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MOVING FORWARD WITH ELECTRICITY TARIFF REFORM

Pilot programs and other experiments have shown the promise of "prosumer" changes.

BY AHMAD FARUQUI AND MARIKO GERONIMO AYDIN

For the better part of the past century, residential customers in the United States and many other countries have paid for electricity through a two-part tariff that has collected most of the revenue through a flat volumetric charge—that is, flat electricity rates paid in cents per kilowatt hour (¢/kWh). In contrast, a large share of the cost of producing and delivering electricity does not vary with the volume of electricity consumed. By not being cost-reflective, such tariffs have neither promoted economic efficiency nor equity in customer bills. Although these limitations have been recognized by the industry, tariff reform has been desultory, characterized by fits and starts mostly driven by energy crises and technology advancements.

Since the 1980s there have been four waves of tariff reform. In the now-ongoing fourth wave, there is an opportunity to move ahead with efficient cost-reflective tariffs because of the widespread deployment of smart meters. The need for cost-reflective tariffs has become pressing because of major shifts in the industry, including a slowdown in utility sales growth and trends toward more distributed generation.

We are on the cusp of a fifth wave of tariff reform that will see residential customers engaging in a "transactive energy" marketplace, akin to how larger entities engage in wholesale energy and capacity markets today. But we cannot reach the full potential of that future without first implementing efficient and cost-reflective tariffs. In this article we discuss ways in which the industry can make the most of our smart grid investments thus far, move forward with tariff reform, and set the stage for a successful transactive energy future.

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Advancements in today's electricity industry have led many to question the sustainability of the traditional utility business model. Individual consumers can install rooftop solar panels and other distributed generation that reduce the quantity of energy incumbent utilities provide. These so-called "prosumers" can even send surplus power "backwards" through the distribution grid and into wholesale markets.

In some states, retail choice and community choice aggregations give consumers the opportunity to bypass their incumbent utility to better customize electricity services and supply based on preferences for cost, environmental attributes, and local community development. Even some of the smallest electricity customers are developing an appetite for customizing electricity usage and production to best suit their needs, and they are supporting and investing in novel tools and methods to do so.

This article focuses on retail tariffs that are charged by vertically integrated utilities or regulated transmission and distribution utilities providing default supply service to customers. Expansion in consumer options for power supply has clashed with the traditional volumetric method of recovering costs that essentially assumes no customer choice. A volumetric charge does not faithfully convey to the customer the actual cost structure of power supply, which is mostly a combination of fixed costs, costs dependent on peak electricity demand, and costs dependent on system conditions at the time and location of energy consumption.

Historically, the traditional volumetric charge was a sufficient cost recovery vehicle for utilities in a world with limited customer-side technology, limited customer options for power supply beyond the incumbent utility, and steady load growth. Today, that charge inadvertently creates a mechanism for prosumers and departing loads to bypass the fixed and demand-based (and peak use–based) costs of being connected to a larger system. The volumetric charge also creates a barrier to taking advantage of new technologies that can help utilities allocate costs to consumers more efficiently and fairly based on their consumption patterns.

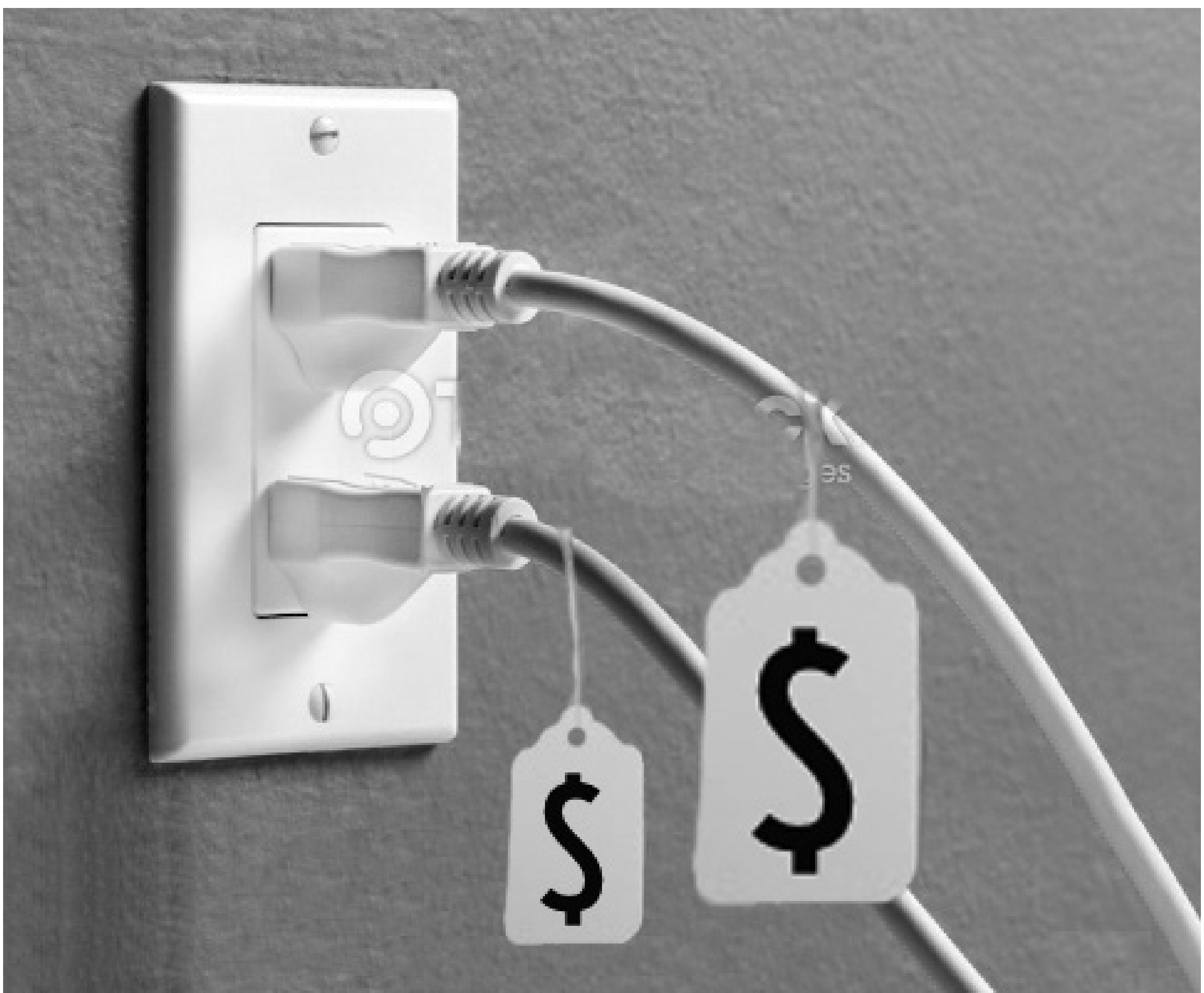
WHAT WE LEARNED IN THE FIRST FOUR WAVES OF TARIFF REFORM

Since the late 1970s the industry has experimented with alternative rate structures to not only allocate costs to customers more efficiently, but also to empower customers to adjust usage patterns to avoid highest-cost electricity production. The industry's primary focus has been on developing time-varying energy charges ("energy-only time-of-use" [E-TOU] charges). In recent years utilities have also experimented with raising fixed charges so they reflect the costs of metering, billing, and customer care.

A third rate component—peak-based demand charges—has been in place for small and large commercial customers around the globe for the better part of the past century. In recent years utilities have experimented more with introducing demand-based charges to residential customers. Demand charges are based on peak electricity consumption and they reflect the costs of building electricity infrastructure to sufficient capacity to meet maximum consumption levels. One defining factor of a demand charge is whether peak demand is being measured at the time of system-wide peak (all customers combined reach peak consumption), within a designated "peak" time period, or at the individual customer's maximum demand. Another defining factor is whether demand charges are recovering distribution capacity costs, transmission capacity costs, generation capacity costs, or some combination thereof. Finally, the time period over which peak demand is measured is another variable. It could be a span of 15 minutes, 30 minutes, or an hour.

This three-part tariff structure—composed of fixed charges, demand charges, and time-based energy charges—better reflects the actual cost structure of power supply. A three-part tariff structure can encourage better use of grid capacity, minimize cross-subsidies between customers, and foster adoption of advanced technologies.

Historical barriers to developing and implementing three-part tariffs have been mostly driven by lack of data and technology for utilities to observe and understand individual customer usage patterns. Over the course of several decades, the industry developed and improved methodologies for understanding customer behavior and preferences through pilot programs. Regardless of customer reactions, an improved three-part tariff structure has helped utilities address some cross-subsidization issues. Addition-



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ally, the industry has found that E-TOU charges give customers the power to avoid high-cost electricity consumption and lower monthly bills, which may also be an essential ingredient to avoiding escalating emergency situations like the 2000–2001 California energy crisis. (See "Special Report: The California Crisis," Fall 2001.) These societal benefits can more than offset the cost of investing in new pricing tools and technologies if only the advanced rate design can incentivize customers to respond to price signals efficiently. Over the last few decades the industry has amassed considerable experience in testing, designing, and implementing E-TOU charges that maximize customer responsiveness.

First wave / As part of the first wave of tariff reforms, E-TOU tariffs were tested in the late 1970s in 12 pilots funded by the Federal Energy Administration (FEA), an organization that later became part of the U.S. Department of Energy. FEA's experimental designs were the first of their kind and they were of uneven quality.

The short-run effects of E-TOU on customer electricity usage were encouraging but not consistent. In most cases customers materially reduced peak consumption in response to the E-TOU rates, with very little (if any) demand-shifting to shoulder or off-peak periods. But some of the experiments resulted in statistically insignificant reductions in peak consumption. The FEA found that higher peak-to-off-peak price ratios and shorter on-peak periods generally led to stronger customer response.

However, these experiments did not test customer responses in the long run, response to multi-part tariffs (e.g., including a demand-based charge and a fixed charge), and customer welfare effects. Most state commissions chose to continue with a flat ¢/kWh tariff, but under the Public Utility Regulatory Policies Act of 1978 (PURPA) they were required to periodically consider time-of-use rates. The industry mostly put the idea of E-TOU implementation on hold until benefits and customer behavior could be better understood.

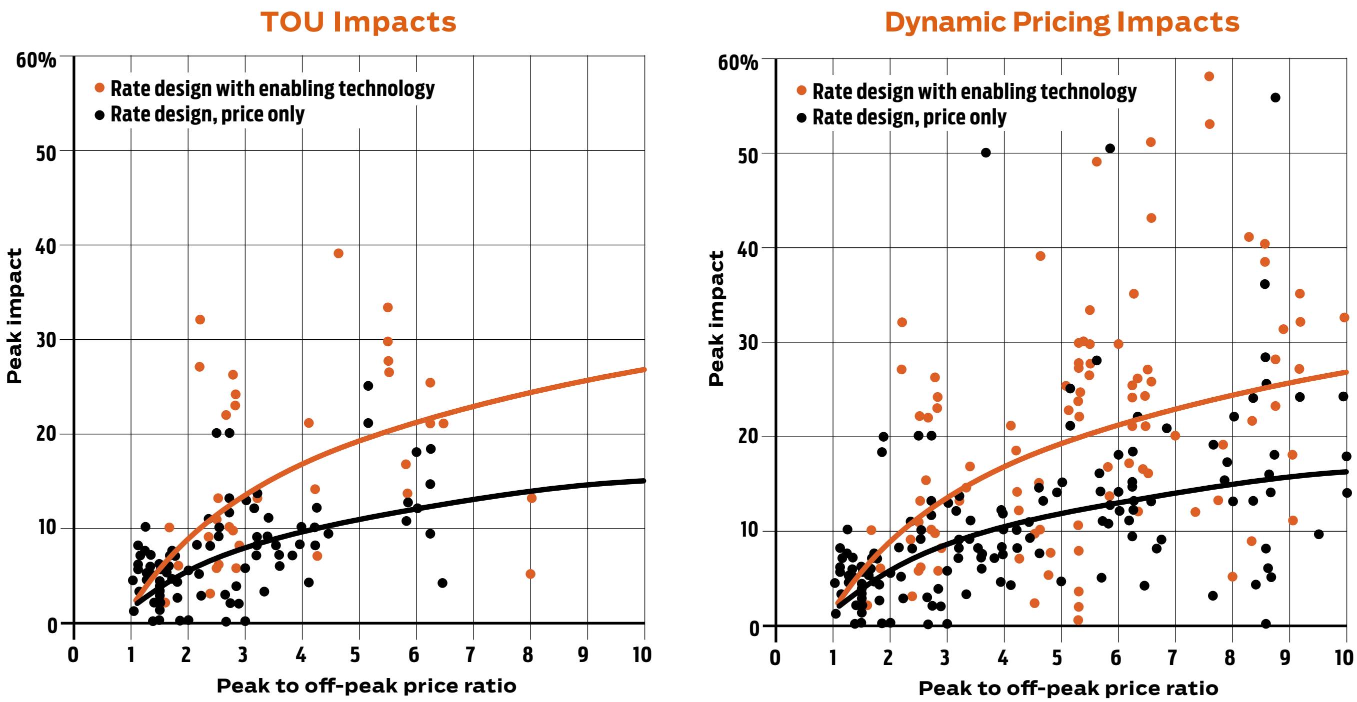
Second wave / The second wave began in the mid-1980s, when the Electric Power Research Institute examined the results from five pilots and found consistent evidence of consumer behavior. Unfortunately, not much came of this discovery because of the lack of smart metering infrastructure and because of the industry's focus on retail restructuring and the expansion of wholesale electricity markets.

However, a few utilities did move ahead with mandatory E-TOU rates for large residential customers. Virtually all utilities moved ahead with opt-in E-TOU rates, but only a few customers were actually on those rates.

Third wave / The 2000–2001 California energy crisis gave impetus to the next wave of pilots featuring dynamic pricing. Compared to E-TOU pricing, dynamic pricing is more of a general term for time-varying energy charges. Unlike time-of-use rates, where the time periods and the prices for each period are known in advance,

FIGURE 1

CUSTOMER PEAK REDUCTIONS IN RESPONSE TO TOU AND DYNAMIC PRICING



SOURCE: Ahmad Faruqui et al., "Arcturus 2.0." Forthcoming dynamic prices may or may not be known in advance and the time period over which the prices are invoked may or may not be fixed in advance.

In the third wave, dynamic pricing pilots included studies of E-TOU pricing as well as other types of dynamic pricing. Some of these pilots featured enabling technologies such as in-home displays and smart thermostats. By 2013, more than 30 pilots featuring more than 160 energy-only pricing treatments were carried out around the globe.

Through those pilots, utilities and regulators learned more about the efficiency benefits time-varying rates could offer, and about factors that improve customer responsiveness during peak demand periods. We learned that load-shifting increases as the strength of the price signal increases, but at a decreasing rate. In California specifically, a major statewide pricing pilot conducted in 2003–2004 provided a conclusive demonstration that customers reduce peak-period energy use in response to time-varying prices.

Momentum from the third wave's scientific experimentation to understand customer behavior continues today. Since 2013, many more pilots have been conducted around the globe, bringing the total worldwide experience to 60 pilots featuring more than 300 energy-only pricing treatments. That number continues to grow. Figure 1 summarizes peak reduction effects from these pilots conducted through 2017, with each data point representing one study.

As customers' peak-to-off-peak price ratio increases, customers reduce their peak consumption more, although at a declining rate. The dark markers in Figure 1 show effects in response to prices only and without enabling technologies. Enabling technologies, such as smart thermostats, were shown to enhance customer responsiveness, as demonstrated by the light markers. These results reinforce previous findings that customers do respond to price signals and that enabling technologies significantly enhance that responsiveness.

In the third wave pilots, observers also discovered that low-income customers can be price-responsive, although not to the same degree as the average residential customer. We further learned more about the effects of other factors such as weather and end-use saturation.

There was some experience with full-scale deployment of time-varying rates, such as in California, France, China, and Vietnam. A 2012 study summarized these experiences and lessons learned on actual customer behavior. Among the discoveries:

> In 2010 Pacific Gas and Electric called 13 events under its critical peak pricing program. Although there were no observable conservation effects, average peak reduction was 14% (with load shifting to subsequent hours) and customers saved an average of 8.2% on their bills. Low-income customers provided about the same percentage of peak demand reduction as other customers.
>
> In France, Électricité de France's critical peak pricing program had been in place in some form since 1996. In 2012 the program demonstrated a high level of price responsiveness compared to other parts of the world. Customers reportedly saved 10% on average compared to other rate options.
>
> China transitioned from government-mandated load shedding to some time-of-use pricing and inclining block rates. In several provinces customers responded with several hundred megawatts in peak reductions, the equivalent of one or two large central generating stations.
>
> In Vietnam rapid growth in electricity use in the 1990s was an impetus for introducing time-of-use pricing in 1998. The national utility initially experienced major hurdles with customer marketing and information campaigns.

We also learned valuable lessons on how to design effective pilots, subject to available budget, time, resources, and other practical considerations. We learned how to better choose the appropriate type of pilot (demonstration, quasi-experiment, or controlled experiment), as well as how to define exactly the pilot motivation, what will be tested, and how it will be measured. We learned how to better establish control groups, recruit customers, and collect and analyze the pilot data.

Overall, the third wave of tariff reform brought the industry rich information on customer responsiveness to time-varying pricing. Pilots in the third wave provided the impetus and scientific evidence for widespread U.S. investments in advanced metering infrastructure. But our understanding of some aspects of customer behavior—like customer responsiveness in certain areas, customer preferences for different rate types, and risks and challenges with full-scale deployment of mandatory time-varying rates—is still incomplete. These remaining information gaps contribute to the barriers that prevent us from realizing the full potential of three-part tariffs today.

Fourth wave / Growth in energy efficiency, distributed solar, and other demand-side resources has raised the specter of a longer-term trend of declining electricity sales for utilities. Traditional two-part retail tariffs that charge residential customers on a mostly volumetric basis will not sustainably provide the revenues needed for utilities to cover their fixed and capital costs. This has led to a growing interest in demand charges and adjustments to fixed portions of retail rates in order to better reflect the true investment costs of maintaining a reliable system and meeting peak demand.

Demand charges can better align prices and costs, encourage smarter load management, improve utility cost recovery, and reduce intra-class cross-subsidies. These charges are already well-established for commercial and industrial customers. A survey of existing residential demand charges in 2014 found nine utilities offering demand charges with a range of 1.5–18.1¢/kW-month. Our own research suggests that this figure has grown to at least 32 utilities offering demand charges today—sometimes with energy-based dynamic pricing rates—to mitigate cross-subsidies caused

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by prosumers and by the slowdown in sales growth.

However, there is very limited empirical evidence on customer response to demand charges. Table 1 shows the results of three older pilots on residential demand charges. These pilots were carried out in Norway, North Carolina, and Wisconsin. Estimated average peak reductions in these pilots ranged from 5% to 29%, brought on by demand charges that ranged from $10.13 to $10.80 per kW.

In the fourth wave, implementation of time-varying rates in most of the United States has not kept pace with the installation of advanced metering infrastructure. The Federal Energy Regulatory Commission estimates that 41% of all customer meters were advanced meters, but only 5% were enrolled in any kind of time-varying rate program in 2014.

Barriers to deployment of smart rates are mostly driven by some remaining uncertainties in how customers will react to a new paradigm in retail tariff structure, and hence what degree of societal benefits can be expected. Significant concerns remain that customers will somehow be harmed or fail to integrate into the new paradigm. Some common barriers to mandatory time-varying rate implementation include:

Insufficient evidence of benefits: Stakeholders may have a perception that pilot programs and other evidence to date are not indicative of benefits that could be realized through full-scale deployment. This could be due to insufficient testing or to lack of awareness of existing evidence. Unless evidence of benefits is compelling, regulators, utilities, and customers will fear that a broader group of customers will not respond to the new rates and that the rates will fail to promote economic efficiency or equity.

Customer dissatisfaction and backlash: The move from flat rates to time-varying rates will more efficiently and fairly allocate costs among individual customers. Bills will rise for some customers who were previously cross-subsidized by other customers. It may take time for those customers experiencing bill increases to understand how to manage their electricity consumption relative to the new rate structure. Additional investment in customer education and outreach will be needed to help customers fully understand the new rates, how to choose among their rate options, and how to adjust their usage patterns to lower their bills.

Effects on sensitive or disadvantaged customers: There may still be uncertainties on how the new rates will affect low-income customers, small users, and customers with physical or technological challenges that prevent them from either fully understanding or reacting to the new rates.

There is no one-size-fits-all solution to addressing these concerns. The best approach can vary greatly because of service territory–specific factors; it also greatly depends on the degree to which customer behavior has already been studied in an area, and which parties (regulator, utility, customers) are hesitant to change the status quo and why. Arizona, for example, already has extensive experience with time-of-use rates, and many utility customers are enrolled in these programs. In contrast, many other U.S. service areas have little or no experience with the actual E-TOU implementation, and these service areas would benefit from pilot programs or other types of testing for customer effects and responsiveness. The highly politicized nature of energy and energy costs to customers has a significant effect on how and when these concerns are raised, and to what degree the public is willing to address and overcome perceived barriers to tariff reform.

But before considering solutions to overcoming barriers to time-varying rates, it helps to take a step back and consider where we are trying to go. In the next section we offer one vision

Table 1

THREE PILOT PROGRAMS ON RESIDENTIAL DEMAND CHARGES

Location	Utility	Years	Number of participants	Monthly demand charge ($/kW)	Energy charge (¢/kWh)	Fixed charge ($/month)	Timing of demand measurement	Interval of demand measurement (minutes)	Peak period	Estimated average reduction in peak period consumption
Norway	Istad Nett AS	2006	443	10.28	3.4	12.1	Peak coincident	60	7 a.m.–4 p.m.	5%
North Carolina	Duke Power	1978–1983	178	10.80	6.4	35.49	Peak coincident	30	1 p.m.–7p.m.	17%
Wisconsin	Wisconsin Public Service	1977–1978	40	10.13	5.8	0	Peak coincident	15	8 a.m.–5p.m.	29%

NOTES: All prices are in 2014 dollars.In the Norwegian pilot, demand was determined in winter months (the utility was winter peaking) and then applied on a monthly basis throughout the year. The Norwegian demand rate has been offered since 2000 and roughly 5% of customers have chosen to enroll in the rate. In the Duke pilot, roughly 10% of those invited to participate in the pilot agreed to enroll in the demand rate. The Duke rate was not revenue neutral; it included an additional cost for demand metering. The Wisconsin demand charge was seasonal. The summer charge is presented here because the utility was summer peaking.

SOURCE: "Rediscovering Residential Demand Charges," by Ryan Hledik. *Electricity Journal* 27(7): 82–96 (August/September 2014).

that relies on technology and efficient tariff design to empower customers to control their bills, respond to electricity market and system conditions, and contribute to efficient electricity use in a nimble and dynamic fashion.

FIFTH WAVE: TRANSACTIVE ENERGY AND SMART HOMES

Understanding and enabling residential customer responsiveness under advanced tariffs will likely be an ongoing effort and challenge, even into the looming fifth wave. Once cost-reflective tariffs are in place, there will still be some technological barriers to full customer engagement. These include limited data *to the customer* from a complex wholesale marketplace, and limited tools for customers to respond to and participate in those markets. We expect the fifth wave of technology innovation to bring these data and tools to customers in the so-called future transactive energy market.

New technology is already beginning to reveal to customers the extent to which electricity cost can vary depending on usage patterns over time. Public policies and initiatives are opening the door for households to have more control over the source of their electricity—beyond retail choice—through distributed generation. Smart appliances, thermostats, and apps are giving residential customers more tools to control and customize usage patterns. Customers will still have the right to access reliable power supply, but these changes will continue to give households more power to optimize their individual electricity use, their cost of electricity, and their environmental footprint. Continued technology improvements and innovations will give rise to smart houses that better coordinate energy usage with customer preferences, and with electricity system and market conditions.

We also expect continued improvements in data exchanges from and to smart houses to give residential customers opportunities to capture value *directly* from wholesale electricity markets. This means that customers will not only react to wholesale market and system conditions, but they will actively participate in wholesale markets through agents or technologies that allow customers to communicate and coordinate directly with market administrators and system operators. Not all customers will have the appetite for engaging in power supply decisions to this degree, but the newer generations of customers who are used to social media, fast-paced and complex communications, and a suite of apps to manage their lives will not find this so strange. Some customers will provide distributed generation and load reduction services to the grid and compete directly with more traditional forms of electricity supply to help reduce electricity production costs, contribute to the reliability of the system, and possibly reduce longer-term capital investment costs.

In one vision of how this could evolve, customers would subscribe to a "baseline" load shape based on their typical usage patterns. They could buy or sell deviations from the baseline on the wholesale market through sophisticated energy management systems or agents. This was originally called "demand subscription," but the idea has morphed into "transactive energy." This vision has gained some traction with millennials through Wi-Fi thermostats, digital appliances, and first-generation home energy management systems. Regardless of the specific method, we believe that in the future the gaps among customers, retail markets, and wholesale markets will be significantly reduced.

But this future cannot be realized if customers do not have even the basic information on how their usage patterns relate to the real cost structure of electricity. Customers cannot react to the high production and investment costs of electricity during peak demand periods if they are shielded from observing these costs at the point of consumption. Customers who are charged the traditional and mostly flat volumetric rate for electricity will be immobilized in the transactive energy future. They will not have the incentives or information necessary to lower their bills in an efficient manner, participate in valuable demand-side services in wholesale markets, or actively contribute to more efficient electricity production and investments in the future.

TRANSITIONING TO ADVANCED TARIFFS

The challenge facing the utility industry is how to take the final steps in implementing mandatory (or, if that's politically impractical, default) three-part tariffs that more accurately reflect the cost structure of providing reliable electricity to individual residential customers. Some in the industry are prepared to take this step; others are not. Even though advanced tariffs are already widely used for medium and large commercial and industrial customers across the country, there is debate over whether they are well suited for residential customers. That is the case even though almost half of all customer meters have been replaced with advanced meters, which provide the necessary technology for offering advanced residential tariffs.

As already discussed, the industry has acquired significant knowledge about customer response to smart tariffs, including E-TOU tariffs and to some extent three-part rates featuring demand charges. Some questions and uncertainties remain about how customers will react with full-scale deployment, but the industry's studies and experiences to date have shown that advanced tariffs do yield real and quantifiable efficiency benefits to customers. Despite this evidence, progress has been stymied because of persistent fears about a customer backlash or a failure to realize expected benefits.

There are ways to overcome these fears, including:

Customer bill effect studies: Utilities and regulators can conduct studies to understand how customer bills will change if the new rates are implemented and there is no change in customer behavior, i.e., the load profiles stay unchanged. These studies can help to identify how much bills will rise for small users. Then, utilities and regulators can find ways to mitigate these bill effects. Some of these are discussed below.

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Customer behavior studies: There are models available today for carrying out simulations to determine the likely customer response. These models draw from findings in prior pilot studies.

Customer outreach and education: Utilities can engage in customer outreach programs to explain why tariffs are being changed and how the new tariffs will work. It will be important to ensure the new rates use clear and understandable language. Utilities can enlist neutral parties to endorse the change and they can use modern social media to spread the word. Tapping into the newer generations of technology-savvy customers will be crucial. Utilities can develop new and more efficient ways to communicate with their customers, help to develop apps and smart energy tools, and otherwise explore methods to enhance the customer experience with technology.

Here are some options for easing the transition:

Transition rates: Utilities and regulators can design transition schemes that change the rates gradually over three to five years.

Bill protection: Alternatively, bill protections can be provided to customers, with those protections being phased out gradually over time.

Add protections for sensitive customers: For the first five years, rates could be optional for sensitive or disadvantaged customers, such as low-income customers, small users, and disabled customers. Or these customers could be provided financial assistance for a limited period of time.

Provide additional information and options to customers: There may be ways to provide additional options for customer participation. For example, consider a subscription concept in which customers "buy" their historical usage at the historical price, and buy or sell deviations from that usage at the new tariffs. This option would also help to transition into the fifth wave of tariff reform involving transactive energy.

Empirical tests for customer response: Utilities can conduct additional pilots to test customer acceptance and load response to the new rates. The pilots should follow some basic precepts the industry has developed in the years prior. They should be carried out as scientific experiments, expected to yield valid inferences about energy conservation and demand response. The pilots should be designed to yield price elasticity estimates that would allow the results to be extrapolated to other prices than the ones being tested in the pilot. Customer samples should be of sufficient size to yield valid inferences about the population. Ideally, pilots should be designed to yield granular information by customer segment. Also, they should test the effectiveness of different marketing, education, and communication technologies.

Household electricity historically has been mostly a uniform commodity for consumers, indistinguishable by source or time of use. For the most part, utilities could price electricity as if it were a uniform commodity without harming their bottom line. But in recent years a number of industry shocks and changes have made it clear that this pricing scheme is not always best for customers or utilities. The status quo is not sustainable going into the future.

The first four waves of tariff reform have gauged consumer response and enabled utilities to price electricity more efficiently as the diverse product it is. At the same time, customers are awakening to the diversity of electricity supply depending on location, time of day, and environmental attributes. Yet there is still much work to be done to implement three-part rates for residential customers more broadly and get the best use out of the smart grid investments that have been made across the country.

The next wave of tariff reform is soon to come. It will empower customers with better tools and more information, enabling them to contribute to efficiency improvements in power supply and giving them more control over the type and cost of power they consume. To address concerns over how customers might behave in this world, we can draw from significant experience in customer pilot programs. R

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