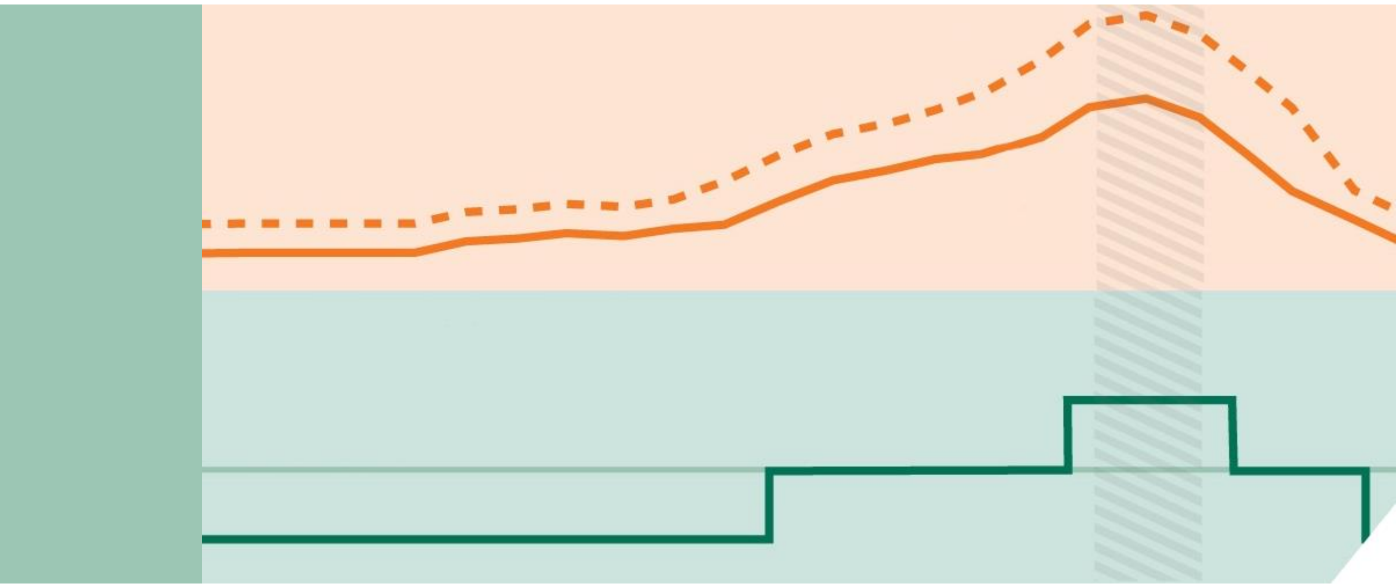

A Primer on Time-Variant Electricity Pricing

Authors

Mina Badtke-Berkow

Michael Centore

Kristina Mohlin

Beia Spiller

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Executive Summary

Throughout most of the country, residential customers pay the same price for each unit of electricity service regardless of the season or time of day when it is consumed. Such flat rates mask the fact that true system costs vary depending on time of day and location, thereby undermining efficient utilization of bulk generation, transmission, and distributed energy resources (DER). Prices that better reflect the time-varying and location-dependent costs of producing and delivering electricity can lead to a number of economic and environmental gains, such as reduced wholesale prices, improved valuation of DER, deferred or avoided investments in costly grid infrastructure, and decreased pollutant emissions.

Different Types of Time-Variant Pricing

Allowing prices to reflect costs that vary over time can be done in many different ways. Commonly implemented types of time-variant pricing (TVP) mechanisms include:

- **Real-time pricing (RTP)** - prices vary frequently (e.g., hourly) over the course of the day to reflect fluctuating electricity costs determined by wholesale electricity prices in deregulated markets.
- **Time-of-use pricing (TOU)** – the day is broken out into two or three periods of time (e.g., peak period, off-peak period, interim period) whereby prices vary by period but remain consistent from day to day.
- **Variable peak pricing (VPP)** – the day is broken out into periods of time (e.g., peak period, off-peak period, interim period) whereby prices vary by period. In addition, for at least one of those periods, the price changes daily to reflect system conditions and costs. The prices in the other periods do not change from day to day.
- **Critical peak pricing (CPP)** – a period of time in the day (i.e., critical event) is identified when the price may increase dramatically to reflect system costs.
- **Critical peak rebate (CPR)** – a period of time in the day (i.e., critical event) is identified when customers are paid for cutting back on electricity relative to the amount they normally use.

Benefits

The potential benefits from load shifting and conservation in response to time-variant prices (TVPs) include reduced wholesale market prices, avoided or deferred capacity investments (in generation, transmission, and distribution), and lower customer bills. TVPs may also increase the returns on investments in distributed energy resources, such as solar panels, energy storage, and energy-efficient appliances. Through load shifting and conservation, TVP may also lead to reduced pollution by shifting demand to times when electricity is generated by cleaner sources. Furthermore, in the future, TVP can – particularly through the adoption of technologies that automate load changes in response to prices – enable the integration of more intermittent renewable energy resources and thereby further increase the environmental benefits associated with TVP.

Numerous pilots across the country have shown that TVP can substantially affect consumption throughout the day and during times when the grid is stressed. The observed amount of load reduced can be substantial, especially when CPP rates are implemented. Demonstrated peak load reductions, for example, range from nine-47% on critical peak days in response to CPP rates.

Key considerations for TVP implementation

- **Advanced metering technology.** Time-variant pricing requires the installation of advanced meters that are able to measure consumption within the interval of time required by the chosen price mechanism. For example, TOU requires measuring consumption in two or three different intervals (each of which continues on a cumulative basis throughout the billing period), while the other TVP options require the meter to measure consumption for each hour of the month.
- **Meter data.** Introducing time-variant pricing on a large scale requires investment in an advanced system that can collect, store, manage, and integrate the larger amount of data that TVP metering generates.
- **Operations.** Operations for time-variant pricing programs may include project management, call center operations, deployment of customer notifications, and other ongoing administrative costs.
- **Rate design.** Which TVP option a utility chooses to offer and how that rate is designed will depend on the needs and requirements the utility is aiming to address. Maximizing effectiveness and customer acceptance are further considerations that play into rate design.
- **Opt-in vs opt-out.** Having residential customers opt in to time-variant price options has historically resulted in a relatively low adoption rate compared to giving customers the option to opt out of an equivalent default plan. A default TVP option from which customers have to opt out results in a much higher reduction of peak demand due to many more customers participating in the program.
- **Ambitious marketing and customer education program.** Achieving customer buy-in with effective marketing and education campaigns is an important factor in successfully implementing time-variant pricing.
- **Flexibility and evaluation.** Conducting ex-post analyses of existing programs can serve as an essential tool to understand how customers are responding to the new prices and to evaluate the need to change or modify the rate design.

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Time-Variant Pricing and its Role in Reforming the Energy Vision

The New York Public Service Commission's Reforming the Energy Vision (REV) proceeding[1] aims to reform New York State's electric utility industry and regulatory practices. The overall objective of the REV proceeding is to develop a cleaner, more reliable, resilient, and affordable electric system. More specifically, the order defines the following six policy goals:

Time-variant pricing can be an important tool in helping advance the REV objectives.

1. Enhanced customer knowledge and tools that will support effective management of the total energy bill;
2. Market animation and leverage of customer contributions;
3. System wide efficiency;
4. Fuel and resource diversity;
5. System reliability and resiliency; and
6. Reduction of carbon emissions.

Customers and distributed energy resources (DER) take a key role in this new vision.[2] More than ever before, today's electric customers have access to new technologies and services that allow them to manage and control how they use energy in their homes. The opportunities from new technologies and services go beyond the individual household. As more and more customers have the ability to use solar and other DER, the opportunity presents itself to reduce electricity purchases and for customers to provide services to the electric grid.

By reflecting the true system costs of electricity, time-variant pricing (TVP) can help advance this new customer-oriented energy system and avail of the largely untapped opportunities afforded by DER. Electricity prices can encourage customers to become active market participants by empowering them to make informed decisions about their energy usage. Reflecting the costs of electricity based on time and location can further serve to animate DER markets, enabling a cleaner and more efficient utilization of capacity and transmission resources.

TVP therefore has the potential to help New York advance the objectives set forth in the REV proceeding. This primer gives an introduction to the rate options, considerations, and potential benefits of TVP relevant to both vertically integrated and deregulated electricity markets.

Introduction to Residential Time-Variant Pricing

Throughout most of the country, residential customers pay the same price for a unit of electric service regardless of the time of day it is consumed.[3] This means that residential electricity rates today simply represent an average cost of generating, transmitting, and distributing electricity.[4] However, electricity is more costly to produce and deliver at particular times of the day or year.[5] While many commercial customers already have access to time-varying electricity prices (TVPs[6]), most residential and small business customers do not. Reflecting the fluctuating costs of electric service for these customers through TVPs is an important step to achieving a more efficient electric system – one characterized by lower wholesale market prices, avoided or deferred capacity investments, and more investment in distributed energy resources.

Time-variant pricing options

There are many different ways to charge for electricity use in a time-variant manner.

There are many ways to allow prices to reflect the time-variant nature of costs: the most appropriate pricing option will depend on the utility's regulatory environment (i.e., deregulated or vertically integrated) and the different types of costs and system conditions the utility needs to manage (e.g., wholesale supply constraints, constrained capacity on the distribution system, critical peaks, daily peaks, etc.).[7] Recognizing these factors, utilities throughout the country have begun to implement[8] TVPs in different ways to address the specific issues that exist in their service territories. Below, we provide an overview of the different types of pricing mechanisms that have been most commonly implemented. Given the scope of this brief section, please refer to Faruqui et al. (2012)[9] for a more thorough discussion of the advantages and disadvantages of each TVP option.

- **Real-time pricing (RTP)** – With RTP, prices vary over very short intervals – such as an hour – and the customer is charged a different price for each interval, reflecting the fluctuating costs of electricity. Sometimes, despite the name, hourly prices are based on day-ahead wholesale market prices, so that customers have time to plan their consumption decisions based on the prices determined the preceding day. The rate is intended to signal to customers on an hourly basis when electricity could be shifted (i.e., moved to another time of day) or conserved, but also when it could be expanded. Historically, this type of pricing has been used for larger commercial and industrial customers, who are likely to have access to technologies that turn off appliances when prices rise above a certain limit. In New York, commercial and industrial customers with 300 kW demands or higher face mandatory hourly pricing.[10] However, two Illinois utilities – Commonwealth Edison (ComEd) and Ameren – have implemented RTP for residential customers on an opt-in basis.[11]

- **Time-of-use pricing (TOU)** – TOU breaks up the day into two or three intervals with different prices that remain fixed day-to-day over the season: off-peak prices (generally during the middle of the night to early morning), interim prices (reflecting times when demand and costs are moderate), and peak prices (occurring during periods of high demand, usually early evening/afternoon). This simple method of pricing encourages customers to reduce their electricity use during peak demand times by charging a higher price and shifting use to times of lower demand by offering a lower price during these periods. TOU is gaining traction amongst California's big utilities. Both Sacramento Municipal Utility District (SMUD) and San Diego Gas & Electric (SDG&E), for example, are slated to roll out a default residential TOU rate. Further east, Massachusetts' Department of Public Utilities has also proposed rolling out default TOU rates.[12]

The most appropriate time-variant pricing option will depend on the objectives of the utility.

- **Variable peak pricing (VPP)** – This pricing mechanism is a particular type of TOU, whereby the off-peak and interim prices mirror the TOU structure, but the peak price varies depending on system conditions. In some settings, the peak period price is chosen from one of a set of pre-determined levels. In other settings, it is tied directly to wholesale market prices. This more complex method of pricing encourages customers to respond similarly as they would for TOU but enables even greater reductions in electricity use when costs are higher by setting a higher peak price on those days. VPP was demonstrated to reduce peak demand by up to 32% in Oklahoma Gas & Electric's (OG&E's) 2011 Smart Study TOGETHER program (see Table 1).

- **Critical peak pricing (CPP)** – With this type of pricing, customers face a high price for peak time electricity use on certain days of the year, generally on days identified as "critical events" (for example, during a heat wave). The customer can avoid paying high prices by reducing electricity use during these periods of high demand (which may only occur up to a pre-determined number of times per year) and benefit from a slightly lower price for non-event hours relative to the flat rate. This pricing provides a strong incentive for customers to reduce consumption during peak hours

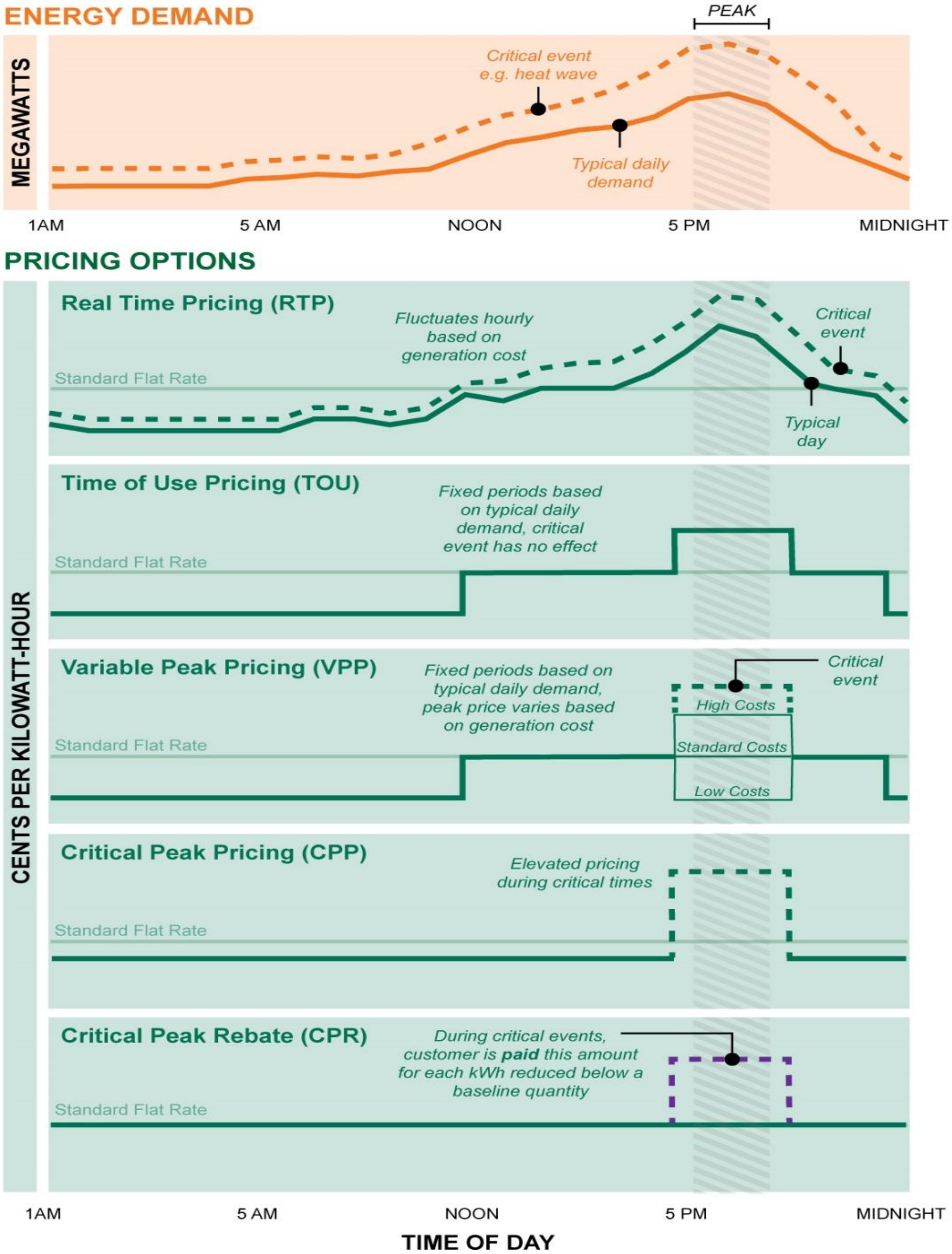
Critical peak pricing has been shown to result in average peak time reductions between 12 and 50 percent.

of critical event days, but provides no incentive to reduce use on non-event days or hours. Critical peak pricing has been implemented by several utilities (for example, New Jersey's Public Service Electric & Gas (PSE&G), Sacramento Municipal Utility District (SMUD), and Arizona Public Service (APS)) across the country, either through pilot programs or new rate options. CPP can result in average peak time reductions from 12-50% (with high ranges achieved by pairing the pricing with enabling technology).[13,14]

- **Critical peak rebate (CPR)** – With CPR, the utility pays the customer for each kilowatt hour of electricity they are able to reduce during the peak hours of critical event days relative to the amount they normally use (known as "baseline amounts"). Similar to CPP, this pricing incentivizes reductions in consumption only during critical events. In contrast to CPP, the customer does not face a risk of increased bills if she is unable to reduce consumption at that particular time; however, the utility faces the challenge of defining the baseline amounts and risks over-compensating the customer if the baseline is not appropriately estimated. Baltimore Gas & Electric (BG&E) made these rebates available to all customers in the service territory after testing them out in prior pilot programs (see Table 1).

As the above descriptions indicate, there are a number of sophisticated pricing programs that can reflect the true costs of electric service better than flat pricing, resulting in more efficient electricity use. They can also be grouped together: for example, CPP and CPR rates can be layered on top of TOU rates (defined as TOU-CPP or TOU-CPR rates), in order to target both the more rare critical peak events and the regular peaks that occur every day. Figure 1 depicts the time-variant pricing options discussed in this section.

FIGURE 1
Different time-variant pricing options



Benefits of Time-Variant Pricing

There are many potential benefits associated with time-variant pricing, for the customer, the system, and the environment.

There are many benefits to implementing time-variant electricity prices (TVPs). The potential benefits from load shifting and conservation in response to TVPs include lower customer bills, reduced wholesale market prices, avoided or deferred capacity investments (in generation, transmission and distribution), better integration of intermittent renewable energy resources, and, depending on the nature of local generating capacity, reduced pollution. TVPs may also provide higher returns on investment in distributed energy resources, such as solar energy and energy storage, as well as energy-efficient appliances.

Given that the different types of TVPs, as described above, will result in different behavioral changes by customers, the size and scope of the benefits associated with each pricing mechanism will differ. Benefits may further depend on the precise value proposition for customers, i.e., on the price levels in each period, customer usage profiles, and on the availability of tools which help respond to the price signals. Below, we list some of the potential benefits associated with TVPs.

Customer bill reductions

Under flat pricing, customers pay the same rate for electricity during all hours of the day. As a consequence, during the hours when the costs of producing and delivering electricity are actually low, flat prices are artificially high. TVPs such as RTP, TOU, and CPP offer lower prices when electricity is less costly to produce and/or deliver. As such, TVP allows customers to reduce their utility bills by taking advantage of low-cost times. For example, New Jersey's PSE&G pilot participants experienced average savings of $160 over the course of the program (see Table 1). Similarly, ComEd's RTP pilot participants reduced electricity bills by an average of 10%.[15]

Contrary to popular belief, low-income households have been shown to benefit from TVP due to their heightened price sensitivity.[16] That said, TVP alone does not guarantee bill savings for every customer. Ultimately, bill savings depend on the customer's ability to shift or reduce electricity use, which can potentially be enhanced with customer education and enablement programs.

Reduced wholesale market prices

Time-variant pricing not only offers the possibility of lower bills for those customers who participate in TVP programs, but if TVP is adopted at scale, its benefits can reach all market participants, creating a more efficient and less costly system. Reduced peak demand and congestion can help avert calling on more expensive power generation, allowing the wholesale market to clear at lower prices. Avoiding the dispatch of higher-priced generation translates to a lower average cost of producing electricity and thus a lower average price for those on flat rates.[17]

Avoided or deferred capacity investments

To the extent that TVP is able to mitigate system-wide peak demand by shifting energy consumption to off-peak times, the need for additional power plants (particularly "peaker plants"[18]) and transmission and distribution infrastructure can be deferred or avoided.[19] For example, OG&E's pricing pilot in 2011 found that if 20% of their residential customers adopted a VPP rate, the utility would be able to avoid a 210 MW peaker plant investment by reducing the need to supply electricity during critical demand times (see Table 1).

Distributed energy resources

Time-variant pricing can work to incentivize distributed energy resources.

TVPs can integrate and help drive the deployment of distributed energy resources (DER), such as energy storage, solar PV, and energy efficiency. Well-orchestrated TVP programs can help align energy demand with the growing penetration of DER supply, leading to more efficient management of the electric system.[20] For instance, TVP can motivate utilization of DER during high-priced peak times when centralized power supply is constrained and/or when transmission and distribution systems are congested; e.g., batteries can be charged during low-priced/off-peak times and utilized during high-priced/on-peak times. Similarly, owners of plug-in electric vehicles (EV) are incentivized to charge their cars when it is both most economical to do so and most beneficial to the grid. In fact, several California utilities such as Pacific Gas & Electric, SDG&E, and Southern California Edison (SCE) already offer pricing plans targeted at EV owners,[21] due to the high penetration of EVs in the state.

Furthermore, TVP can improve the financial attractiveness of DER. Higher-priced peak hours can improve the economics of DERs such as rooftop solar if the peak period occurs during times of abundant solar generation. These rates can also stimulate investment in energy-efficient appliances, helping customers conserve during high-priced times.

Environmental benefits

Time-variant pricing can help to integrate intermittent renewable resources, resulting in a cleaner electric system.

TVPs encourage conservation and shifting of electricity consumption to times when electricity is cheaper; behaviors that are further enhanced by stimulating investments in energy efficiency and battery storage. Load shifting from on-peak to off-peak periods and reduced overall load from conservation can result in a decrease of polluting emissions from the power sector. To the degree that shifting and lower overall use reduces peak demand, inefficient peaker plants that are called on to meet the highest loads will be dispatched less frequently. However, the environmental impact of shifting electricity use depends on the relative emissions rates of the power plants that are on the margin at the time of load reduction versus the time of load increase.[22]

Using TVP to shift load to times when renewable electricity sources are abundant can also encourage investment in clean energy technologies such as wind and solar PV. Furthermore, from a long-term perspecitve, TVP can – particularly through the adoption of technologies that automate load changes in response to prices – enable the integration of more intermittent renewable energy resources and thereby further increase the environmental benefits of TVP.

Experiences with Time-Variant Pricing

Numerous pilots have shown that well-designed time-variant prices can have a sizable effect on consumption.

Much of the experience in deploying TVPs for residential customers across the country has come from pilot projects. Numerous pilots have demonstrated that well-designed, sufficiently marketed TVPs can in fact have a sizable effect on consumption during high-priced hours of the day and critical events. The load reductions can be substantial, especially when CPP rates are implemented. Furthermore, reductions in peak consumption are larger when customers have access to devices such as smart thermostats that help them respond to prices.[23] Finally, these pilots have been used to more precisely quantify the potential near-term benefits of TVPs (e.g., avoided capacity and generation investment, bill reductions). Table 1 shows impacts on customer load from a select number of TVP pilots conducted across the country.

While we cannot readily extrapolate the results of these research efforts to all other circumstances, they do increase our understanding of the effects of TVP on electricity demand and provide valuable insight with respect to implementing and managing such programs.

TABLE 1

Impacts from selected TVP pilots

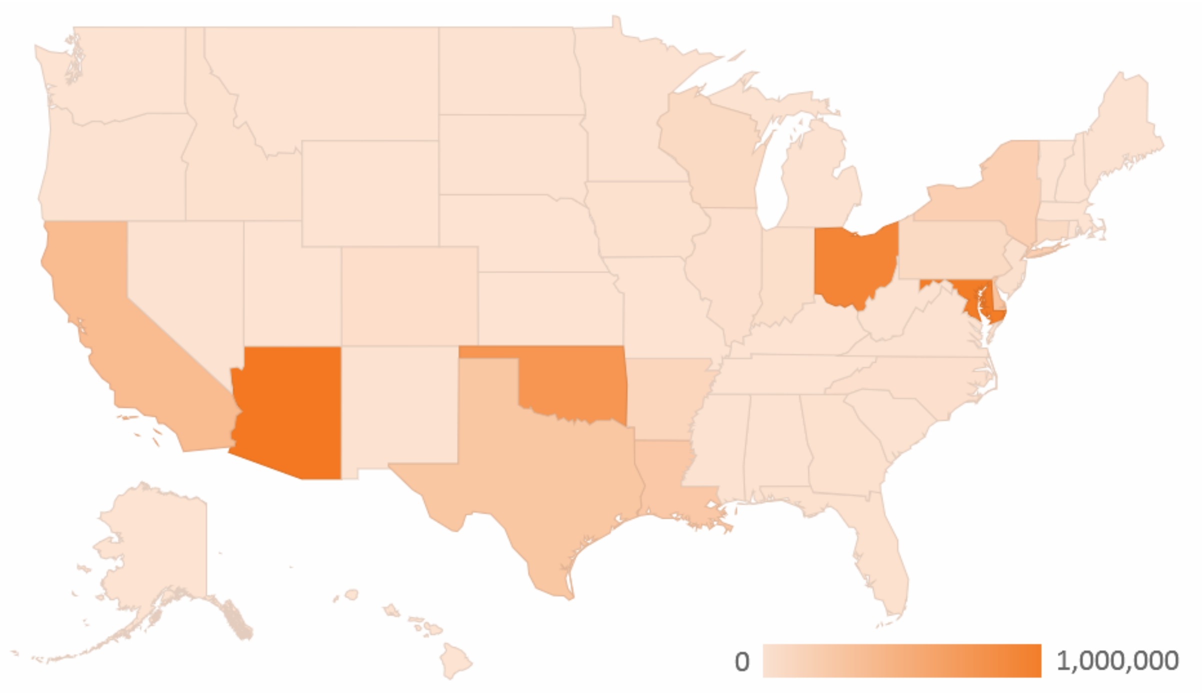
UTILITY	PILOT NAME	TVP STRUCTURE	OPT-IN OR DEFAULT	TECHNOLOGY	AVERAGE IMPACTS ON PEAK LOAD (DAILY)	AVERAGE IMPACTS ON PEAK LOAD (CRITICAL EVENT DAY)	NOTES
New Jersey Public Service Electric and Gas*[1]	2008 myPower Pricing Pilot	*TOU-CPP*	Opt-in	None	-5%ǂ	-19%ǂ	*86% of pilot participants saved on average $160.*
				Smart Thermostat[24]	-21%	-47%	
Baltimore Gas and Electric*[2]	2008 Smart Energy Pricing Pilot	*CPR*	Opt-in	None	-	-23%	*Given the outcomes of their pilot, BG&E has extended the peak time rebate program to residential customers with smart meters.*
				Energy Orb[25]	-	-27%	
				Energy Orb + A/C Switch[26]	-	-31%	
		TOU-CPP	Opt-in	None	-2%	-20%	
				Energy Orb + A/C Switch	-4%	-33%	
Oklahoma Gas and Electric**[3]	2011 Smart Study Together Pilot	*TOU-CPP*	Opt-in	None	-6%	-17%	*Given pilot results, OG&E found that if adoption of the VPP rate reached 20% of the residential population, they would be able to avoid a 210 MW peaker plant investment. They have almost reached the goal with over 100,000 residential customers enrolled.*
				IHD[27]	-8%	-23%	
				Smart Thermostat	-6%	-34%	
				IHD + Smart Thermostat	-7%	-32%	
		VPP	Opt-in	None	-10%	-16%	
				IHD	-10%	-18%	
				Smart Thermostat	-18%	-28%	
				IHD + Smart Thermostat	-21%	-32%	
Sacramento Municipal Utility District**[4]	2012 Smart Pricing Pilot	*TOU*	Opt-in	None	-10%	-	*SMUD estimates savings of $12-140 million from making the rates accessible to the residential base depending on the tariff and technology employed.*
				IHD	-13%	-	
			Default	IHD	-6%†	-	
		TOU-CPP	Default	IHD	-12%†	-9%†	
		CPP	Opt-in	None	-	-21%	
				IHD	-	-25%	
			Default	IHD	-	-14%†	

* Distribution and transmission only company
** Vertically integrated company
ǂ These reductions are an average between customers with and without central A/C.
† While per-customer effects were smaller in default groups, aggregate effects may be larger due to higher participation rates.

Many utilities already offer a voluntary TOU rate to residential customers, but there have been few ambitious attempts at large-scale rollouts of TVP for this customer segment. Some notable exceptions are Salt River Project (SRP), APS, OG&E, and BG&E, which have all managed to bring TVP to a substantial portion of their residential customers.[28] Figure 2 illustrates the number of residential customers that were on TVP in the different states in 2013.

FIGURE 2

Number of residential TVP customers by state in 2013 [29]



Key Considerations for TVP Implementation

The benefits of TVP implementation are potentially substantial – particularly as the electric system evolves toward reduced reliance on highly polluting generation resources in the coming years and decades. It is essential to understand what it takes to achieve and maximize these benefits in practice. This section uses lessons learned from utilities that have implemented TVP – either through a pilot or a mass-marketed tariff – to describe which elements a utility should consider in order to maximize the effectiveness of TVPs.

Advanced metering technology

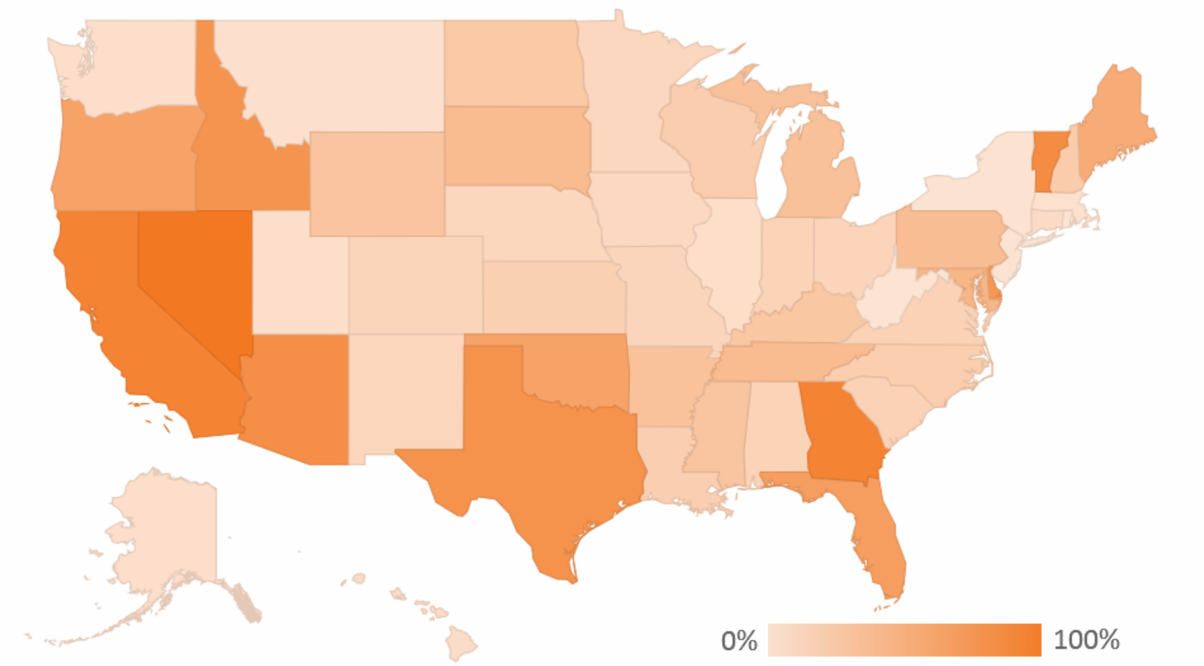
Utilities must be able to measure consumption in each interval in order to be able to charge time-variant prices; this can be done with or without AMI.

Implementing TVP requires a meter that is able to measure electricity use in specific time intervals. However, advanced metering infrastructure (AMI) offers various additional capabilities and services such as automated outage detection, remote connection and disconnection capabilities, data collection and management systems, and improved distribution management.[30] Increasingly, some of these functionalities can also be provided through other technologies than AMI. These functionalities provide detailed, time-based, continuous data that can allow customers to better understand and control their energy usage and save money. Utilities can benefit too: advanced metering technologies, such as smart meters, can reduce costs incurred by manual meter readings or field visits for such issues as disconnections, meter errors, and outage investigations.[31] Implementing TVP adds an extra dimension of benefits to advanced metering investments. For example, SMUD's pilot showed that making TVP accessible to its entire rate base, which their AMI investment enabled, could provide $12-140 million in benefits to the utility over a ten-year period from avoided capacity and generation alone (see Table 1).

Where AMI is already in place – 43%[32] of homes already have smart meters in the U.S. – TVP can utilize the existing infrastructure. However, where AMI has not been adopted, it is important to assess whether TVP can be supported by alternative technologies and products more effectively or less expensively than by AMI, as pointed out in the recent REV order.[33]

FIGURE 3

Smart meter deployments by state in 2013 [34]



It is important to note that the implementation of TVP does not hinge on the deployment of advanced metering functionalities. However, the advanced metering capabilities afforded by AMI and its alternatives allow for enhanced system visibility and control. Furthermore, advanced metering functionalities can be critical to achieving a more efficient and well-functioning electric system characterized by improved system reliability and large-scale integration of distributed generation.

Meter data

With more complex pricing come added requirements for data storage, validation, and billing-systems integration. Flat rates only need to store one observation per household each month, but TVP greatly increases the number of observations.[35] While advanced meter data management systems are typically implemented as part of AMI and Advanced Meter Reading (AMR)[36] projects, TVP introduces additional considerations for managing data.[37]

Upgrades to the billing system and meter data management system can be costly depending on the state of the systems already in place. Yet previous experience shows that including data management and billing system upgrades in the utility's AMI deployment plan is a proactive way of ensuring that TVP is implemented with the least cost. Both SMUD and ComEd proactively implemented meter data management systems for their TVP pilots. These systems, as well as the utilities' experience in integrating interval data, were leveraged in their respective TVP and AMI deployment plans.

Operations

Notifying customers of high-priced times is a key step to ensuring that customers are able to respond.

Operations support for time-variant pricing includes project management, call center operations, deployment of customer notifications, and other ongoing administrative costs such as website maintenance. In VPP, CPP, and CPR rate structures, critical peak events are usually communicated to customers in advance, typically on the previous day. These notifications require investments in technologies that manage these communications to customers and present challenges for program management due to the stringent need for accurate notifications.[38]

SMUD's experience in the SmartPricing Options pilot, which required notifying customers of critical events, demonstrates the importance of providing significant resources for this sort of outreach. In the first year of the pilot, critical peak events and notifications were managed by a single person and verified for accuracy after the event had taken place. In an effort to improve accuracy and reduce errors in the second year of the pilot, SMUD employed a dedicated multi-departmental team to manage the events. This team was required to be available seven days per week during summer months to monitor the accuracy and performance of vendor systems in real time. SMUD notes that, because of these changes, managing the program in the second year was significantly more resource-intensive, but resulted in a more "successful summer of CPP messaging to all customers."[39]

Increased call center volume, especially within the first year of a change in pricing, is also common.[40] This is even more important if the utility is offering a free or discounted smart thermostat, in-home display, or other enabling technology. In this case, increased call volumes to utility call centers may occur due to installation issues arising from integration with meters and home area networks, even if those activities have been outsourced to a third party.

Rate design

When tasked with designing a time-variant rate, utilities have to assess a variety of parameters. First, whether the utility is located in a deregulated state or is vertically integrated may affect whether the TVPs are levied on the supply or distribution portion of the bill or both. For example, SMUD's pilot prices were a bundled rate that included supply as well as delivery, while ComEd's RTP rate only applies to the supply portion of the bill. Second, the utility's objectives for changing customers' behavior patterns will inform its preferences with respect to rate design (e.g., TOU promotes reduced consumption every day of the year while CPP promotes peak load reductions on critical event days). For those TVP designs that include some sort of period-based pricing (i.e., all non-RTP designs), the utility must design the number and duration of each pricing period. The price differential between peak and non-peak periods is an important determining factor for a customer's change in behavior.[41]

Another major challenge for the utility is designing a rate that adequately reflects system costs while providing sufficient financial incentives for customers to alter their consumption patterns in a way that aligns with the utility's objectives. For example, even with a strong price signal, customers may find it difficult to shift their demand to off-peak times under a restrictive TOU rate structure in which the peak period (or peak and interim periods combined) is very long (e.g., 16 hours). Instead, a TOU rate with a relatively short peak period of three to four hours, as seen in SRP's popular EZ-3 rate, lets customers more easily shift their use of major appliances and air conditioning to the much longer off-peak period.[42] The greater flexibility embedded in this rate design can lead to more sustainable behavior changes, resulting in more reliable, predictable, and pronounced peak load reductions for utilities.

Providing a variety of time-variant rates is important given the heterogeneity of the customer base.

Furthermore, providing a menu of options will allow different types of customers to find price structures that best suit their varied needs, because customers are far from homogenous. Ambitious marketing and outreach combined with a variety of offerings can help to increase customer adoption.

Pilots have proven to be crucial in determining which rate design is the best fit for a specific utility. In a 2010-2011 pilot, OG&E found that a VPP rate combined with a smart thermostat led to the most significant reductions in peak loads (see Table 1). OG&E then offered this rate to all residential customers in 2012 as part of the SmartHours program along with an offer for a free smart thermostat.[43] Similarly, BG&E conducted a pilot testing out CPR and TOU-CPP and, given the results from the pilot, decided to offer CPR to all residential customers with a smart meter (see Table 1). Thus, pilot studies can help the utility learn more about customer preferences and the effectiveness of proposed rates.

Opt-in versus opt-out

Behavioral economics has shown that individuals are less likely to opt in to any program.

Choice structure is an important consideration when deciding how customers should enroll in TVP. By and large, if customers have to actively choose to participate in (i.e., opt in to) a program, recruitment rates are lower than under an opt-out approach in which customers are automatically enrolled and are given the option to opt out if they do not wish to participate.[44] This holds true regardless of the choice or issue involved; for example, enrollment numbers in programs involving retirement savings[45] or organ donation[46] are largely affected by whether the participant has to actively sign up or actively opt out of the program. The same holds true for enrollment in TVP programs, resulting in different levels of recruitment rates. For example, in SMUD's pilot, 18% of solicited customers enrolled in the TVP program under an opt-in structure, while 96% were enrolled under an opt-out structure.[47]

The enrollment method may also affect the potential reduction in peak demand that TVP can induce. For example, a customer's propensity for participating in the TVP in an opt-in regime may be strongly correlated with her ability and/or willingness to reduce and/or shift her electricity use. It is not surprising, then, that customers who affirmatively opt in will likely contribute larger peak-time reductions than those who are enrolled passively. Table 1 shows this discrepancy in average response for SMUD pilot participants who opted in relative to those who were defaulted onto the rate (i.e., given the option to opt out). The average peak-time reductions for opt-in groups can be twice as large when compared with the default groups.

However, default TVP programs should not be underestimated. Large acceptance rates combined with smaller average reductions in peak demand can actually result in overall greater electricity use reductions relative to opt-in rates. Even though serving TVP to a larger customer base costs more, SMUD found that the benefit-cost ratio was almost double for default compared to opt-in (see Table 1).

Ambitious marketing and customer education program

Achieving high customer interest and acceptance with effective marketing and education campaigns is an important factor in implementing TVP. Marketing will fulfill different roles depending on the recruitment method: in an opt-in scenario, marketing is especially critical to attract program participants, while in an opt-out scenario, customer awareness becomes more important for achieving program goals. Effective marketing is a sticking point for some utilities that have not traditionally relied on customer-focused marketing campaigns, but some – including SRP, OG&E, and SMUD – have excelled at gaining customer acceptance of TVP programs and pilots.

The success of these utilities in marketing TVP began with market research to determine whether customers understood the proposed rate and were interested in it, and to identify the best marketing methods for recruitment into a pilot. Focus groups can be used to understand the issues customers care about, such as saving money, gaining control over their energy use, protecting the environment, or even a sense of civic duty.

Utilities must allocate a sufficient marketing budget for outreach efforts to be effective. For example, in SMUD's 2009 TVP pilot, marketing – including hiring a full-time marketing professional for eight months – was one of the largest portions of the budget. SMUD developed separate marketing materials for each of seven treatment groups, including brochures, follow-up postcards, web and print ads, and welcome kits for participants. SMUD also used outbound calls and social media to attract customers and created micro-sites dedicated to the new rate options. As a result of their campaign, SMUD achieved relatively high opt-in rates of 16.4-18.8%.[48]

Outreach can help bring awareness to customers and enhance customer responsiveness.

In a large-scale implementation of TVP, utilities should focus not only on marketing to attract customers to the rate, but also on reducing customer resistance to the rates. They can do this by, for example, offering bill protections, a menu of diverse rate options (rather than just one), guidance on which rate to choose, and technical support.

SRP, APS, and OG&E have achieved widely adopted opt-in TVP plans. After deploying AMI and launching their EZ-3 TOU plan, SRP has achieved total TOU participation of 30% – or about 280,000 – of its customers.[49] SRP facilitates customer choice with two TOU options and a prepay plan. The utility's website uses clear, easy-to-understand messaging to inform customers about the rate options available to them. Similarly, APS provides a menu of five distinct TOU plans and a webpage that helps customers choose among those rates; the utility has achieved similar adoption rates to SRP. OG&E's SmartHours plan lets customers view their previous day's usage online at SmartHours.com, provides a free smart thermostat and home energy efficiency kit, and offers customers a one-year risk-free bill guarantee. As a result, OG&E is on its way to its goal of obtaining 20% adoption of its opt-in VPP plan by 2016.[50] They currently have over 100,000 residential customers on the plan.[51]

Flexibility and evaluation

Ex-post analysis is key to helping the utility perfect the pricing mechanism over time, in order to achieve the desired customer response.

Key to ensuring the long-term effectiveness of TVP is the ability to remain flexible in light of changing conditions. Understanding customers' preferences and responsiveness to prices is an important first step. This is done through ex-post analysis, by tracking retention and attrition levels over time, and estimating the effect of the prices on electricity use patterns throughout the day and over time. Essential to evaluating the load impact is to establish a credible control group of customers that are otherwise comparable to the customers on TVP.

This ex-post analysis has the potential to change the next round of rates. For example, if the utility has a goal of achieving a certain level of demand reduction with a CPP, ex-post analysis can identify whether the TVP has been able to achieve this goal. If the analysis demonstrates that the pricing mechanism has not achieved the intended reductions, raising the price may help the utility reach their goal.

Similarly, if a popular TOU rate with a peak period in the middle of the day causes consumption to shift into the evening, this may create a new peak demand time, requiring the utility to reconsider the timing of the peak period. In this case, the utility can redesign the rate so that the peak time is in the evening rather than the middle of the day.

This ex-post analysis can be especially important to be able to help integrate distributed generation into the system. For example, in areas with increasingly high levels of distributed solar generation, the utility may want to increase consumption during times of peak solar generation (i.e., middle of the day) and decrease consumption in the early evening to avoid a large ramping requirement. To achieve this, the utility can set the peak period in the early evening and allow an off-peak period to occur during the middle of the day, to steer demand away from the evening ramping period and toward peak solar generation times. In comparison to period-based TVP such as TOU, RTP has the advantage of automatically adjusting the prices in response to changing conditions.

Finally, systematic ex-post analyses of new TVP pilots and programs provide valuable lessons for TVP implementation; these lessons will be essential in helping guide and advance new efforts to implement TVP across the country.

Notes

[1] CASE 14-M-0101 - Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. 25 Apr. 2014. *Order Instituting Proceeding*.

[2] CASE 14-M-0101 – Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. 26. Feb. 2015. *Order adopting regulatory policy framework and implementation plan.*

[3] Lazar, Jim. *Rate Design Where Advanced Metering Has Not Yet Been Implemented*. Rep. RAP, 2013. Web.

[4] Alvarez, Paul. *Smart Grid Hype and Reality: A Systems Approach to Maximizing Customer Return on Utility Investment*. 2014. Print.

[5] Alvarez (2014)

[6] The term, "time-variant prices" or "time-variant rates" is a working term throughout this brief. It encompasses traditional time-of-use rates (TOU rates) as well as newer rates including critical peak pricing (CPP), variable peak pricing (VPP), critical peak rebate (CPR).

[7] Borenstein, Severin. "Time-Varying Retail Electricity Prices: Theory and Practice." *Electricity Deregulation: Choices and Challenges*. By James M. Griffin and Steven L. Puller. Chicago: U of Chicago, 2005. Print.

[8] The term "implementation" in this brief encompasses both TVP pilots and large-scale programs.

[9] Faruqui, Ahmad, Ryan Hledik, and Jennifer Palmer. *Time-Varying and Dynamic Rate Design*. Rep. Regulatory Assistance Project, 2012. Web.

[10] Per Case 03-E-0641 and subsequent individual utility filings.

[11] Faruqui, Ahmad. *The Principles and Practices of Time-Variant Pricing*. Presented to CPUC, 2014. PPT.

[12] Faruqui, Ahmad, Ryan Hledik, and Neil Lessem. "Smart By Default." *Public Utilities Fortnightly*. 2014. Web.

[13] Faruqui, Ahmad, and Sanem Sergici. "Household Response to Dynamic Pricing of Electricity: A Survey of 15 Experiments." *Journal of Regulatory Economics* 38.2 (2010): 193-225. Web.

[14] Customers on CPP with smart thermostats reduced 51% on critical days in Pepco DC's 2010 Power Cents Pilot Study. See *PowerCentsDC™ Program Final Report*. Rep. EMeter Strategic Consulting, 2010. Web.

[15] Summit Blue Consulting. *Evaluation of the 2006 Energy-Smart Pricing Plan: Final Report*. Rep. CNT Energy, 2007. Web.

[16] Wood, Lisa and Ahmad Faruqui. *The Impact of Dynamic Pricing on Low Income Customers.* InstiteElectric Efficiency. (2010).

[17]A research study by the Brattle Group showed that even a small reduction in peak load significantly reduced wholesale prices in a deregulated market (*Quantifying Demand Response Benefits in PJM*. Rep. PJM and MADRI, 2007. Web.)

[18] Peaker plants are plants with high marginal generation costs that are called upon only when demand is very high. They may be used as little as 100 hours per year but can comprise up to 10-20% of annual electricity costs in the US (Energy Research Council. *Best Practices: Demand Response*. Research brief. 2013. Web.).

[19] Faruqui, Ahmad, Ryan Hledik, Sam Newell, and Johannes Pfeifenberger. "The Power of Five Percent." *The Electricity Journal* 20.8 (2007): 68-77. Web.

[20] Faruqui, Hledik, and Palmer (2012)

[21] See PGE.com, "New Electric Vehicle Rate Options"; SDGE.com, "EV Rates"; and SCE.com, "Electric Vehicle Rates."

[22] Hledik, Ryan. "How Green Is the Smart Grid?" *The Electricity Journal* 22.3 (2009): 29-41. Web.

[23] See Faruqui and Sergici (2010) for a discussion of the effects of technology on peak time reductions.

[24] A smart thermostat is a thermostat with advanced capability: it can be programmed to receive and respond to price signals, and has increased controls to allow the customer to respond automatically to changing conditions.

[25] An energy orb is a spherical countertop appliance that changes colors depending on the price that the customer is facing at any particular time.

[26] An A/C switch is a switch that cycles central air conditioners on and off when prices reach a pre-determined level.

[27] An in-home display (IHD) is a countertop appliance that displays certain information to help the customer make decisions about electricity consumption. Information can include the price at a given time, the amount of electricity consumed in the past hour or day, and/or the total cost to the customer of the electricity consumed over some specified period of time.

[28] SRP has enrolled approximately 30%, and APS 51%, of customers on opt-in TOU rates (See Faruqui 2014). Over 640,000 of BG&E's customers have earned credits from the Smart Energy Rewards peak-time rebate program (See Baltimore Gas & Electric. *BGE Customers Receive More Than $2.5 Million in Credits During the Company's First Energy Savings Day of the Summer*. 29 July 2014. Web.). OG&E currently has over 100,000 customers on a VPP rate (see Table 1).

[29] Based on data from U.S. Energy Information Administration (EIA). Annual Electric Power Industry Report. 2015.

[30] U.S. Department of Energy. *Operations and Maintenance Savings from Advanced Metering Infrastructure – Initial Results*. 2012. Web.

[31] Ameren Illinois for example estimate meter reading savings to be approximately $62 million over a 20 year business case time horizon (Amaren Illinois. *Advanced Metering Infrastructure Cost/Benefit Analysis*. Rep. 2012. 23. Web.)

[32] Institute for Electric Innovation. *Utility-Scale Smart Meter Deployments*. Rep. 2014. Web.

[33] CASE 14-M-0101 – Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. NYS Public Service Commission, 26 Feb. 2015. Page 97.

[34] Based on data from U.S. Energy Information Administration (EIA). Annual Electric Power Industry Report. 2015.

[35] More specifically, while simple TOU rates do not drastically increase this amount, hourly RTP will result in approximately 730 observations per month per customer (1 data point per hour). In a service territory with one million residential customers, this equates to 730 million data points per month or 8.7 billion data points per year.

[36] AMR differs from AMI in that it does not have the capability to transmit the information directly to the utility; instead, a utility truck will drive by and wirelessly gather the data without having to go into the building to read the meter.

[37] See U.S. Department of Energy. *Experiences from the Consumer Behavior Studies on Engaging Customers*. 2014. for a discussion of considerations and challenges in data management.

[38] U.S. Department of Energy (2014) discusses the impacts of errors in customer notifications.

[39] Potter, Jennifer, Stephen George, and Lupe Jimenez. *SmartPricing Options Final Evaluation*. Rep. U.S. Department of Energy, 2014. 28. Web.

[40] In the first year of their pricing pilot, Entergy New Orleans saw higher call center volume, peaking in the summer months when the program was in effect. (See U.S. Department of Energy. *Customer Participation in the Smart Grid*. 2014. Web.)

[41] Faruqui and Sergici (2010)

[42] Vermont Law School IEE. *Salt River Project: Delivering Leadership on Smarter Technology & Rates*. Rep. 2012. Web.

[43] Oklahoma Gas & Electric. *SmartHours.com*. 2015.

[44] U.S. Department of Energy. *Analysis of Customer Enrollment Patterns in Time-Based Rate Programs*. 2013.

[45] Beshears, J., J.J. Choi, D. Laibson, and B.C. Madrian. "The importance of default options for retirement saving outcomes: Evidence from the United States." *Social security policy in a changing environment* (2010): 167-195. University of Chicago Press.

[46] Johnson, Eric J., and Daniel G. Goldstein. "Defaults and Donation Decisions." *Transplantation* 78.12 (2004): 1713-1716. Web.

[47] Potter, George, and Jimenez (2014): 73.

[48] While this may not seem very high, the average adoption rates for opt-in TVP pilots vary between 5 and 15% (See Cappers, Peter, Annika Todd, Michael Perry, Bernie Neenan, and Richard Boisvert. *Quantifying the Impacts of Time - Based Rates, Enabling Technology, and Other Treatments in Consumer Behavior Studies: Protocols and Guidelines*. Rep. Lawrence Berkeley National Laboratory, 2013. Web.)

[49] Salt River Project. *2013 Annual Report*. 7. Web.

[50] U.S. Department of Energy. *OG&E Uses Time-Based Rate Program to Reduce Peak Demand.* 2013. Web.

[51] Oklahoma Gas & Electric (2015)

Table 1 Notes

[1] Summit Blue Consulting. *Final Report for the MyPower Pricing Segments Evaluation*. Rep. Public Service Electric and Gas Company, 2007. Web. (Numbers in table refer to summer month reductions only).

[2] Faruqui, Ahmad, and Sanem Sergici. *BGE's Smart Energy Pricing Pilot Summer 2008 Impact Evaluation*. Rep. The Brattle Group, 2009.

[3] C. Williamson. *OG&E Smart Study TOGETHER Impact Results: Final Report – Summer 2011*. Rep. Global Energy Partners, 2012. Web.

[4] Potter, George, and Jimenez (2014)