Union of Concerned Scientists

ISSUE BRIEF

Flipping the Switch for a Cleaner Grid

Using Time-Varying Rates to Boost Renewables and Save Money

HIGHLIGHTS

To limit the scale and scope of future climate impacts, we must accelerate our shift away from an electricity system dominated by fossil fuels toward one powered by clean, renewable resources. One way to facilitate this effort is to encourage demand flexibility, where we shift our use of electricity to align with times when it is cleanest and most efficient for the grid.

Utilities can help encourage these beneficial demand shifts through the use of time-varying electricity prices, which signal to consumers better and worse times to use electricity by moving prices lower and higher accordingly. When carefully designed and communicated, this relatively straightforward solution has the potential to yield economic and environmental dividends for all.

When it comes to electricity, most of us use it whenever we want, however we want, because we have no reason not to: the majority of households in the United States pay “flat” or “average” electricity rates that stay constant over the course of the day and often the year. But these uniform rates mask the fact that our electricity grid is far from static. Consumer demand varies from hour to hour, day to day, and season to season—and so does the mix of generators providing electricity to meet that shifting demand. This means that electricity is cleaner and cheaper to provide at some times, and more expensive and heavily polluting at others.

By obscuring the true costs of electricity consumption, flat rates have contributed to our electricity system becoming more expensive and less efficient. For example, peaks in demand are met largely by relying on fossil-fuel power plants, some of which sit idle most of the year even though customers pay for their construction and maintenance. And, because peak consumption costs contribute to utilities’ future rates, these demand spikes can result in higher electricity costs for consumers over time. Lastly, as we build out our clean energy resources, flat rates leave no way to incentivize customers to shift consumption toward times of the day when clean energy resources are most plentiful—a missed opportunity to capitalize on abundant zero-emission electricity.

A critical step in propelling us toward a lower-carbon, lower-cost electricity system is pulling back the curtain on the dynamic costs of production and consumption. One of the simplest ways to do this is also one of the most promising: using price signals to indicate when electricity is cleaner and less expensive, and shaping and shifting electricity use accordingly. Time-varying electricity rates—

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Electricity grid operators must constantly balance consumer demand with electricity supply to maintain reliability and avoid blackouts. We can achieve significant environmental and economic benefits by aligning consumer demand with periods of high renewable energy generation; time-varying rates are one of the best ways to facilitate this shift.

which move higher or lower over the course of the day, week, and/or season in accordance with true system costs—can save money and better match consumer demand with our supply of clean energy resources (see Figure 1). Changing how and when we use the grid enables and empowers everyday consumers—and the innovators who serve them—to play a direct role in making the whole system run cleaner and more efficiently, and in making it easier for renewables to come and stay online.

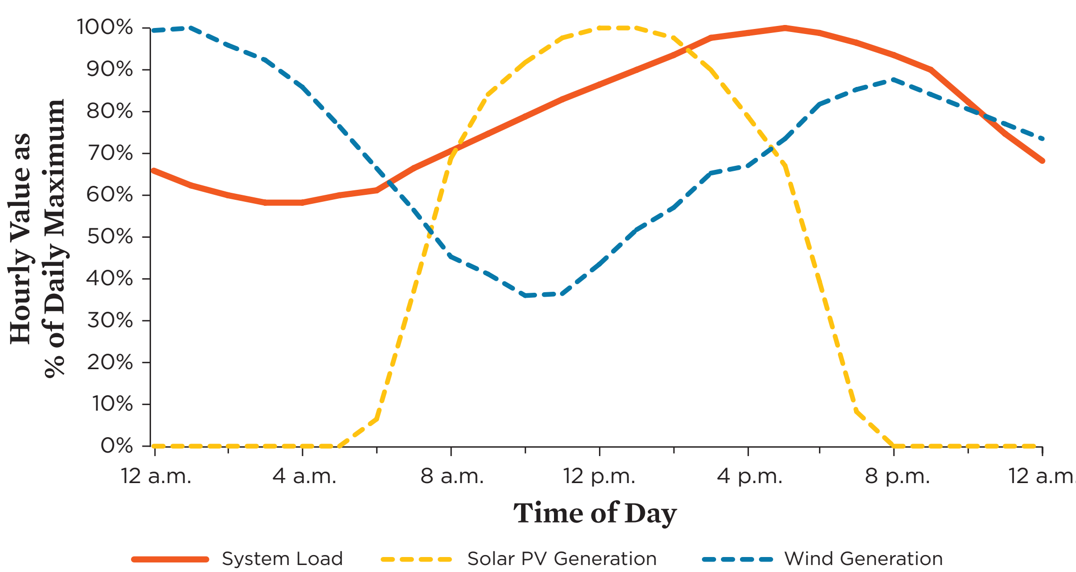
[Time-varying rates differ in their structure and level of complexity, but all use changes in price to incentivize more efficient electricity consumption.]

How Price Signals Can Shape Electricity Use

Time-varying rates differ in their structure and level of complexity, but all use changes in price to incentivize more efficient electricity consumption. Here, "efficient" electricity consumption does not simply mean using less, though an increase in overall energy efficiency—and thus a decrease in overall energy use—does benefit the system. Instead, the concept also considers cost and pollution reductions that result from shifting electricity consumption away from periods when we have to call upon inefficient and heavily polluting generation.

The most common forms of time-varying rates are described below (and illustrated in Figure 2). The diverse options give utilities flexibility in choosing the rate structure that best incentivizes the shifts required by their specific grid needs.

FIGURE 1. Peak Electricity Demand and Clean Energy Supply Are Mismatched



Today, peak electricity demand is not usually aligned with peak clean energy supply. By incentivizing customers to shift electricity use to periods of greatest clean energy resource availability—such as during midday hours when solar production is highest and in the late evening hours when the wind blows hardest—time-varying rate designs can result in a cleaner, more efficient electric power system.

NOTE: System load curves and resource generation curves can change across days, seasons, and regions. This figure displays one resource scenario based on an illustrative July 2016 day for the California ISO.

SOURCES: CAISO N.D.A, CAISO N.D.B.

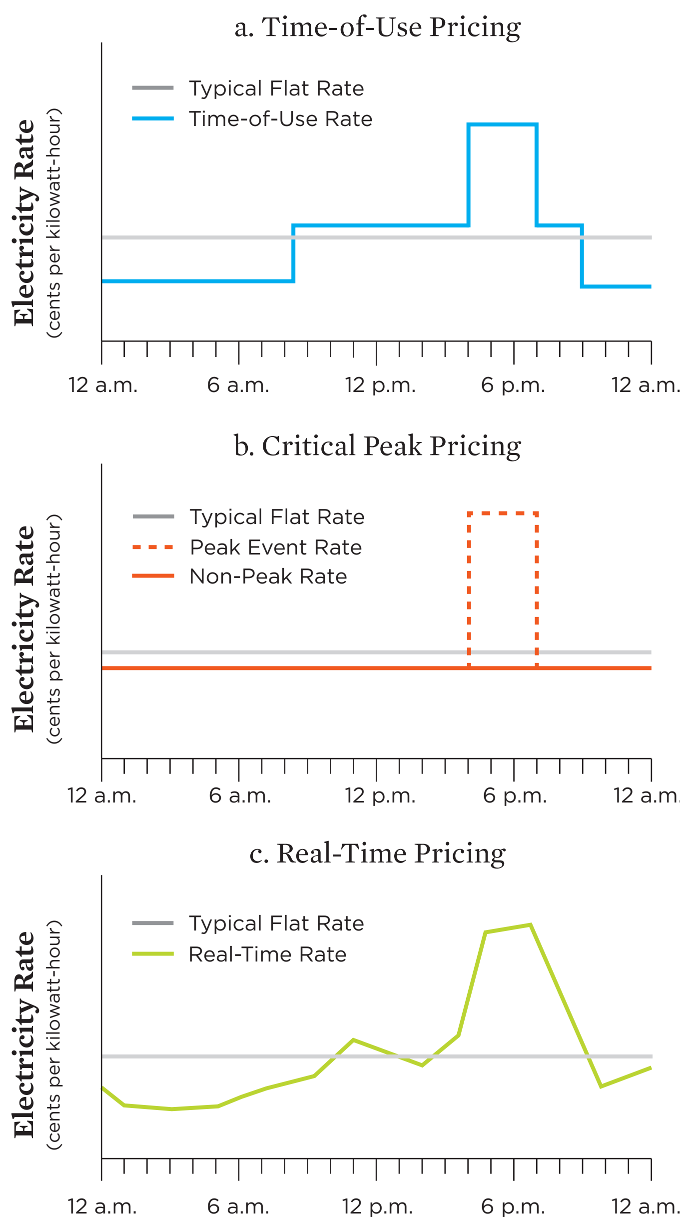
- **Time-of-Use Pricing:** These rates, with predictable on-peak and off-peak periods, encourage changes in the overall use of electricity over the course of the day. During hours when system demand is typically at its highest, prices are, too; when demand is traditionally lower, prices are reduced. Time-of-use rates are commonly established as two- or three-tiered systems with preset prices. In a three-tiered system, for example, utilities may charge the highest price during the early evening, a moderate price during the daytime and later evening hours, and the lowest rate overnight through the early morning. In most time-of-use programs, weekends and holidays are subject to a lower rate across all hours.

  In regions where electricity demand is tied to seasonal patterns, such as higher-than-average demand in the summer because of air conditioning or the winter because of electric heating, pricing tiers can be tied to the seasons to reduce peak strain on the electricity system.

- **Critical Peak Pricing:** This rate change is invoked just a few times a year, when demand is at its highest, to avoid calling into service the most expensive, least efficient generators. In a critical peak pricing program, utilities notify customers about 5 to 10 times per year, typically with a day's notice, that a set number of hours the next day will be considered a peak event, and that rates during those hours will jump accordingly. In return for deferring or decreasing electricity use during those select windows, customers receive a lower rate the rest of the year. A variation of critical peak pricing is "peak-time rebates," in which utilities provide rebates for reduced electricity use on peak event days, as opposed to charging higher rates over the same periods. In this variation, customers are not exposed to the risks of higher rates, but also do not receive lower rates over the rest of the year.

- **Real-Time Pricing:** This highly dynamic rate structure adjusts the prices customers see in parallel with the broader fluctuations in electricity system costs. Rates can vary in increments as small as five minutes, and as large as one or more hours. Typically, real-time pricing requires "smart" meters, which communicate consumption data to utilities at a set interval, as well as some form of in-home device to convey up-to-date prices to customers and, in some cases, automatically control select household appliances (see next section for details). This type of rate provides consumers with the greatest opportunity to shift their usage to best match the availability of clean and low-cost power.

FIGURE 2. Time-Varying Electricity Rate Designs



a. Time-of-use pricing employs preset rates that repeat each day to encourage shifts in electricity use away from peak hours. b. Critical peak pricing specifically targets the 5 to 10 days when electricity use is highest by charging very high rates during peak hours on those few event days, and lower flat rates for the remainder of the year. c. Real-time pricing approximates the actual cost of consumption over the course of the day.

NOTE: The above rates are illustrative only; actual scale and timing of rates will depend on the utility region's supply mix and demand patterns.

A key advantage of time-varying prices is that the actual structure of the rates can evolve over time in response to changing electricity infrastructure and resource mixes. As more solar resources come online, for example, it could make sense for customers to shift even more of their electricity use to the middle of the day when solar power generation is most abundant. The more we are able to take advantage of clean energy resources when they are available, the less that must be invested in costly fossil fuel–based peaking generators and related fossil-fuel infrastructure.

How Households Can Shift Demand

For time-varying prices to work, consumers must be able to change their electricity use in response to prices moving higher and lower. Some changes are as simple as choosing to run a dishwasher at an off-peak time, or selecting a delayed-start option on an appliance (if available). Other methods are more technologically involved; a fully grid-connected home could automatically—and imperceptibly—adjust consumption in response to grid signals.

Demand flexibility controls fall into three main categories:

- **Discretionary:** Many home appliances can be operated whenever the consumer chooses (e.g., dishwasher, clothes dryer). This type of demand control can be harnessed under any type of time-varying pricing strategy, from delaying use of a dishwasher for a couple of hours during a peak period event (critical peak pricing), to recognizing that wash cycles will be consistently cheaper if run during off-peak hours (time-of-use pricing). No additional technologies are required for this form of control.
- **Interruptible:** Certain energy uses (e.g., refrigerator and air-conditioner compressor cycling, water heater) can be temporarily paused or turned down to respond to fluctuating supply costs. These loads are typically paused or adjusted for just minutes, so their interruption has no adverse impact on appliance performance or consumer comfort. Interruptible loads can be managed to occur independently from one another, or aggregated to occur at the same time, depending on the load-reduction goal, household usage patterns, and the amount of coordination possible. Device-to-grid and device-to-device communications enable and optimize this form of control, respectively.
- **Energy storage:** Tank water heaters and electric vehicle batteries are just two examples of energy storage systems in which the timing of actual energy use (i.e., hot water, driving) is different from when electricity is taken from the grid. These types of systems can best be thought of as a form of intraday battery. They are well-suited for shifting loads that otherwise would be occurring during peak hours. New energy storage technologies are rapidly evolving, from simple timers to advanced device-to-grid communications that can not only optimize and automate appliance performance, but also provide ancillary services such as helping to maintain reliability and stability in the event of a downed power line or power plant outage.

Of course, not all electricity consumers are alike. Households vary widely in terms of the appliances that are installed, how efficient they are, and how and when homeowners use them. Further, there are significant geographic differences in energy required for heating, cooling, and water heating, which are

Residential customers can respond to time-varying rates in a range of ways, from low-tech (e.g., delaying the start time of a dishwasher) to high-tech (e.g., charging an electric vehicle through an integrated solar photovoltaic system).

the largest loads for most residential customers. These differences include seasonal average temperatures as well as primary fuel source (for example, natural gas, oil, propane, kerosene, and wood are commonly used in place of electricity for space and/or water heating in some parts of the country).

Looking forward, as more and more gasoline-powered vehicles switch over to electric, the transportation sector will become an increasingly significant share of electricity load. Therefore, it is critical that electric vehicles and their associated charging infrastructure are designed to accommodate "smart" charging, whereby vehicle charging takes place at optimal times based on grid supply and demand.

Designing a Beneficial Time-Varying Pricing Program

Some utilities have tried implementing time-varying rates for residential customers in the past, but for a long time, the economics were unsupportive. The technology required to tie volume of consumption with time of consumption was either beyond what was commercially available, or too expensive to justify for small, residential loads. As an interim step, some utilities have deployed inclining block rates, or rates that increase for each incremental block of electricity consumed above some baseline. This approach recognizes the increased costs of serving higher loads, but does not differentiate costs across times of use. However, the increasingly wide-scale deployment of smart meters and the growing availability of home energy management systems, in addition to increasing energy efficiency and renewable energy requirements in many states, are beginning to result in time-varying pricing programs making technical and economic sense.

While updating our electricity rates to recognize and reward demand flexibility will result in population-wide economic and environmental benefits, it is critical that these same rates preserve individuals' access to affordable, reliable power. Here, we outline the key tenets of designing a beneficial and equitable time-varying pricing program.

SUCCESSFUL DEPLOYMENT REQUIRES CUSTOMER OUTREACH AND EDUCATION.

Across the board, successful program implementation and customer buy-in relies on clearly and transparently communicating all aspects of the program to customers. This includes communicating the intent to change from flat to time-varying rates and the implications of that change, and outlining the various ways in which customers can modify their everyday behaviors to maximize savings under the new program. Even when customers are by default put on a rate (as opposed to

Customer outreach and education are key to a successful time-varying rate program. One way in which utilities can maximize customer buy-in is by providing "shadow" bills that show customers' current electricity usage and costs alongside a hypothetical bill showing what the customer would pay under the future rate structure.

> ***[Clearly and transparently communicating all aspects of a time-varying rate program can maximize customer buy-in and program implementation.]***

volunteering to join after learning about it), significant savings and behavior changes are observed if the rate is clearly communicated (see the box on p. 6). Utilities must be proactive in their education and outreach approach and, wherever possible, increase the likelihood of participation by implementing the simplest design that achieves the intended goals. As programs get under way, utilities must ensure that customers have access to the data related to their electricity usage.

It is also critical to clearly convey how the new pricing system will affect customers in practice. Utilities can employ the tactic of "shadow billing," whereby customers receive their current bill alongside a hypothetical bill showing what the customer would have paid that month if the future rate system were already in place. This allows customers the opportunity to not only become familiar with the new rate design, but also identify any major practices or behaviors that could result in higher costs under the new system, and take action to adjust those behaviors before the rates come into

> ***Utilities should provide support and leverage opportunities available through local, state, and federal energy efficiency programs to bring load-shifting technologies within reach.***

play. Especially in regions with strong seasonal variations in demand, supplying at least a full year of shadow bills provides the greatest opportunity for customers to avoid being surprised by the new structure.

ENERGY BURDENS SHOULD BE LESSENED, NOT WORSENED.

For low-income households, electricity expenditures often comprise a significant proportion of fixed budgets. There is little, if any, room for these costs to go higher. Customer groups with limited ability to alter patterns of electricity use—such as the elderly and chronically ill—could also be disproportionately affected by a change in rate structure. Utilities must be cognizant of such concerns, and have a robust plan in place for ensuring that these ratepayer groups are not made worse off under an updated rate design. This can be done by implementing a safeguard that limits any customers of concern to paying no more than the old rate would have totaled, at least for a period of one to a few years. The benefit of this approach is that all customers are still provided with the economic incentive to shift and reduce loads while ensuring that vulnerable customers are protected from economic harm or physical discomfort.

Simultanously, utilities must strive to provide access to—and information about—technologies that can help increase a customer's ability to shift loads. Some of these technologies are lower-cost (e.g., a programmable thermostat), in which case the utility could simply inform customers about how to purchase and install them; other technologies, however, can come with higher upfront costs (e.g., a grid-connected washing machine) that put them out of reach for lower-income households. Utilities should provide support and leverage opportunities available through local, state, and federal energy efficiency programs to bring these technologies within reach.

PLAN FOR RATES TO CHANGE OVER TIME.

Time-varying rates are specifically designed to reflect the costs and benefits associated with using the electric grid at one time as compared with another. As a result, when on-the-ground realities shift—such as growth in solar power or wide-scale deployment of electricity storage—the times

Time-Varying Pricing: A California Success Story

While the vast majority of residential electricity customers are charged flat rates, a number of utilities have launched time-varying pricing pilot programs in recent years to test the potential for future widespread deployment. One of these is the Sacramento Municipal Utility District (SMUD), which serves approximately 545,000 residential customers.

In 2012 and 2013, SMUD ran a pilot program in which a portion of its customers could opt into (i.e., volunteer to participate in) a time-of-use program, and another portion were assigned the time-of-use rate by default and could opt out; both groups considered here had access to in-home displays showing electricity usage information. Comparing the two groups' experiences, SMUD found that a majority of all customers reported taking discrete actions in response to the programs, such as shifting laundry and dishwashing hours, turning off lights and other appliances, or changing thermostat settings. Still, the opt-in group averaged a nearly threefold reduction in household demand during peak periods compared with the default group (16.7 percent versus 5.8 percent).

At the same time, the enrollment rate was much higher for the opt-out group than the opt-in group (98 percent and 19.5 percent, respectively), so the aggregate savings were far higher for the default group. In addition, outreach and informational materials worked out to about $4 per opt-out customer, compared with more than $60 per opt-in customer. Scaling these results for residential customers over its entire service territory, SMUD estimated that default enrollment would be cost effective, resulting in $34 million in net benefits, while voluntary enrollment would result in $5.5 million in net costs (both on a 10-year net present value basis). SMUD is now preparing to default all residential customers onto a time-of-use rate.

As the results of this and other pilot programs start to roll in, the future looks bright for well-designed—and well-received—time-varying pricing programs.

SOURCES: CAPPERS ET AL. 2016; POTTER, GEORGE, AND JIMENEZ 2014.

of day (and seasons of the year) when costs are highest can change, too. Utilities must understand and plan for the necessarily evolving nature of these rate designs, with foresight driving complementary policies and actions, and regulators should allow room for this periodic adjustment as well. Any changes to program terms or rates must be clearly communicated to consumers; if the changes are major, utilities should scale them up gradually so that customers have sufficient time to learn and adapt to the new rates.

> ***[Utilities must understand and plan for the necessarily evolving nature of these rate designs, and utility regulators should allow room for this periodic adjustment as well.]***

Time-Varying Prices Can Fast-Track a Clean Energy Future

A cleaner and more efficient power grid is necessary to forestall the worst of future climate impacts. Today, we are at the start of a clean energy revolution, one in which renewable resources such as wind and solar are poised to dominate the vast majority of our electricity generation. But even with all of the momentum behind the deployment of clean resources and technologies, there are still important ways in which we can hasten their arrival and integration. Implementing

Time-varying rates can play a major role in driving renewable energy development. By providing a price signal to indicate when electricity is cleaner and less expensive, these rate structures incentivize customers to shift their consumption toward times of the day when clean energy resources are more plentiful. This, in turn, provides an additional incentive to utilities to invest in zero-emission energy resources such as wind and solar to meet this demand, rather than relying on expensive, polluting fossil fuel–fired power plants.

time-varying electricity prices on a wide scale, whereby customers can identify times of cleaner, cheaper, more efficient electricity on the grid—and adjust their electricity consumption accordingly—is one critical next step.

To harness the tremendous potential of demand flexibility through time-varying electricity prices, we must empower consumers to be able to fully interact with, and participate in, the various programs. Time-varying rates will send economic signals to consumer appliance manufacturers and clean-tech entrepreneurs encouraging innovation to support this participation. Further, well-designed programs can help facilitate the development of, and increase customer access to, such technologies as grid-interactive water heating, air-conditioners with off-peak storage in the form of ice, energy storage, and targeted efficiency opportunities for savings during high-cost hours. Throughout, we must ensure that demand-flexibility technologies are made available to all customer populations.

Time-varying electricity prices have the potential to provide significant environmental and economic benefits for all electricity customers. New electricity rate structures should recognize and reward these opportunities accordingly.

__Julie McNamara__ is an energy analyst in the UCS Climate and Energy Program. __Mike Jacobs__ and __Laura Wisland__ are senior energy analysts in the program.

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