# Doing Your Laundry at 10 p.m.: How Time-Variant Pricing Can Improve California's Energy System

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How does California's energy pricing system impact consumer behavior, grid reliability, and the environment? This paper addresses the criticisms of the current system: pricing inefficiencies, blackouts, and negative environmental impacts. Although demand is highest during certain times—noon to six pm on weekdays—consumers pay a rate based on total electricity generated, regardless of demand fluctuations. Much like a plane ticket costing more on Thanksgiving, time variant pricing is used to alter consumer behavior and can encourage electricity consumers to modify their habits. Decreased reliance on "peaker plants," the fossil fuel heavy backup plants needed to meet high demands, will subsequently decrease greenhouse gas emissions. Other advantages of time variant pricing include more reliable electric grids and increased investment in green technologies. Time variant pricing raises concerns including skepticism of overall consumer behavior response and impacts on low-income families. These concerns are addressed, with successive policy solutions recommended by the authors. This paper concludes that time variant pricing will lower overall electricity costs to both consumers and producers, improve grid reliability, and ultimately cut greenhouse gas pollution by reducing the use of fossil-based generation.

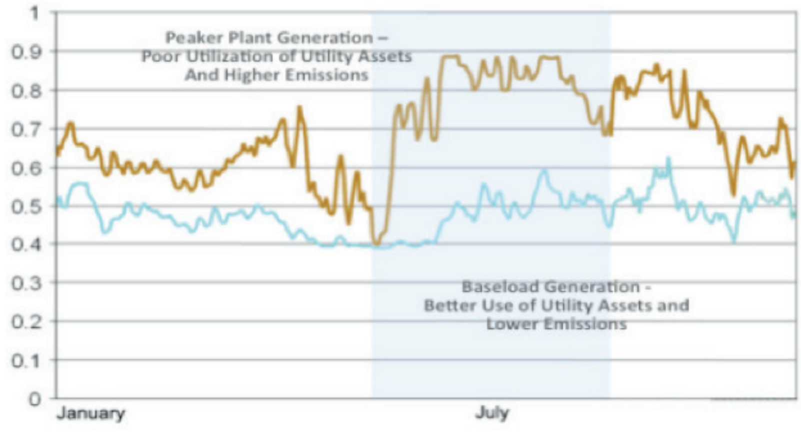
When you book a flight for Thanksgiving, are you prepared to pay more than you would in January for the same flight? If you vacation during off-season, do you expect a discount on your hotel and to bargain for cheaper souvenirs? Ever notice that movie matinees are cheaper than the evening shows, bridge tolls go up for rush hour, and the price for parking is based not only on how long you park, but when you park? These are examples of time-variant pricing, when market-based prices are free to respond to changing demand for goods and services over the course of a day or year. If these examples make sense to you, time-variant electricity rates should not seem strange either.

Electricity demand fluctuates throughout the day and over the course of the year. Most people use very little electricity in the middle of the night, but at 4:00 p.m. on a hot summer day, our air conditioners, refrigerators, lights, computers, and other devices demand a lot from the grid. The difference is important, and problematic.

The timing and size of our electricity demand has significant implications for the design of the electric system, and the climate. The electricity system is built so that it has the capacity to supply the highest daily level of demand. To accommodate the especially high peaks in electricity demand, usually from 12:00 to 6:00 p.m. on weekdays, California relies on "peaker" plants. Most of these sources are gas-fired power plants that operate for a small portion of the year when demand is very high. These plants are built at a low capital cost and designed to be able to come online quickly to produce electricity. In order to achieve these qualities, the plants use technologies that burn fuel less efficiently than baseload power plants. Therefore, peaker plants generate more emissions and have higher marginal costs of operation than baseload sources, which run nearly constantly.[1] If California moved some of its electricity use from difficult-to-fulfill peak demand periods to easy-to-fulfill off-peak periods, it would streamline its electric system, requiring fewer peaker plants.

An effective way to shift this demand is through electricity pricing reform. Currently, default residential rates in California are static across time, but with recent legislation there is an opportunity to improve this pricing structure to encourage more efficient energy use.[2] Policies such as time-variant pricing that encourage consumers to shift energy use from peak to off-peak periods have the potential to lower overall electricity costs to both consumers and producers, improve grid reliability (i.e., fewer blackouts), support clean tech innovation, and ultimately cut greenhouse gas pollution by reducing the use of fossil-based generation. The California Public Utilities Commission (CPUC) should approve default time of use rates and encourage additional voluntary dynamic

**Figure 1.** Peaker plant vs. baseload generation CO2 emission rate (tons/MWh)




Source: Comments to the California Energy Commission from the California Energy Storage Alliance, March 3, 2011.

pricing programs. For these rates to be most effective and equitable, thorough education and awareness efforts, the ability to opt-out, and economically efficient peak to non-peak price ratios should accompany rates.

## HOW CAN POLICY SHIFT DEMAND AND CHANGE BEHAVIOR?

Getting consumers to change their energy habits is difficult; however, policy can influence how much electricity they demand throughout the day.

Opponents of time-variant electricity pricing are concerned that consumers will be unable to change electricity usage during peak periods, thus facing higher electricity bills.[3] Consumer advocates are particularly concerned about the impact on at-risk populations such as the elderly, those living in inland parts of the State with hotter climates, and low-income customers, who may have a harder time adapting to the price changes.

However, much of residential electricity use is discretionary. It currently costs consumers the same amount to run energy intensive appliances, such as a clothes dryer or dishwasher, at 4 pm as at 10 pm, even though the true costs of generating that power are quite different (i.e., more expensive in the afternoon than in late evening). If there was a significant difference in cost to the consumer at these time periods that reflected the actual cost of producing electricity and if consumers were well informed of this cost difference, they would be far more likely to wait until bedtime to hit start. Designing electricity pricing to reflect true production costs can create an incentive for residents to shift electricity use to off-peak times. Under this policy, California would need to build and maintain fewer "peaker" plants, which would save money for both consumers and utilities and be beneficial to the environment.

Efficient and cost-based electricity pricing, paired with education and deployment of smart, user-friendly technology, is an important way to shift demand to times when electricity is cheap and cleaner and also to reduce demand when it is expensive and more polluting. The default residential rate tariffs in place in California today do not provide a financial incentive for individuals to shift their power use to lower demand times of the day. Programmable thermostats, auto-delays on dishwashers, batteries, and other readily available household technologies can expand consumers' ability to control the timing of their energy use.[4] Furthermore, the major California utilities have deployed smart meters to nearly all their customers, and accompanying devices like in-home displays and remote applications give consumers even more information and control over their energy use. However, without price incentives these technologies are likely to remain as niche and optional gadgets rather than widespread cost saving devices.

### Time-variant pricing in California

California, a pioneer in clean tech development and clean energy policy, is now leading the adoption of time-variant pricing. Recent state legislation provides the CPUC the legal authority to overhaul the current inefficient tier structure for residential rates[5] and to adopt time of use pricing as default rates for the State's investor owned utilities (IOUs).[6] Time of use rates are a specific type of time-variant pricing in which there are daily peak, off-peak, and possibly intermediate prices, but these prices are the same each day over the entire season. Other types of time-variant pricing in which rates change in response to real-time supply and demand may be offered as voluntary, opt-in programs, but cannot be the default rate structure for residents.[7] While moving to time of use rates will be a significant change for California's residents, the IOUs already use time of use pricing for commercial, industrial, and agricultural consumers, and the utilities offer voluntary residential programs on an "opt-in" basis.

## WHY DOES TIME-VARIANT PRICING MATTER?

Time-variant pricing has the potential to lower overall electricity costs to both consumers and producers, improve grid reliability (i.e., fewer blackouts), support clean tech innovation, and ultimately cut greenhouse gas pollution by reducing use of fossil-based generation, particularly through reducing use of peaker plants. Below we summarize a few of the main benefits.

Time-variant pricing that encourages residents to shift energy use to off-peak hours and reduce peak electricity

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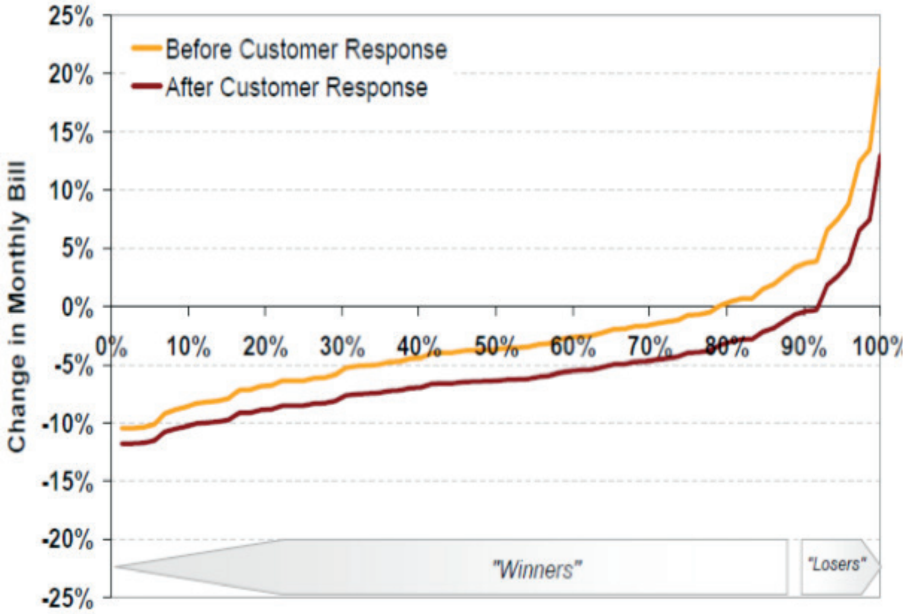
demand will lower greenhouse gas pollution. Figure 1, showing generation sources in the Southern California Edison (SCE) territory, demonstrates that using peaker plants causes significant increases in carbon dioxide and other forms of hazardous air pollution. The brown line shows actual emissions of peaker plants, and the blue line shows actual emissions of baseload generation plants. Simply switching any single given use of electricity from peak to off-peak in July would reduce emissions by 35 – 40 percent on average.

**Figure 2.** Distribution of dynamic pricing bill impacts for low-income customers




Source: EDF Residential Rate Proposal with data from Brattle Group report.

Time variant pricing will also help to drive demand for clean energy technologies and support technological innovation. Take electric vehicles as an example. The number of electric cars in California today (approximately 24,000) is remarkable given the higher than necessary electric-charging rates that drivers face. People ideally charge their cars overnight when demand for electricity is lowest. However, rather than realizing price savings due to the low cost of generating electricity in the late night, they pay rates that are far above this cost, many paying approximately $0.30 per kilowatt-hour (six times the cost of service at that time of the day).[8] This means that electric vehicle drivers in California who stick with their standard electricity contract could save approximately $1,350 annually if rates reflect the time of usage, amounting to over $32 million in annual savings for all owners.[9] Many electric vehicle drivers, however, do opt into a new rate plan that has lower costs during off peak hours, charging vehicles $0.10 per kWh at night.[10] But even these rates are far above marginal costs because they are still tiered and because they roll-in fixed costs. Time variant rates would improve the economics for electric vehicles and help California meet its target of 1.5 million electric vehicles by 2025.[11]

Changing electricity rate structures to reflect the time of use will also create an added incentive for innovation in energy storage technologies, which are critical for managing increased use of intermittent renewable generation. Time-based pricing would make energy storage more valuable to consumers.[12] Batteries and other forms of storage could be charged during off peak periods when the prices are low (with low or no greenhouse gas pollution, i.e., wind at night in California), and can be used later during peak hours to substitute for more costly energy from higher polluting fossil-fuel plants. In this sense, dynamic pricing and energy storage innovation will help to not only lower peak electricity costs, but will also reduce greenhouse gas pollution.[13]

This same logic applies to the use of distributed generation like rooftop solar and technologies to help us be smarter (more timely) with energy use. If regulators in California allow electricity prices to increase when there is a surge in demand, then the incentives of rooftop solar will be improved. Peak energy demand periods generally occur when there is still electricity being generated from rooftop solar systems, so people will see greater returns on their investment.[14] Economist Lee Friedman confirms that "marginal-cost based time-variant rates would align incentives, and customers knowing that they will receive fair value are more likely to purchase such installations."[15] Time-variant pricing will also accelerate demand-response technologies, as people will have a price signal and incentive to use energy more wisely.

## ADDRESSING POTENTIAL PROBLEMS

Despite the promising environmental and economic benefits of time-variant pricing, many people remain skeptical of its positive impacts. Electricity is billed in magnitudes of pennies per kilowatt hour, and most people barely ever think about their electricity bills. Skeptics doubt that time of use will do anything but result in increased bills for consumers. However, pilot programs that test time-variant rates show that consumers do respond to the price signals by reducing peak-time energy use. Well-designed time of use experiments dating back to the 1970s demonstrate that consumers respond as expected to price incentives.[16] As proven in over seventy pilots, residents reduced electricity use during peak periods up to 58 percent and on average around 20 percent.[17] Education, outreach, and smart technologies are necessary for consumer responses, but even minimal efforts in these areas can have significant effects. Furthermore, these rate programs have been well received. In follow up surveys to these pilot programs in the United States, 80 percent of customers reported that they prefer the new dynamic prices to their old rates, and 90 percent would recommend it to family and friends.[18]

The second related concern is how time-variant pricing will impact household energy bills, particularly for low-income residents. Overall, ratepayers will be better off as they take advantage of the improved incentives. Low-income households are actually likely to save the most due to their relatively even electricity use throughout the day and demonstrated ability to shift load to lower-priced off-peak periods. As Figure 2 demonstrates, over 90 percent of low-income customers are expected to save money under time-variant rates. The figure shows the results of a simulation of bill impacts of changing to a time-variant rate for a large urban utility. Assuming low-income customers do not shift their usage at all, almost 80 percent are still likely to realize savings because they already use a greater proportion of their electricity during low-cost periods. If one assumes they can reduce their peak usage by 10 percent, over 90 percent of customers classified as low-income realize savings.[19]

However, changing rate designs can lead to redistributions of income that reflect the wide variations in consumption patterns across households. Models of customer behavioral responses to dynamic pricing show that the benefits outweigh the costs for all categories of consumers, even across differing levels of awareness of and responsiveness to prices and variant uses for electricity. Nonetheless, a large share of the benefits does accrue to a small number of ratepayers who are very responsive to the time of use rates.[20] There's no escaping from the fact that some people will end up with higher bills if they do not adjust consumption patterns away from times when prices are the highest. Education, outreach, and enabling technologies can go a long way in helping consumers better manage their energy use and realize savings from the rates.[21] It is also important that users who are legitimately unable to shift consumption, especially those with high-electricity use medical devices, can easily opt-out of the time-variant rate.

A third concern is how expensive this electric rate reform will be for California. The main cost of time-variant rates is the cost of smart metering infrastructure, which includes the cost of meters as well as the cost of associated software and billing systems and communications equipment. Smart meter deployments by the Pacific Gas and Electric Company (PG&E), Southern California Edison, and San Diego Gas &Electric, under the direction of the CPUC, are nearly complete, and the costs have already been accounted for in CPUC rate proceedings.[22] The major benefits from this investment include the avoided cost of capacity (generation, transmission and distribution) and energy, plus other monetizable benefits like reduced outage times due to faster pinpointing of problem locations.[23]

In addition to the cost of smart meters, some people have concerns that the equipment emits electromagnetic radiation that can be harmful to human health. In addressing the comments of advocacy groups dedicated to this issue, the CPUC cited a study by the California Council on Science and Technology, which found that the levels of radiation from properly installed smart meters are lower than common household devices such as cell phones and microwave ovens.[24] The CPUC also issued rules to protect customers' privacy and data security, while still ensuring customers and utilities can access the data to make improvements.[25] For those whose concerns still linger, utilities are required to allow customers to opt-out of smart meter installation.

Similarly, electric utilities will not face a large implementation cost and are even expected to see cost savings. As customers respond to peak prices by shifting energy use, the operation of the electric system will become more efficient and the utilities' cost per kilowatt-hour will fall. This decreases the need for investment in reserve peaker generation capacity whose capital costs and high maintenance costs must be paid regardless of how infrequently it is used. Lower peak demand will mean that utilities run fewer expensive and inefficient peaker power plants and will save at least 3 – 5 percent of electricity generation costs.[26]

## IMPORTANT COMPONENTS TO MAKE THE POLICY WORK

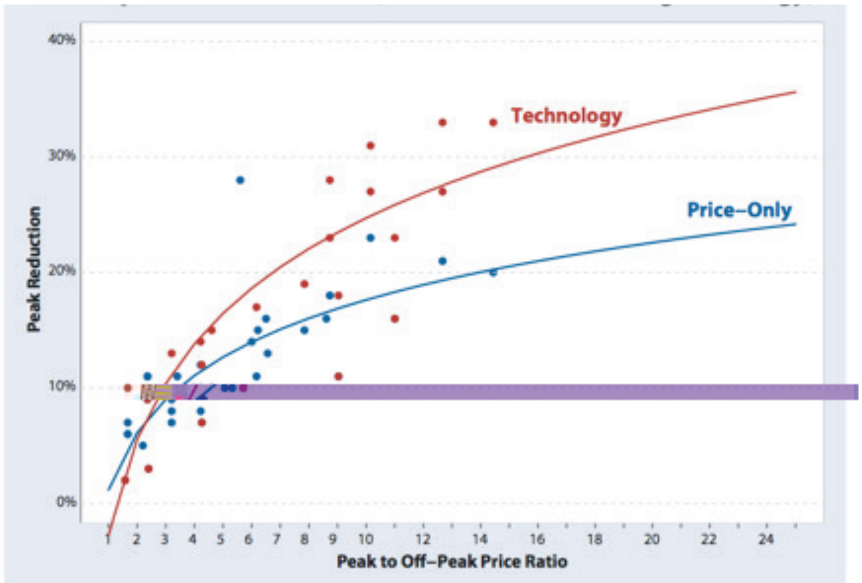
There are five components that are critical to make time-variant electricity pricing work efficiently and in a way that is fair for ratepayers.

### (1) Educate and empower consumers

To maximize the benefits of the rate reform, ratepayers need to know how to use available technologies to optimize energy use and save money. A thorough research-based marketing and education effort will help residents understand the benefits and opportunities of time-variant rates. Offering ratepayers information about their electricity consumption patterns could provide customers with easy ways to shift load and lower their bills. Utilities should use "shadow billing" to show customers how their electric bill would be different with new time of use pricing compared to default rates, and should introduce these comparisons before default time of use rates go into effect.[27]

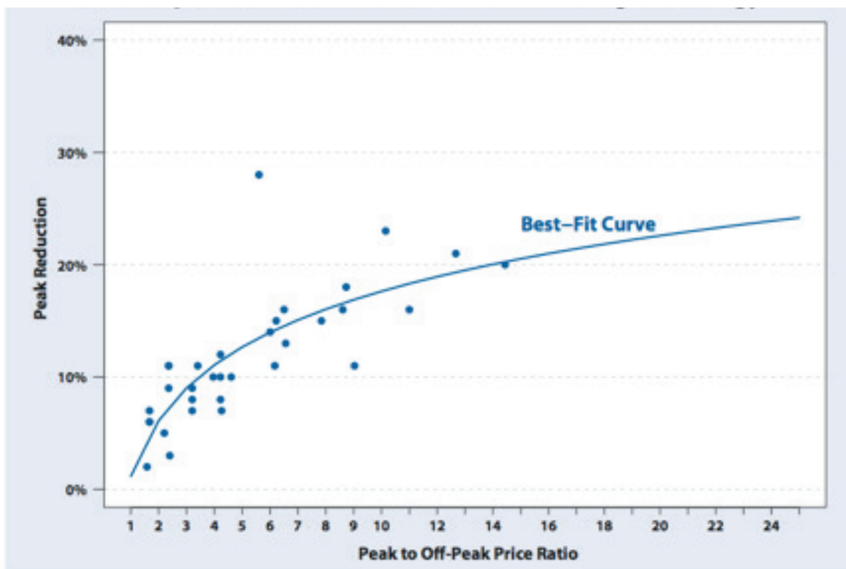
Utility bills should also include tips for ratepayers on how to shift use from peak to off-peak periods, including information on available devices and technologies that can help customers manage their energy usage. Home area networks give consumers the ability to monitor real time energy usage and prices, and some also include devices that help customers automatically adjust their appliances and heating and cooling in response to those prices. Currently, the IOUs are required to provide an online list of at least five home area networks that are compatible with the smart meters they have installed and have a target of connecting 5,000 of these devices by the end of this initial period.[28] However, progress on deploying these devices has been slow, and utilities and stakeholders must become more engaged in enabling these energy management tools.[29] Even simple devices like programmable thermostats can make a big difference to customers. Utilities should consider expanding energy efficiency rebate programs to include programmable thermostats, smart thermostats, and home energy management systems. Figure 3 shows that increased use of these technologies is associated with larger reductions in electricity use during peak hours.

**Figure 3.** Impact of technology on electricity consumption




Source: Regulatory Assistance Project and the Brattle Group

**Figure 4.** Impact of price on electricity consumption




Source: Regulatory Assistance Project and the Brattle Group

### (2) Offer bill protection

Bill protection means that consumers on new time-variant prices are guaranteed not to have a higher electricity bill for the first year. This safeguard is needed to help ratepayers adjust to the new policy and new energy-smart technologies.[30] Temporary bill protection offers customers the ability to gain experience with the new time-variant rates without being exposed to the risk of higher bills. Participants may also opt for technical assistance to help them better take advantage of the program.[31]

### (3) Make time-variant rates be the default, but also offer "opt-out" option

It is too early to make time-based pricing mandatory, yet California will lose many ratepayers with an opt-in program due to consumer inertia. The previous California Statewide Pricing Pilot demonstrated that participation in an opt-out rate could be as high as 80 percent of the eligible population, while participation in an opt-in rate might be closer to 20 percent.[32] This opt-out provision will also alleviate concerned constituencies, as it allows residents who do not see savings after their first year on the program (with bill protection) to go back to the current standard tiered rates. It is also important that the tiered rates reflect the actual average costs produced by users in that rate structure, so that across usage periods and without accounting for behavior changes, they are no more or less expensive time of use rates.[33]

### (4) Get the prices "right"

The peak-to-off-peak price ratio is a key driver of customer response. A large price differential provides greater savings opportunities and more incentive for ratepayers to shift when they use electricity.[34] The appropriate price differential should be based on the cost difference of providing electricity during the different periods. Figure 4 shows that with a bigger difference in peak and off-peak electricity prices (horizontal axis), that there will be larger reductions in electricity use during peak hours (vertical axis).

## TIME-VARIANT PRICING IN THE SCHEME OF THINGS: THE BIG PICTURE

It only takes a brief power outage to realize how reliant we are as a society on electric power for our work, comfort, safety, and entertainment. And it is no overstatement to say that our energy systems are incredibly complex and present some of the greatest challenges of our society today. The "energy challenge" is not one singular issue. We must contend with several challenges: natural resource scarcity, reliance on foreign oil, grid reliability, high costs, local air pollution, depletion of water resources and water pollution, and yes, climate change.

Time-variant pricing is by no means a panacea for this energy challenge, and in fact, there is no single fix for addressing all of these concerns. While time-variant pricing is an important next step, it requires careful planning. Rate design will likely be an iterative process to address issues of equity and consumer responses to electricity prices. Rate reform must also be addressed in a much broader policy context; dynamic pricing is most compelling when seen as a way of thinking strategically and holistically about our energy use. To that extent, California should implement time-variant rates in tandem with increased investment in energy efficiency and distributed renewables. Pricing will then not only be effective in causing direct market responses, but also will present the opportunity for a cultural change in consumers' thinking, behavior, and attitudes regarding energy use.

For many of us, climate change alone is reason enough to enact energy policies that decrease greenhouse gas emissions while also reducing energy costs. Dynamic pricing will almost certainly decrease emissions from peaker plants, and perhaps even more importantly, will be crucial for encouraging innovation in clean energy technology that can reduce emissions even further. Again, the benefits of appropriate pricing are not only the direct reductions in peak power demand, but also the improvements we will see from being more aware of the true costs of our energy and taking steps to pay the proper price for these costs. We know the technology for a modern, clean grid exists – we already have smart meters, rooftop solar, energy storage systems, and electric vehicles. Time-variant pricing is a key link that will accelerate demand for these technologies, maximize their capabilities, and synergistically coordinate our energy needs with our resources.

As California implements other policies to address climate change, particularly bringing more time-sensitive renewable energy such as wind and solar online, it is even more important to think critically about how to match the timing of daily supply and demand of our energy in order to ensure there is a reliable, affordable, and ideally clean source of electricity at all hours of the day.

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## ENDNOTES


[1] California Energy Commission, "Thermal-Efficiency of Gas-Fired Generation in California: 2012 Update," March 2013, *http://www.energy.ca.gov/2013publications/CEC-200-2013-002/CEC-200-2013-002.pdf*

[2] California AB 327, signed into law in October 2013, allows for structural changes to residential rates. CA AB327. 2013-2014 Regular Session. (2013, October 07). LegiScan. Retrieved March 24, 2014, from *http://legiscan.com/CA/bill/AB327/2013*

[3] David Baker, "Sweeping Changes Sought for Electricity Bills." San Francisco Chronicle, January 10, 2014.

[4] The Edison Foundation, "Utility Scale Smart Meter Deployments: A Foundation for Expanded Grid Benefits," August 2013, *http://www.edisonfoundation.net/iee/…/IEE_SmartMeterUpdate_0813.pdf*

[5] Currently, default residential rates are based on four tiers, with the price of electricity increasing dramatically the more you use. While this system was designed to encourage energy efficiency and conservation, past legislation blocked rate increases in the lower two tiers, so that all increased costs have been borne by customers in the higher tiers. Today, consumers who use a substantial amount of energy pay far more than the cost of generating the electricity, and thereby subsidize the cost for other consumers. The result is a significant distortion in incentives across the tiers. AB 327, passed in October, removes the caps on Tiers 1 and 2 and allows rates to gradually move to fewer tiers. Whether or not time of use rates are implemented, therefore, electricity bills for low-use customers will almost certainly increase.

[6] The CPUC has jurisdiction over the IOUs in the State, but not publicly owned utilities. The three main IOUs are Southern California Edison, San Diego Gas and Electric, and Pacific Gas and Electric.

[7] CA AB 327. *http://leginfo.legislature.ca.gov/faces/billStatusClient.xhtml*

[8] Lee Friedman, Electricity Pricing and Electrification for Efficient Greenhouse Gas Reductions, Next 10 and UC Berkeley, July 2013

[9] Assumes 5,400 kwh used to charge EV per year, as is typical is Department of Energy calculations, *http://www.fueleconomy.gov/#HEVEVPHEV*. Assumes 24,000 current owners of EV in California *http://www.greencarreports.com/news/1084429_where-are-the-electric-cars-today-in-ca-how-about-100-years-ago*

[10] Southern California Edison, Electric Vehicle Rates, *https://www.sce.com/*

[11] Michael Cabanatuan, "Governor approves 6 laws encouraging electric cars" San Francisco Chronicle, September 28, 2013.

[12] Regulatory Assistance Project and The Brattle Group, Time Varying and Dynamic Rate Design, July 2012

[13] Friedman

[14] Regulatory Assistance Project and The Brattle Group

[15] Friedman

[16] Paul L. Joskow and Catherine D. Wolfram, Dynamic Pricing Of Electricity, Alfred P. Sloan Foundation and Massachusetts Institute of Technology, Haas School of Business, University of California, Berkeley and NBER, December 2011

[17] "Time Varying Rates," Neural Energy, accessed December 1, 2013, *http://www.neuralenergy.info/2013/10/time-varying-rates.html.*

[18] *Ibid.*

[19] *Ibid.*

[20] Paul L. Joskow and Catherine D. Wolfram, "Dynamic Pricing Of Electricity," Alfred P. Sloan Foundation and Massachusetts Institute of Technology, Haas School of Business, University of California, Berkeley and NBER, December 2011.

[21] Regulatory Assistance Project and the Brattle Group.

[22] In California, the CPUC authorized Southern California Edison to install approximately 5.3 million new Smart Meters; San Diego Gas and Electric Company 1.4 million electric Smart Meters and 900,000 natural gas meters; and PG&E, approximately 5 million electric meters and 4.2 million natural gas meters *http://www.cpuc.ca.gov/PUC/energy/Demand+Response/benefits.htm.*

[23] US Department of Energy Smart Grid Investment Grant Program, "Operations and Maintenance Savings from Advanced Metering Infrastructure – Initial Results", December 2012.

[24]*http://www.cpuc.ca.gov/NR/rdonlyres/5AC64F42-EC0A-4FC6-91EA-FE31A7C0F17D/0/CABSmartMeterLetter.pdf*

[25] *http://docs.cpuc.ca.gov/PUBLISHED/NEWS_RELEASE/140316.htm*

[26] Severin Borenstein, "Effective and Equitable Adoption of Opt-In Residential Dynamic Electricity Pricing," Energy Institute at Haas, April 2012.

[27] *Ibid.*

[28] Home area networks connect with the smart meter to provide a user real time information on their energy consumption. The devices may also include additional features that communicate with appliances or heating and cooling systems, and allow for automated response to high rates or peak events.

[29] Smart Energy Universe. "California Home Area Network Implementation Plan." Accessed March 23, 2014. Available: *http://smartenergyuniverse.com/14-home-area-networks/6564-california-home-area-network-implementation-plan*

[30] Paul L. Joskow and Catherine D. Wolfram, "Dynamic Pricing Of Electricity," Alfred P. Sloan Foundation and Massachusetts Institute of Technology, Haas School of Business, University of California, Berkeley and NBER, December 2011.

[31] *http://www.neuralenergy.info/2013/10/time-varying-rates.html* (December 1, 2013)

[32] Regulatory Assistance Project and The Brattle Group

[33] The flat rate should be an average of the prices of off-peak, mid-peak, and peak electricity, weighted by the proportion of the energy consumed in each period by the entire group of users. The rates across the two programs would still reflect the same underlying, time-variant cost structure, but those on the flat rate will pay the same price per kilowatt hour at any time. This design ensures that customers pay the same costs, but protects those on the flat rate from volatility of time-varying rates. These users, however, would not be able to reduce their total monthly bill amount by changing their consumption patterns. See Severin Borenstein, Effective and Equitable Adoption of Opt-In Residential Dynamic Electricity Pricing, Energy Institute at Haas, April 2012

[34] *Ibid.*