant degree, that the treatment group realized savings at the individual level (i.e., when they left set points at the preprogrammed level). However, surveys conducted throughout the pilot show positive participant response to the set point modulation strategies applied. Overall, participants were satisfied with the technology installed, noting its ease of use and the convenience of preprogramming (Fournier, Leduc, and Sansregret 2017).

Hydro-Québec's LVCT pilot provides a contrast of sorts with other innovations described throughout this report in that it is micro-scale with applicability only to a limited subset of utilities (i.e., those with high concentrations of electric baseboard heating in their service territory). However, as will be shown later in this report, Hydro-Québec is also engaged in large-scale pilots involving innovative technologies and serving broad populations (see Section 2.2.1). The range of innovative activity, from circumscribed and local to broad-based and global, as evidenced by Hydro-Québec's activity, exemplifies the scope of several of the utilities catalogued in this report and in many others not mentioned herein. Opportunities to change the energy landscape, empower customers and incorporate cleaner, renewable solutions are abundant along the energy value chain. And it is the forward-looking companies that are capitalizing on them, both in their home markets and abroad.

2.1.2 Canada—ATCO's Intelligent Street Lighting Pilot

ATCO, a leading energy and infrastructure provider in Alberta and beyond, recently piloted an intelligent street lighting project with the city of Lloydminster that delivered a variety of benefits. In addition to cutting energy and maintenance costs for the city, the project also improved lighting quality and safety for drivers, cyclists, and pedestrians; reduced emissions;

and cut light pollution. The pilot phase of the project concluded in late 2018 and impacts are still under final evaluation.

ATCO replaced 58 outdated, high-pressure sodium (HPS) streetlights at 250 watts per fixture along a main arterial road with light-emitting diode (LED) bulbs at 161 watts per fixture and simultaneously installed an intelligent streetlight system (Figure 3). The technology provides remote monitoring and adaptive capabilities such as “light on demand” that dims streetlights when sensors do not detect movement and automatically brightens when the presence of vehicles, cyclists, and pedestrians is detected. It is a joint project between ATCO and the city of Lloydminster, with ATCO covering the control system and ownership of the lights and Lloydminster covering the conversion from HPS to LED lighting.

LED lights outperform HPS technology on several fronts, including:

- LED bulbs have more accurate color rendering and higher light quality while using less energy
- LED bulbs last much longer, thus requiring lower maintenance costs during their life cycles
- LED bulbs result in less light pollution
- LED bulbs turn on instantly to full output, while HPS bulbs may take 5–10 minutes to reach full and stable output.

Using an adaptive system rather than the more common scheduled dimming for dusk to dawn operations in conjunction with LEDs allows the utility to reduce energy consumption, emissions, and light pollution all at once.

With this system, traffic moves in a safe circle of light as the integrated wireless control system enables communication between the streetlights—the first light detects motion, brightens, and then signals the succeeding lights to brighten before traffic approaches. The dimming and brightening actions happen seamlessly, well ahead of a vehicle’s headlights.

The features in this technology allow for customization and tailoring of light levels to the specific locations and the community’s requirements. The system also has a fail-safe mode in which it reverts to normal operations (i.e., dusk to dawn) controlled via a photoelectric sensor in the event of problems with the control system. Depending on adoption of this technology by municipalities, it may drive the need to revisit streetlight rate design, or, at a minimum, develop a dimming rate schedule for these sorts of applications.

In summary, the new lighting system can:

- Lower maintenance costs up to 50%, reduce street light energy consumption by up to 80%, and lower carbon emissions, all while ensuring public safety and security
- Support the creation and further buildout of smart system capabilities
- Enhance safety and have a positive impact on our environment through reduced light pollution
- Receive continual feedback on the status of the system reducing the need for costly night time streetlight patrols.

In August 2018, the Illuminating Engineering Society recognized ATCO with its 2018 Illumination Award of Excellence for Energy & Environmental Lighting Design for this initiative. This award recognizes quality lighting installations that incorporate advanced energy-saving strategies and environmentally responsible solutions into the design. ATCO was one of only two Canadian winners among more than 400 international submissions.

ATCO is committed to making energy easy for its customers in an increasingly disrupted world through sustainable, innovative, and comprehensive electricity solutions such as the intelligent streetlights and smart city projects. The Intelligent Street Lighting Pilot Project is a key initiative in ATCO's journey to explore potential smart city products and services that expand beyond connected street lighting.

Source: ATCO

Figure 3. ATCO employee replacing a high-pressure sodium bulb

2.1.3 United States—Puget Sound Energy's Green Direct Program

As Washington-based companies, government entities, and institutions have increased their demand for renewable energy in recent years, investor-owned utilities have faced the challenge of developing offerings to meet their expectations. Washington State has a regulated energy market with no retail competition, which leaves electricity consumers reliant on the utility to help them achieve their energy goals. For the Washington-based companies that are members of the RE100 initiative,[3] these energy goals are to achieve 100% renewable power by 2050 at the latest.

To address these market demands, the largest investor-owned utility in the state, Puget Sound Energy, implemented a Product and Services Group in 2015. This Group was tasked with developing new business lines that respond to and anticipate customer demands and new technologies. One such demand was increased access to renewable energy. No longer satisfied with participating in ordinary green tariff programs, customers wanted to contribute to and own a part of new and local renewable projects. Customers also expressed a preference for long-term fixed contracts for renewable resources to increase cost savings and hedge against fuel price fluctuations.

Taking these concerns under consideration, the Product and Services Group at Puget Sound Energy began work on a new utility offering. Green Direct, the outgrowth of this process, was launched in November 2016. The program represents the outcome of extensive stakeholder engagement and consultation with corporations, municipal governments, the Washington Utilities and Transportation Commission (the state utility regulator), and nongovernmental organizations including the World Resources Institute and Rocky Mountain Institute. Involving the state utility regulator was particularly important, as new utility offerings need to be approved on the basis that the rates are "just and reasonable" for both program participants and other customers. To ensure that this tariff offering adhered to regulatory standards, Puget Sound Energy involved the state utility commission early and often, gaining final approval in September 2016.

Green Direct is the first subscriber-style green tariff program combining elements of traditional green tariffs with principals from the community solar industry. As in a community solar model, customers are able to access a larger renewable resource project, with benefits such as long (i.e., 20 years) contract terms, economy-of-scale cost-effectiveness, and efficiency (Barua and Bonugli 2018). These economic benefits are enhanced compared to community solar projects because the Green Direct program features a utility-scale project, rather than a community-scale project.

Large commercial customers (>10 million kilowatt hours (kWh)/year) and public entities can invest in a portion of a utility-scale renewable energy project, getting involved in the early project development phase and negotiation of the power purchase agreement. Green Direct program subscribers typically sign up for a 5–10-year contract and will receive credit on their electricity bill for the energy produced. They also pay additional charges for program administration fees, renewable energy credit costs, and a Resource Option Energy Charge, which is a fund to minimize cost shifts to customers who do not choose to participate in the program.

According to the energy news and analysis website *Utility Dive*, Green Direct is the first tariff to both allow aggregation of customers and meet all six of the Renewable Energy Buyers Alliance[4]

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[3] RE100 is a global corporate leadership initiative bringing together influential businesses committed to 100% renewable electricity. More information is available at http://there100.org/re100.

[4] More information on the Renewable Energy Buyers Alliance is available at https://rebuyers.org.

Principles (Trabish 2017). Led by four nonprofit organizations, the Renewable Energy Buyers Alliance works with large buyers that have voluntary demand for clean and renewable energy. The six Corporate Renewable Buyers' Principles "represent large customers' renewable energy needs and help them streamline solutions for buying cost-effective renewable energy." The six Buyers' Principles include 1) choice in procurement options, 2) access to cost-competitive options, 3) long-term pricing, 4) new projects that reduce emissions beyond business as usual, 5) increased access to standardized and simplified processes for contracts, and 6) opportunities to work with utilities and regulators to expand choices in buying renewable energy (Corporate Renewable Energy Buyers Principles 2018). Through a subscription-style tariff, Green Direct customers have input in the procurement of renewable resources and a long-term contract, but also maintain the simplified billing process of a green tariff.

The first phase of Green Direct opened for subscription applications at the end of 2016 and was fully subscribed by June 2017. Phase I featured a 137-megawatt (MW) wind project, with an average 40 MW load. There are 21 subscribers in this phase, including corporations, universities, and local governments. The first set of customers includes Target; REI; Starbucks; Western Washington University; Sound Transit; King County; and the cities of Anacortes, Bellevue, Snoqualmie, and Mercer Island (Barua and Bonugli 2017). The Green Direct program is currently in initial stages of its Phase II subscription application, after which it will offer a competitive solicitation process to choose a project. The program then enters a long-term process because the power purchase agreement is signed after customers have subscribed and the project must be permitted and constructed. The Phase I project is slated to come online in 2019, and the Phase I subscribers will be transferred to the Green Direct tariff at that time. Although this process is longer than the typical green tariff, customers have demonstrated their willingness to wait to gain new renewable resources, cost savings, and input in the resource procurement.

In this utility offering, Puget Sound Energy used enhanced customer engagement, innovation through a dedicated team, and an iterative process to create a new business model to provide renewable energy.

2.2 South America

2.2.1 Peru—Enel X and Hydro-Québec's Electric Bus Pilot Project

In late 2018, the Global Sustainable Electricity Partnership, a consortium of multinational electric utility companies focused on electrification and decarbonization of the economy, finalized an agreement with several Peruvian Ministries (Energy and Mines, Environment, and Transport and Communications) and Protransporte (the local public transit operator) to integrate an electric bus into a main bus route in the city of Lima. The 2-year pilot is administered and financed by the Global Sustainable Electricity Partnership and two of its members—Hydro-Québec and Enel X. Both Hydro-Québec and Enel X have been active in the electric mobility space for several years. Hydro-Québec has participated in several ongoing EV pilots in Canada and, in 2012, implemented the Electric Circuit, Canada's first public charging network for EVs. It offers more than 1,800 charging stations (1,650 at 240 volts and 177 at 400 volts) that are installed in the parking lots of the Circuit's numerous partners across Québec and in northeastern Ontario. Enel X has several worldwide projects and has been engaged with the Chilean government and transportation authorities for several years to implement a fleet and infrastructure plan that, today, comprises the highest number of electric buses in South America (and the second highest in the world behind China) (Santiago Times 2018).

For the 2-year duration of this pilot project, an electric bus will operate on one of the busiest arteries in Lima, collecting real-time data on speed, battery performance, operations, and environmental impact. The data will be analyzed and compiled in a report that the Peruvian government will use to implement large-scale electrification across the country's public transit systems.

The main objectives of this pilot project are to demystify the e-bus technology for local policymakers, transit operators, and riders, and to encourage the integration of more electric buses into the public transit system.

The pilot is expected to launch operations by September 2019. It will deploy BYD's 12-m Andino bus on a route that runs the length of Avenida Javier Prado from the Ate District to the San Miguel District (about 23 km), one of the busiest thoroughfares in Lima (see route map in Figure 4). The Andino bus can run more than 360 km on a single charge and only requires 4 hours to fully recharge the battery, ensuring that the vehicle can remain in the field for most of the route's service schedule. Real-time operational data will be collected, analyzed, and aggregated via ViriCiti's monitoring platform to inform the stakeholder decision making for the future growth of electric mobility in Peruvian cities.

Developing electric transportation is among the Peruvian government's commitments to reduce the country's carbon footprint. The government strongly supports the project and has presented it as one of the projects included in its Nationally Appropriate Mitigation Actions under the United Nations Framework Convention on Climate Change.

Source: Enel X

Figure 4. Route for electric bus through downtown Lima

2.3 Africa

2.3.1 Cote d'Ivoire—Compagnie Ivoirienne d'Electricite's Electricity for All Program

Energy access as a pathway to sustainable development is a principal goal of the United Nation's Decade of Sustainable Energy for All initiative. It is also a policy goal of many African nations as their economic growth accelerates.

However, common to many utility service territories around the world, the cost to connect customers on the so-called "last mile" of the distribution system can be significant owing to lack of infrastructure, the remoteness of the population, and other factors. This up-front connection cost, when it is passed on to the customer, can prove an insurmountable hurdle, which leaves many people without access to energy. Even in places where people may be able to afford purchasing some quantity of energy on a volumetric basis every month, the connection cost can be a hurdle to increased energy access.

In Cote d'Ivoire, the cost for the country's utility (Compagnie Ivoirienne d'Electricité, or CIE) to connect a household to the grid is around $300 USD, more than 50% of what the bottom decile of the country's earners would bring home in a year. To address this barrier, the utility has entered into partnerships with several state and nonstate entities to enact a program helping customers along the last mile to afford a grid connection. This program, "Electricity For All" (known locally as "Programme Electricité Pour Tous" or PEPT), not only has appreciably expanded utility service across the country, but has also has cut down on electricity theft, which has afflicted some areas where significant portions of the population do not have access to energy. PEPT began in 2014 as a pilot in the northwestern Odienné Department and has since been implemented in many of the rural areas around the country. Since 2015, the program has also been operational in Abidjan, the country's largest city.

PEPT gives customers access to no-interest, unsecured loans to defray their connection costs. This loan is paid down during the course of their electricity service (generally, 3 to 10 years for most customers). As part of this program, CIE installs a smart meter (through third parties) at the point of service, and this technology allows customers to adjust the amount of electricity they consume according to their ability to pay. The initial cost of this meter is about 1,000 CFA Francs,[5] or a little less than $2 USD, which the customer pays at the time of connection.

Customers with these smart meters are charged for electricity under a linear tariff that assesses a prepaid fee for a preset number of kWh every month. This tariff gives customers a firm expectation of the level of monthly electrical service and allows them to calibrate payments to stay within their means.

On top of this linear tariff's flat fee, customers also pay a fixed amount, which goes toward the repayment of the remaining balance of their connection costs. As a hypothetical example, say a customer is paying 60 CFA Francs for 1 kWh of electricity. In addition to this 60 CFA Francs, they will also pay an additional amount, say 30 CFA Francs per kWh, to pay down their connection cost, making their total bill 90 CFA Francs for 1 kWh. The specific amount of the repayment fee is calculated using an estimated minimum energy consumption for the customer during the recovery period.

Underpinning the PEPT program are several partnerships, with CIE at the center. The utility acts as program operator and administrator, managing connections and installation of smart meters through subcontracted partners, and collecting payments from customers. CI Energies, a state-owned asset company, acts as a program monitor, and Anaré, the electricity regulator, ensures compliance with the program rules and eligibility criteria. The World Bank has provided some $25 million USD to cover a portion of the connection costs from individual customers absorbed by CIE —$10 million was used for connecting 40,000 customers in 2018, and the balance will be used to fund another 60,000 in 2019. Additionally, the African Development Bank and the European Union have both agreed to contribute €30 million to PEPT, with disbursement of these funds anticipated sometime in 2019.

Until Q1 2019, CIE had been responsible for furnishing the capital to cover the PEPT program's unpaid connection costs. Although an expanded customer base has enabled higher revenue collection for the utility, these additional revenue streams have not been able to close the gap between the capital provided by CIE and that provided by the development finance institutions. To address this gap and place the program on sustainable footing going forward, the government of Cote d'Ivoire, in partnership CIE Energies, has established a special revolving fund

[5] The West African CFA franc is the currency of eight nations: Benin, Burkina Faso, Guinnea Bissau, Ivory Coast, Mali, Niger, Senegal, and Togo. At the time of this writing, there were 583 CFA francs per $1USD. There is a different Central African CFA franc currency for that region of the continent.

specifically to defray up-front connection costs under PEPT.[6] CIE still prefinances connections, but it now submits these costs to the fund for reimbursement.

PEPT's reach has been growing steadily since its inception. In 2016, the program had achieved a 33% "coverage rate" (i.e., the percentage of the population energized); 2017 saw that jump to 38% and preliminary figures suggest that 2018 will see the figure reach 44%.

Interestingly, CIE notes that the default rates on the balance of connection costs is high among PEPT customers, but that 96% of the beneficiaries continue to pay for energy transactions under the linear tariff. To CIE, this represents a not only a victory in terms of development goals, but also a growing base of revenues. By the end of 2018, 1,380 connections—about 0.2% of total 560,000 connections made under the PEPT—were paid in full.

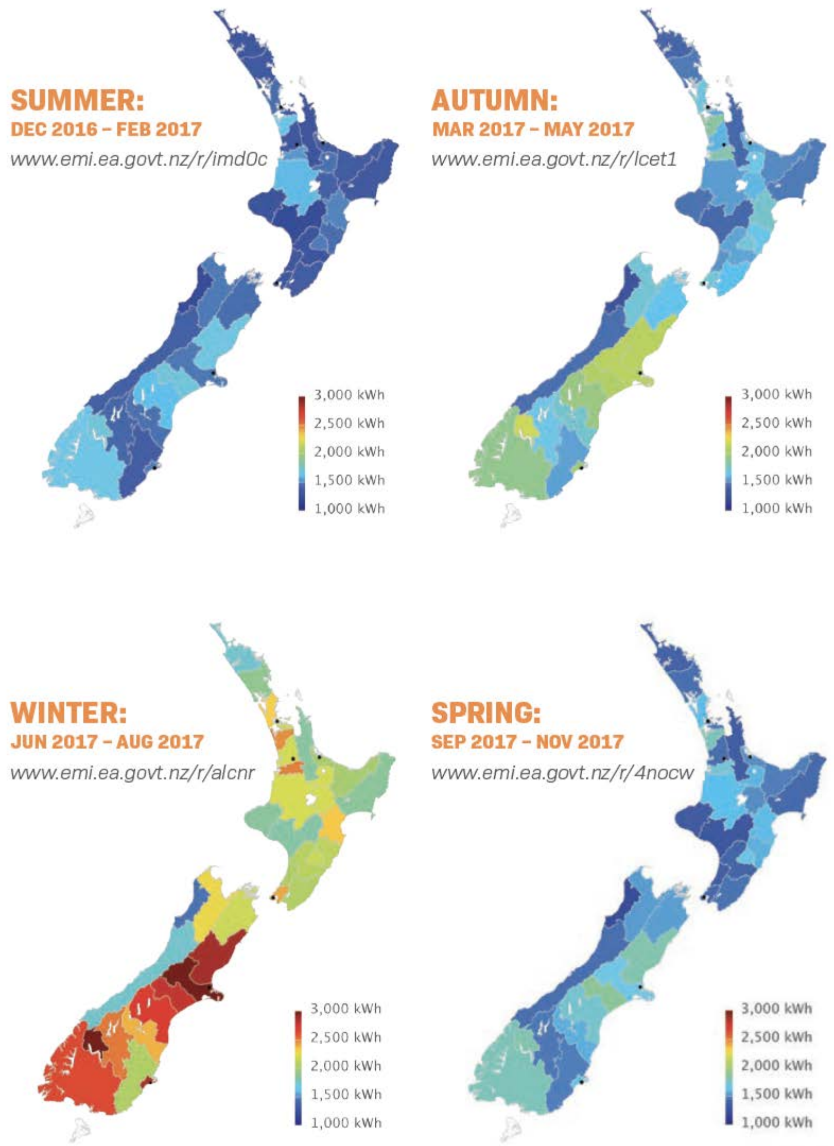
2.4 Oceania

2.4.1 New Zealand—Vector Energy's Hot Water Load Management Trial

Vector Limited, headquartered in Auckland, is the largest electricity and gas distributor in New Zealand. As well as promoting several innovative offerings (ranging from electric vehicle charging stations to battery-supported microgrids). Vector also offers a new twist on an old technology: electric hot water control.

Residential and commercial water heating is a significant portion of electricity consumption, and often accounts for the single largest source of building load. Vector, a winter-peaking utility (see Figure 5), estimates that residential hot water peak demand during winter months can represent up to 20% of total peak. Having the option to temporarily control hot water heaters during peak periods (typically June–August early in the morning and later in the evening) allows the utility to accommodate load without investing in new infrastructure and without noticeably impacting customers.

[6] The PEPT fund comprises government funds, grants, donations, bonds, investor capital, development finance institutional capital, and bilateral cooperation institutional capital. A principal goal in sourcing funds is to maintain a low cost of capital to reduce or eliminate the need to charge PEPT beneficiaries interest on their outstanding connection charge balance.



Source: Vector

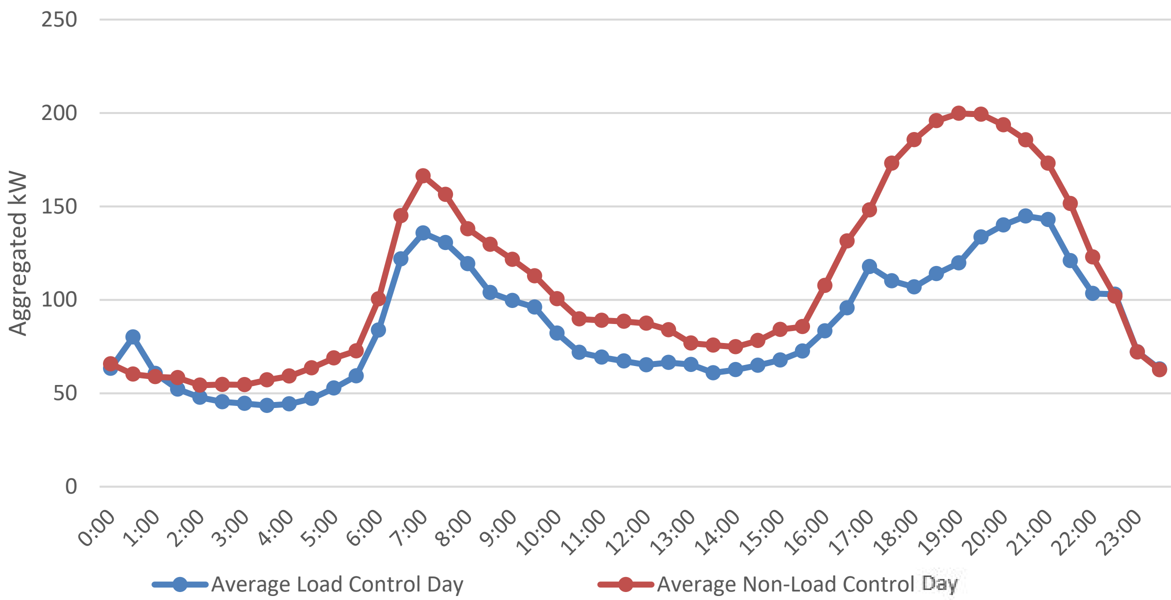
Figure 5. New Zealand peak loads by region

Vector's particular innovation was to revamp a DSM program they have been operating since the 1950s and give it a wireless makeover. This legacy program involved a ripple control system that sent a high-frequency pulse over power lines to activate a relay in a household circuit board and either turn on or off the electrical water heater for load control purposes. While this system has proven effective in reducing system peaks, it does not afford the utility much control or granularity in determining exactly which water heaters it could target. A smarter solution could yield marginally better results and give the utility greater visibility into its system.

This smarter solution came in the form of a radio device from the smart city's technology company Telensa. Telensa's devices, or nodes, have been used all over the world for street lighting applications, but Vector is one of the first utilities to apply it to load control for water heaters. Between August of 2017 and August of 2018, the utility piloted this technology in 104 homes to determine if they could provide a replacement for the ripple control system. Nodes were installed in each of the participants smart meters and connected to the relay that would formerly receive the ripple signal. Under the ripple control system, once the signal was broadcast from the substation, it would hit relays at random in a sort of broadside approach. These radio devices allow Vector to identify which homes could contribute to the highest peak shaving potential and send the shut-off signal directly to them.

This capability not only allows for intelligent management of the system during peak periods, it also allows for a greater range of control modes. Moreover, because Telensa's devices operate on radio frequencies, sidestepping the cellular network, they are a highly cost-effective solution.

The results of this pilot were notable. The aggregate peak load of participating customers (averaged over the course of the pilot) was reduced by over 40% during the evening peak period on load control days versus non-load control days (see Figure 6). Moreover, the utility did not receive any customer complaints regarding the functioning of their hot water systems during the pilot program.



Source: Vector

Figure 6. Average load control day versus average non-load control day during Vector pilot

Vector conducted this trial in a predominantly residential neighborhood served by a substation that is forecasted to require upgrading in 2023, given current rates of growth in the area. The utility anticipates this technology, deployed at scale, could defer the need for the projected $2.4 million NZD upgrade for another 10 years, in addition to other benefits such as reducing transmission charges and providing reserves. This sort of non-wires alternative to infrastructure investment can tamp down on customer rate increases and avoid the emissions associated with generation build-out. Much like the Hydro-Québec pilot of LVCTs, Vector's DSM pilot maximizes existing resources in its system to improve long-term benefits to its broader customer base.

2.5 Europe

2.5.1 Portugal—Energias de Portugal's EV.X Mobile Application

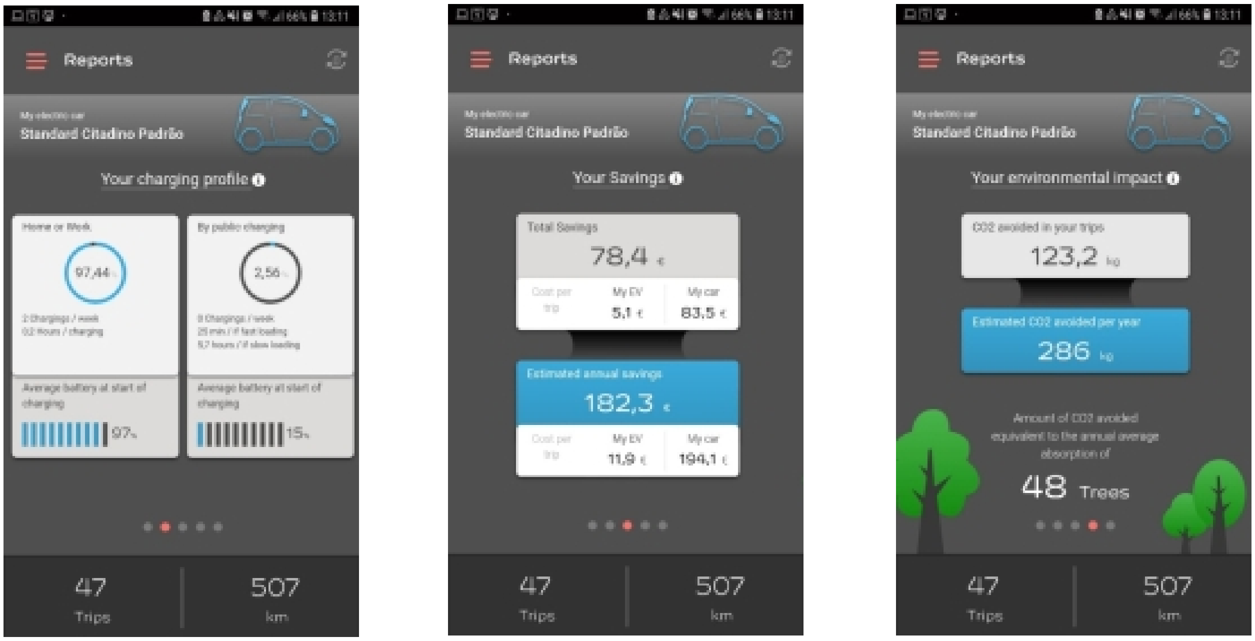
Energias de Portugal (EDP) provides another example of a utility actively seeking business opportunities to capitalize on the expanding EV market. However, EDP's approach is notable for incorporating more than just capital expenditures and infrastructure build-outs; in concert with these measures, the utility has developed a customer mobile application that uses behavioral analysis to provide users with targeted and data-driven information on the benefits of EV adoption.

Launched in 2018, the EV.X app supplies users with the potential financial savings and carbon reductions that they could capture if they were to drive an EV in lieu of their standard internal combustion engine vehicle. The app records all trips users take by car, aggregates the trip information (number of trips, distance, and fuel consumption), and then provides analysis reports to show the counterfactual scenario of what these trips could have saved in expenditures and emissions if the user had been driving an EV. The app also provides information on the location of charging stations along the routes taken to alleviate any user concerns regarding range anxiety, which, by EDP's estimation, is a principal barrier to customer adoption of EVs.

As of this writing, EV.X had some 2,800 users and 126,663 trips recorded (an aggregate distance of 2.36 million km). These trips amount to nearly 86,130 kg of carbon dioxide emissions and would translate to €118,810 in savings (€1.041 per trip) if they had been taken in an EV. EDP aims to enroll 100,000 customers by the end of 2019.

The app is available in 21 countries—not just the utility's customer base—in the Apple and Google app stores. Similar to other utilities in this report that house their innovative business lines in their unregulated subsidiaries, EDP has developed and administers EV.X through EDP Comercial, an independent power producer that also focuses on energy services to a broader marketplace than just bulk power.

The application employs a mix of real and preferential user data to calculate the financial and environmental benefits (see screen captures in Figure 7). The real data come from not only the trips taken, but also the specific make and model of car driven by users (users can specify the make, model, and year manually, or can enter in their license plate number for auto-population). The preferential data come from selecting a make and model of EV to produce the counterfactual scenario. The app pulls data from a large database it maintains on EV performance by manufacturer (only models available in Portugal). In this way, users can determine which vehicles would deliver the greatest utility given their unique driving characteristics.



Source: EDP

Figure 7. Screenshots from EV.X app

EDP motivations for developing the application include:

- Growing their brand in the electric mobility space
- Assisting customers in making informed decisions about the specific benefits of EV adoption
- Assisting customers in overcoming negative perceptions about EVs, such as range anxiety and the difficulty of locating charging stations
- Developing a database of driver patterns that could inform future infrastructure development and EV fleet management policies and regulations
- At a higher level, supporting the European Union's environmental objectives.

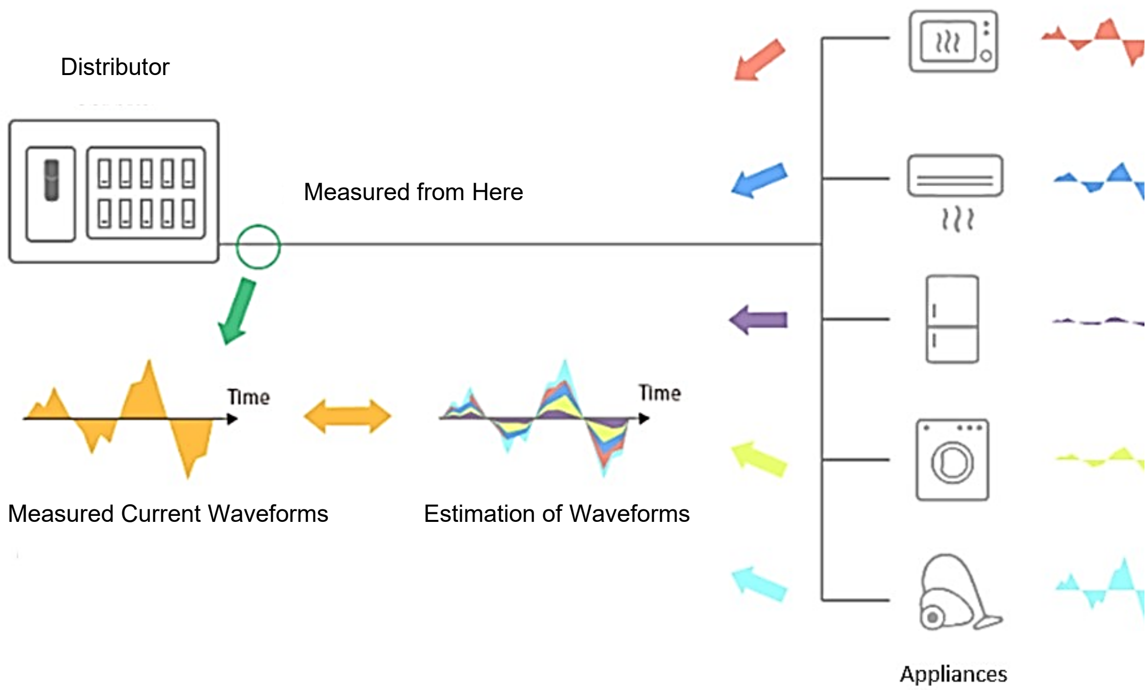
It is still too early in EV.X's operational history to provide any statistics on EV adoption rates driven by application use. At present, EDP tracks download rates as a primary metric for success (other key performance indicators include user rating in the Apple and Google app stores and the number of "active" users of the applications).

The EV.X application is, relative to some of the other programs in this report, a small-scale measure, but it is truly innovative in its approach to driving market development. Consumer preferences can be shaped by not only the availability of actionable data, but also the persistent presence of alternatives in daily decision making. In this way, EDP has leveraged a limited investment in a mobile application into what could prove to be a highly influential tool for influencing consumer perceptions of EVs. If successful, EDP has not only played a part in meeting regional goals for carbon reduction, it has also expanded its revenue opportunities through expanded charging infrastructure and investment potential in electric mobility.

2.6 Asia

2.6.1 Japan—Tokyo Electric Power Company's "Elderly Care Plan"

In August 2017, the Tokyo Electric Power Company (TEPCO) launched a program through one of its subsidiaries (TEPCO Energy Partner, Inc.) that allowed customers to monitor the energy usage of elderly relatives living independently. The program, the Elderly Care Plan, is based on energy disaggregation technology, which parses load signals from a single utility meter out into appliance-specific data. The technology employs sensors that can sample electric current at high resolution and algorithms that identify and match certain patterns in the current to the "behavior" patterns (i.e., waveform signatures) of certain appliances, such as refrigerators, air conditioners, ovens, microwaves, and others. Figure 8 provides a conceptual visualization of how the technology functions.



Source: TEPCO

Figure 8. Disaggregation visualization

The Elderly Care Plan program was born of a confluence of two market conditions. The first is Japan's growing population over 65, estimated to be some 27% of the total population in 2017 and projected to trend upward to more than a third by 2040 (World Bank 2019a; National Institute of Population and Social Security Research 2017). This represents a growing demand for products and services tailored to the elderly demographic. Second, Japan's electricity market was liberalized in the restructuring process implemented through amendments to the Electricity Business Act in April of 2016 (Kobayashi and Okatani 2018). Following liberalization, TEPCO has been facing competition from new entrants into the electricity generation and retail sales markets. Accordingly, it has sought to differentiate itself through innovative product offerings that project a reputation for social consciousness and customer responsiveness.

As with several other programs in this report, the Elderly Care Plan is offered through a retail sales subsidiary, TEPCO Energy Partner. As of this writing, the program is available to customers for a monthly fee of ¥2,980 (about $26 USD) across the Japanese archipelago. The program was initially piloted to 300 trial users for one year before it was released to the broader public.

The target market for the Elderly Care Plan is customers in their 40s–70s who have taken on at least some custodial care of relatives in their 60s–and up. These elder relatives will have a single sensor installed in the distribution panel of their home that analyzes usage in real time (data are sent from sensors to the cloud in 15-second intervals) and disaggregates the appliance loads via proprietary algorithms. These appliance-specific data are then communicated to customers/custodians through an app that can assess any behavioral anomalies by usage patterns. For example, if the air conditioning is not being turned on during peak heating days, this could be a signal to dispatch someone to the home to investigate. The data also allow customers to monitor changes in usage over time, which can provide early indicators of any declines in physical or mental health. And, as with monitoring products, the Elderly Care Plan can provide a back door for understanding where EE measures can effectively reduce load by tracking, analyzing, and displaying user consumption patterns.

TEPCO plans to apply disaggregation technology to other business lines, including home energy management systems. As they do, other companies are entering the disaggregation space with a variety of products and services targeted to a range of customer segments, including utilities, consumers, facility managers, and others. TEPCO's particular innovation was to apply this technology to Japan's unique demographic context and fulfill a customer need that is particularly salient to its cultural milieu.

2.6.2 China–State Grid's Internet of Vehicles: A Smart Electric Vehicle Sharing Management System and Port Electrification

State Grid Corporation of China (SGCC), the largest utility in the world with more than 1.1 billion customers, has been one of the most active utilities in the electric mobility space. In addition to developing infrastructures and programs to support China's burgeoning fleet of EVs, SGCC has been electrifying ports and marine terminals in the Yangtze River Basin to connect commercial vessels to onshore electrical power and thereby avoid the use of onboard diesel generation. The following case study provides an overview of both SGCC's investments and innovations in charging infrastructure, connectivity (internet of vehicles or IOV), and port electrification.

2.6.2.1 Internet of Vehicles

SGCC supports an EV charging network serving more than 20 provinces in China (see Figure 9). It is an 8,700-mile network served by more than 225,000 charging stations and piles (individual low-voltage chargers), stretching from the equivalent of Oklahoma to New York, and from Wisconsin to Florida. At the end of 2018, China led the world with 1.7 million registered EVs on the road and has goals to boost that number to 5 million by 2020. Ensuring that drivers can keep their cars charged will be a key factor in the continuing success of China's EV program.

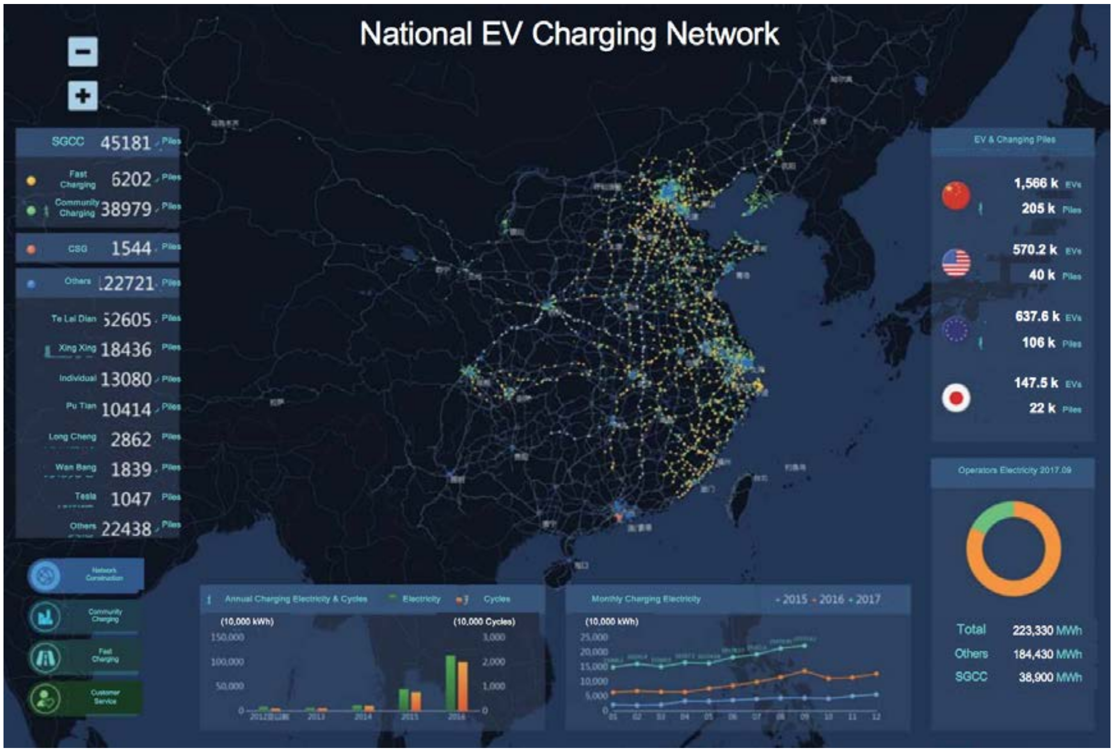


Figure 9. State Grid Corporation of China electric vehicle charging network

Aside from its sheer size, what makes this network of piles and stations noteworthy is its interconnectivity. SGCC, through a specially incorporated subsidiary State Grid EV Service Company (SGEVS) has built a virtual IOV platform from this expansive dispersal of physical assets, enabling information-sharing between different charging station equipment operators and delivering app-based products and services to serve the end-use customers. Incredibly, this IOV platform, and the physical assets it comprises, was built out in less than a decade and continues to expand as of this writing.

The IOV platform manages all data flowing through the entire 225,000 station/pile network, allowing for comprehensive and efficient charging, billing, fault monitoring, and ticketing at each one. Ownership of these assets is generally split among five major operators and a handful of smaller entities, making interoperability and standards critical. SGEVS's IOV platform accomplishes this, ensuring ease of use for customers while coordinating grid operations. SGEVS anticipates that this network will serve as the basis of a future smart grid with more distributed and localized energy services.

SGCC also has established partnerships with domestic and international EV manufacturers including Ford, VW, BMW, and Tesla to create 22 national charging standards, two industry standards, and 61 corporate standards. It has proposed four new standard proposals to the International Electrotechnical Commission, three of which have been approved and released.

On the customer-facing side, SGEVS has created a business model that ensures an easy charging experience while offering a choice of service providers. The company believes that equipping the customer with tools (apps) that create a positive and beneficial experience and that generate revenue and strengthen customer relationships is as important and strategic as the actual charging. Accordingly, SGCC has evaluated a full suite of apps that are both directly and indirectly related to the actual vehicle charging and has deployed three successful apps:

- e-Charging: Recharge account with a range of payment options, screen scan pay, and customer preferred charging plans
- e-Ride Sharing: Online ride share/reservations, EV timeshare rental, find/be a car pool passenger
- e-Riding: EV rental, purchase and swap, traffic navigation to locate the nearest recharging station and to avoid congestion, 24-hour customer service/emergency repair, and purchase of EV insurance.

To keep pace with customer interests and needs, SGCC continually evaluates its apps to strengthen and enhance its existing functions and to identify products and services for new apps.

Recognizing the magnitude and ingenuity of this charging network and IOV platform, the Edison Electric Institute awarded SGCC the International Edison Award in 2018 for "distinguished leadership, innovation, and contribution to the advancement of the electric industry for the benefit of all" (EEI 2019). The impacts of SGCC's EV program extend across sectors, from transportation to electrical distribution, and will have implications for environmental, social, and technological developments in years to come. The utility continues to refine its platform and build out infrastructure (including charging stations, piles, and roadways) to accommodate and propel a burgeoning fleet of EVs in China.

2.6.2.2 Port Electrification

The Yangtze River accommodates a range of vessels in its waters. Container ships, cruisers, and ferries all operate along this busy commercial artery that runs nearly 4,000 miles from the Tibetan Plateau in western China to the East China Sea. While in port, these vessels have traditionally depended on their auxiliary diesel engines to generate electricity for unloading and loading activities. In an effort to counteract the air quality impacts from the consistent use of diesel fuels across the Yangtze River Basin, SGCC is building a network of more than 4,339 shore power supply facilities to provide onshore power to docked ships.

This network—launched in 2018 and scheduled for completion in 2020—includes 341 high-voltage (more than 380 volt) onshore charging piles; 687 sets of low-voltage, large capacity onshore charging piles; 802 sets of low-voltage, low-capacity onshore charging piles; and 2,509 sets of offshore charging piles sited on pontoon docks. The diversity of piles reflects that of the vessels that course the Yangtze waterway. One of SGCC's greatest challenges in developing this network was working with a wide range of ship sizes that had a similarly wide range of mooring requirements (e.g., anchorage, piers, and pillars).

As in the case of its IOV platform, SGCC implemented charging standards and produced several technological innovations to ensure broad usability of the charging infrastructure. Such standards and innovations include:

- A standard cascade "T" connection, enabling cascade power supply with multiple vessels

- A standard mobile energy storage unit, providing power supply to small ships restricted to offshore anchoring
- One national standard, five energy industry standards, and four standards of the China Electricity Council for onshore power charging
- Land-to-pontoon dock power cable connection technology that automatically adjusts cable length during high tide or low tide
- Universal power interface standardization technology for all vessel types
- Mobile energy storage unit for vessels
- Parallel and cascade connection technology for multiple vessels connection
- Onshore Power Supply Cloud service platform.

This last innovation was the brainchild of the same team that developed the IOV platform, and it serves a similar function. The Onshore Power Supply Cloud allows for one-stop bill settlement services, multiple payment channels with remote monitoring and control, and intelligent operation and maintenance and other support services for both ports and vessels. Since the end of 2018, the Onshore Power Supply Cloud has been integrated into the IOV platform.

Pilot projects have so far been carried out in 10 provinces and cities along the Yangtze River, including Shanghai, Jiangsu, Zhejiang, Anhui, Hubei, Hunan, Henan, Jiangxi, Sichuan, and Chongqing.

2.6.3 India—BSES Rajdhani Power Limited's Home Energy Report Program

DSM is a tried and, in many cases, true means for utilities to achieve reductions in system-wide peaks,[7] while maximizing the effectiveness of their asset portfolios and reducing emissions. Traditionally, DSM has been implemented through demand response markets and EE programs, the latter of which usually comprised of an audit, upgrade, and pay-as-you-save model. This model has proven effective in some jurisdictions (see California's more than 40-year history of programmatic EE activity), although it relies on consumer uptake of often capital-intensive technologies, and can require extensive measurement and verification challenges, among other hurdles.

A more recent development in the EE space, behavioral energy efficiency (BEE), takes an alternative approach. BEE programs operate on the principle that that people's energy choices are influenced by social and psychological factors in equal or greater measure to economic factors (e.g., prices, costs, income, etc.). Behavior-based programs use noneconomic incentives to change how people perceive their energy use, influence that usage, and achieve energy savings. Energy feedback, a subset of the broader category of behavior-based EE, provides customers with more detailed, timely, and contextual information about their energy use than typical utility bills in order to help reduce their energy consumption.

Although home energy report (HER)-based BEE programs are not new and have been employed by several utilities across several developed economies, it has been a far less common application in developing economies. India—a country with more than 1.3 billion people and an

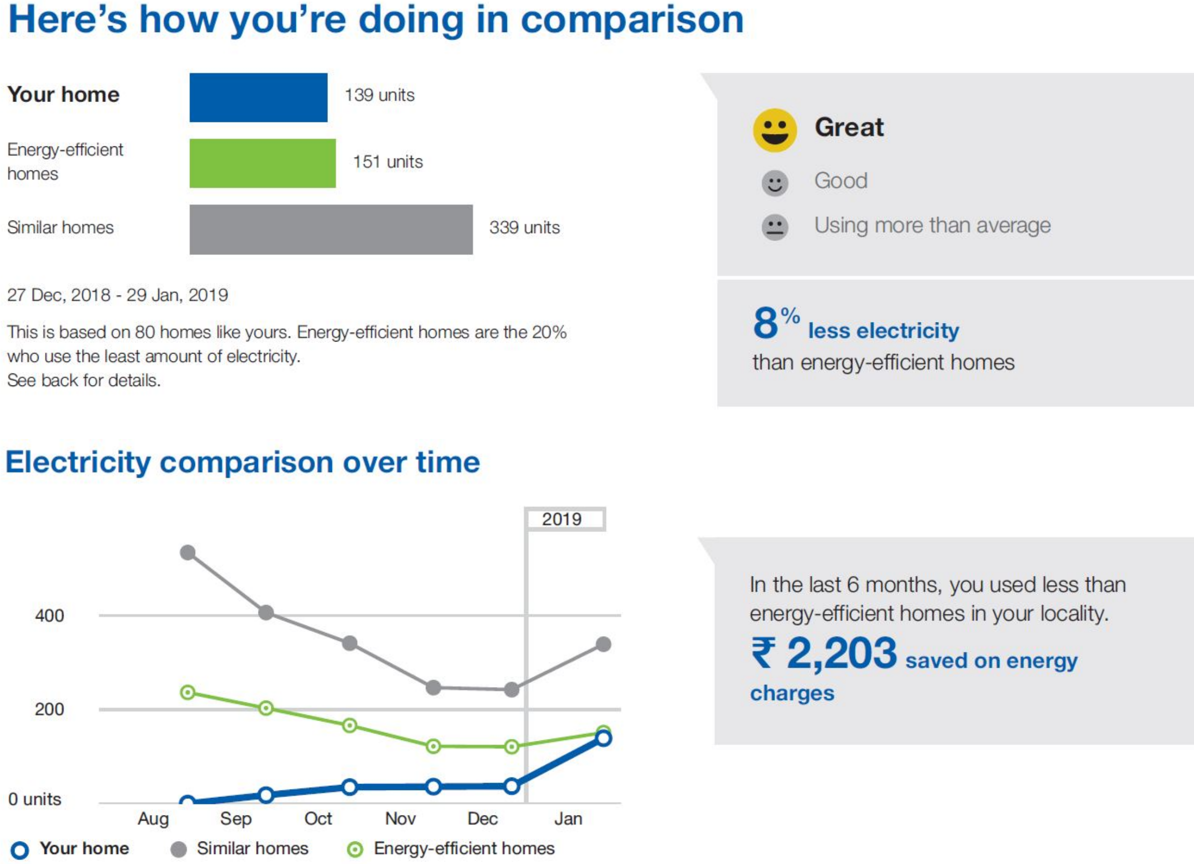
[7] Utilities often try to reduce system-wide peaks because they are the most expensive to serve and reliability is improved by lowering them.

anticipated eightfold increase in residential energy demand by 2050—would seem a perfect candidate to introduce a BEE program (World Bank 2019b; Sachar et al. 2019). And, in October 2018, that is exactly what BSES Rajdhani Power Limited (BRPL) did.

BRPL is an electricity distribution company serving more than 2.5 million customers in the southern and western areas of New Delhi. The company, a public-private partnership with the Delhi government that has operated since 2002, recently embarked on a series of innovative customer-facing programs including net metering for rooftop installations, an EV charging network, and a HER-based BEE pilot, the first in India. The pilot was made possible with a grant of more than $1 million from the U.S. Trade and Development Agency and the participation of Oracle Utilities Opower platform (a cloud-based, software-as-a-service package of solutions serving more than 60 million customers worldwide). The pilot is slated to run for 18 months and currently involves 200,000 customers.

The program operates as a randomized control trial, much like pharmaceutical testing, in which customers are randomly assigned to "treatment" (i.e., customers who receive the HER) and "control" or baseline groups (customers who do not). The difference in outcomes between these two groups is measured during the pilot period to determine the statistical effectiveness of the intervention of sending a HER to customers. A similar HER program in Malaysia employing the same randomized control trial methodology has seen the treatment group achieve 1%–3% usage reductions compared with the control group in the 3 years since its inception (Sachar et al. 2019).

The HER is sent to customers both as a bimonthly paper version and a monthly email version. The report, shown in Figure 10, consists of two charts—one showing monthly usage and another showing usage over time—that demonstrate how the customer's home performance measures up against other homes in the area. The report also displays estimated savings for EE behaviors based on these comparisons.



Source: BRPL

Figure 10. Excerpts from behavioral EE customer bill

In addition to the HER, the treatment group also receive web and mobile-based analytics that can offer more extensive detail than what is available in the HER as well as customized tips on how to further reduce usage.

BRPL's pilot is made possible with the concurrent mass rollout of advanced metering infrastructure at the national level. Advanced metering infrastructure (smart meters) enables the precise measurement of energy use at subhourly intervals that BEE relies on to generate the HER. It was BRPL's particular insight to leverage this movement with a grant opportunity and a technology, BEE, that has been building a successful track record for close to a decade. Faced with exploding demand on their system, BRPL's decision to implement BEE represents a timely and forward-looking choice to reduce the impacts of future infrastructural build-outs.

3 Conclusion

The evolution of the electricity sector—from deregulation, to higher penetrations of DERs, to digitalization and the growing capabilities of transactive energy—is presenting new opportunities and challenges for utilities across the globe. As an industry, utilities have been steadily ceding customer market share and revenue growth opportunities to retail electric suppliers, DER providers, independent power producers, and others for more than two decades. But, in corresponding measure, utilities have also been responding with innovative means of meeting customer needs and strengthening existing relationships, while also seeking new opportunities from the regulators that have typically approved their investment decisions. These innovations have the ancillary benefit of also moving the distribution system to a smarter, cleaner, and more responsive platform, as they concurrently reinforce the relevance of the utility business model in a dynamic 21st century.

The innovations catalogued in this report represent only a sampling of the many such projects and programs utilities are implementing worldwide. In sum, they represent a spectrum of technology frontiers and socioeconomic contexts that illustrate the diversity of needs and potential solutions for electricity consumers worldwide. Amidst this diversity, however, there are core commonalities. Customer engagement and retention, use of smart devices and connectivity, and a pursuit of lower emissions and higher efficiency strategies—these are the driving forces behind all of the innovations documented in this report.

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