Time-Varying and Dynamic Rate Design

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Acronyms

ACEEE	American Council for an Energy-Efficient Economy
AMI	Advanced Metering Infrastructure
Auto-DR	Automated Demand Response
BGE	Baltimore Gas and Electric
C&I	Commercial & Industrial
CAC	Central-Air Conditioning
CL&P	Connecticut Light and Power
CPP	Critical Peak Pricing
CPP-V	Critical Peak Pricing-Variable
CPR	Critical Peak Rebate
DSM	Demand Side Management
EdF	Electricite de France
EVN	Electricity Vietnam
GHG	Greenhouse Gas
HAN	Home Area Network
IHD	In-home Display
ISO	Independent System Operator
kVA	Kilo-volt Amps
M&V	Measurement and Verification
MW	Megawatt
PCT	Programmable Communicating Thermostats
PG&E	Pacific Gas & Electric
PTR	Peak Time Rebates
RCT	Randomized Control Trial
RTP	Real Time Pricing
T&D	Transmission and Distribution
TOU	Time-of-Use
TRC	Total Resource Cost Test
VPP	Variable Peak Pricing

Foreword

Together, this paper and its companion piece, *Rate Design Using Traditional Meters,* examine the wide spectrum of retail pricing practices for regulated energy services and identify those that have particular promise in contributing to the achievement of critical public policy objectives, which we might broadly categorize as equity, efficiency, and the sustainable use of our finite natural resources. The papers should prove an excellent resource for policymakers, power companies, advocates, and others as they navigate the arcana of utility pricing and engage on a topic that has, by virtue of advances in information technology and changes in the underlying economics of power production and delivery, become at once more complex, more controversial, and, too often, more distracting.

The complexity and controversy are not avoided in these papers. Though for the most part they express views that are consistent with those of the Regulatory Assistance Project, it is not true in all cases. This is a virtue. We embrace the dialectic: over the coming months and years we will continue to work on these issues, follow progress globally, and re-examine our views in the light of new findings. These papers are only our most recent look at the state of the art. There will be others.

Still, a few comments today are warranted. Regulators are constantly told to "get prices right," a refrain whose meaning is more easily understood in the speaker's mind than it is conveyed to those who must put it into practice. In our experience, the prescription must be taken with two doses of realty's practical learning: one, that getting prices "right" is by no means straightforward and, two, that, even if one manages to set prices that in some fashion might be called "right," some of the key objectives of pricing will nevertheless remain unmet. Foremost among them is overcoming society's very serious underinvestment in cost-effective energy efficiency and other clean energy resources, and it is primarily for this reason that we say that pricing reform must be dealt with in a much broader policy context.

But, first, what is "right"? The question has surely been debated since governments began pricing these services "affected with the public interest," but the form of the debate only began to take its modern shape in 1949 with the publication of Marcel Boiteux's "La Tarification des demandes en pointe," which gave renewed currency to certain prerequisites for economic efficiency: one, that those who cause a cost to be incurred should pay that cost and, two, that, by paying, the cost-causers will necessarily comprehend the real value of the resources that they are committing to their consumption.[1] Here was a practical application of neoclassical economic theory to the pricing of networked utility services, and it was very influential.

The seminal work in English on the topic followed in 1961: James Bonbright's *Principles of Public Utility Rates.*[2] In it, Bonbright identifies ten criteria to be considered when setting utility prices and acknowledges, importantly, that they cannot all be entirely satisfied simultaneously. There will always be trade-offs. Nine years later, Alfred Kahn published *The Economics of Regulation,* which, among other things, made the case for subjecting to competition certain regulated services, when those services no longer exhibit the characteristics of natural monopoly.[3] Thus, in two decades, the intellectual foundations for a range of reforms in utility regulation were set and, in the thirty years since, we've seen extraordinary changes in the provision and pricing of air travel, telecommunications, electricity, and natural gas—that is, in essential infrastructural industries—around the globe.

But, for all that, the question of how to get prices right remains. Bonbright can't be evaded. What constitutes economically efficient pricing? Should efficiency be the

1 Boiteux, 1949

2 Bonbright, 1961

3 Kahn, 1988 (Original work published 1970)

primary objective and, if so, how can it be ensured without a proper accounting of environmental damage costs and other unmonetized externalities, both positive and negative, that attend the production and consumption of electricity and gas? What are the benefits of participation in a network and do they justify approaches to pricing that will, in the eyes of some, offend Boiteaux's injunctions? What is equitable? How does the underlying market structure—monopolistic, regulated, or competitive—affect pricing? Are prices in competitive markets "better" than their administrative analogues? How does pricing influence consumer behavior, and how does that behavior influence utility incentives to invest? How will utility revenues be affected by different pricing structures or, more to the point, how will utility profitability be affected? How complex is the pricing structure? Can it be easily understood by consumers and easily administered by the utility? In short, how are the competing objectives balanced? What kinds of pricing will achieve preferred outcomes?

These are complicated questions all. Their answers deserve careful analysis and even more careful judgment. Dogmatism is unhelpful: the tools of economics, powerful and important, are nonetheless limited. It isn't enough to say "Let the market decide." On the contrary, in certain instances, it's irresponsible. Design matters. Markets may deliver what they're intended to deliver, though not always in ways expected, but rarely do they deliver that which is desired but unvalued. And it's very difficult to fix them after the fact. For proof of this, one need look no further than the United Kingdom, which is facing the unpleasant prospect that its electric markets are unlikely to produce the amounts and kinds of resources that it needs to meet its own climate protection goals. Or New England, whose forward capacity market was the first to permit end-use energy efficiency and other demand response resources to participate in the provision of reliability services, but which worries now that the market fails to properly compensate the providers of those services. Such shortcomings counsel us to move cautiously before trying to drive behavior by the passing-through to retail customers of market prices, if we cannot be confident that the consequences they bear will best serve the public good.[4]

As a general matter, encouraging customers to manage their consumption in response to price signals, so that the efficiency and value of their usage increases, is a good thing. Retail prices should relate to the underlying costs of production—all costs, including those we can't easily calculate. This is the economist's argument—at once academic and practical, for the most part uncontentious, and always invoked. Its implications, however, can overwhelm. If we find that our approach to energy production and use is impossibly sustainable, then it is no longer possible for policymakers to accept the exalted principle *and then promptly ignore it.*

But let's imagine that prices do cover all costs. There are still the practical aspects of pricing to be dealt with. How are those costs best represented in prices? George Bernard Shaw's famous snort —"If all the economists were laid end to end, they'd never reach a conclusion"—is not more aptly demonstrated than by the mavens of regulation who debate this point ad nauseum, and often at a pitch that belies the significance of the effects that their favored alternatives will likely produce. What is the thing sold? How should its prices be denominated? What should be the price's level and periodicity? Should it vary temporally and, if so, at what intervals? Should it pass through, from moment to moment, actual wholesale commodity prices or are there less volatile means of reflecting time- (and, in certain cases, location-) dependent costs? How should the costs of poles and wires be recovered? Should costs that appear fixed in the short term be collected in unvarying and unavoidable fees, unrelated to usage? Should price levels be determined with an eye to elasticities of demand?

4 Another example will demonstrate that this is not an abstract concern. Consider that under most market structures firms are rewarded for increasing the utilization of their existing capacity. In the power sector, this means that profitability will increase as system load factors (the ratio of total consumption to maximum potential consumption, given actual peak demand) increase. As a practical matter, this is achieved through the shifting of on-peak demand to off-peak hours, when marginal costs are lower. Total system costs will be lower as well; everyone is better off. But what if on-peak demand is served by low- or non-emitting resources and off-peak demand is served by highly polluting ones? This is precisely the conundrum faced at times in places where on-peak usage may be met at the margin by natural gas and hydro-electric production, while off-peak usage variations are often served by ramping the output of coal-burning plants up and down.

There are other considerations. Some of the more innovative and beguiling price structures being proposed require significant investment in new technology and data telemetry. Establishing that there are positive net benefits from these investments is by no means straightforward, especially when the full effects on behavior of the pricing structures they enable are imperfectly appreciated. And what about the customers who, for whatever reason, cannot react to the signals they are given and thus are harmed? That harm might be appropriate as a general matter (if we are true to the "the cost-causer pays" theme) and the overall public good may outweigh the losses of the relative few, but there are some customers for whom a change in the status quo can have altogether deleterious effects, whose private pain will be, along other dimensions of welfare, disproportionate to the good achieved. What sickness then is this medicine healing?

We recognize that more dynamic, time-varying pricing enabled by smart grid investment holds much promise. But, as we see it today, its value lies not so much in the responsiveness of customers to such pricing (although there is certainly value there) as in the new and expansive opportunities that it offers system operators to design and run the system that we must have, if we are to succeed in the great task remaining before us. That new system will be one in which the variability of supply, variable because the resources that drive it—sun, wind, water—do not submit easily to human timetables, will be matched by variable load, variable not so much because a million individual demanders respond to changes in price but because the exercise of their discretion will have been placed (to be sure, voluntarily) into the hands of system operators and other market actors. A decarbonized power sector will not come about merely because customers respond to price fluctuations. There are too many other influences on behavior that confound "rational" economic thinking on the parts of users. Moreover, as the dynamic pricing pilots around the United States and elsewhere are consistently demonstrating, retail responsiveness to price rarely manifests itself as overall reductions in energy use, but almost entirely in the shifting of use in time—that is, it mostly affects demand for capacity, not demand for energy. Yet, far and away, the problem—the environmental problem—is energy.

Much can be done with current technologies. The United States, for example, has had decades of experience with inclining block, seasonally-differentiated, and simple time-of-use pricing structures. They've sent meaningful, albeit rough, signals about the varying costs of production across time, and have led to significant long-term changes in consumption habits. In 2005, China adopted a policy of "differential pricing," whereby industrial users pay prices that are linked to the efficiency of their manufacturing: the less efficient the process, the higher the unit price for electricity. Five years later, China mandated that residential inclining block pricing be implemented throughout the country, and has instructed provincial regulators to design the blocks so as to best address the particular consumption characteristics of their populations. One size does not fit all.

There is much yet to learn. A number of pilots have been conducted and more will follow. Pricing will evolve over the coming years. The movement toward new forms must be deliberate and considered, calculated to yield the greatest long-term benefit for all. This will be especially challenging in a system that does not allow all the costs of production to be reflected in price and in which the consequences of this failure are not immediately felt. But even this ideal, were it achievable, would not be enough to effect the hoped-for ends. Economics is too uncomplicated a construct to provide sure solutions for so complicated a problem. Anyway, there are at our disposal less expensive means to drive investment and encourage new-shaped behavior. For these reasons and others besides, pricing must remain within the province of thoughtful public policy. Our intent with these papers is to expose to the reader the many and varied approaches to energy pricing that practice and technology afford us, and to sound too a gentle note of caution. All that glitters, as the old saw goes, isn't gold.

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Executive Summary

This report, written largely for regulators and policymakers around the globe, discusses important issues in the design and deployment of time-varying rates. The term, time-varying rates, is used in this report as encompassing traditional time-of-use rates (such as time-of-day rates and seasonal rates) as well as newer dynamic pricing rates (such as critical peak pricing and real time pricing). The discussion is primarily focused on residential customers and small commercial customers who are collectively referred to as the mass market. The report also summarizes international experience with time-varying rate offerings.

The rate design principles presented in this report are based on the authors' first-hand experience in designing and evaluating innovative rate designs over the past three decades, conversations with other experts in the field, and the rate design and pricing literature. While the report is focused on design principles, there is much leeway in the application of the principles. Much of the success of the deployment of time-varying pricing will depend on the attitudes and preferences of the customers in the target market and the effectiveness of activities supporting the deployment by utilities, regulators, and other stakeholders. While there are many potential benefits to time-varying rate deployment, there are also risks and costs that must be addressed through careful thinking and planning. Even though experimentation and full-scale deployment in several parts of the globe have yielded valuable insights that can help mitigate risks, there remains room for additional research to further improve our understanding and facilitate the development of effective solutions to these concerns.

The key findings of the report are summarized below.

Metering technology is rapidly changing, creating the opportunity to provide time-varying rates for the mass market. Smart meters are being deployed increasingly around the globe. Roughly 64 million smart meters are currently in place and 825 million are expected to be installed over the coming decade.[5] Among many potential benefits of this new technology is the ability to provide innovative pricing schemes to retail electricity customers. While traditional electromechanical meters are read manually and on an infrequent basis, smart meters record and digitally communicate electricity consumption data on frequent intervals (e.g., 15 minutes or hourly), thereby allowing for the provision of time-varying rates.

Time-varying rate options present varying risk-reward tradeoffs to consumers. Time-varying rates include time-of-use (TOU) rates, critical peak pricing (CPP), peak time rebates (PTR), and real time pricing (RTP), as well as variations and combinations of these rate designs. Each design provides a different degree of price volatility and uncertainty for customers, and therefore presents a different opportunity to reduce their electricity bill by shifting load from higher-priced hours to lower-priced hours.

There are many potential benefits of time-varying rates. Time-varying rates have played an important role in justifying investment in smart metering. Among the *potential* benefits are avoided or deferred resource costs (including generation capacity and, to a lesser extent, transmission and distribution capacity), reduced wholesale market prices, improved fairness in retail pricing (i.e., providing a better match between the costs that customers impose on the system and the amount they are billed), customer bill reductions, facilitating the deployment of both distributed resources (such as solar electric systems) and end-use technologies (such as plug-in electric vehicles), and environmental benefits (through possible emissions reductions).

Time-varying rates also impose costs on customers. From the customer perspective, there are two main costs associated with time-varying rates. The first is the

5 Based on data provided by eMeter.

incremental monthly metering cost that customers would be required to pay. This is often the cost of smart metering net of operational benefits (e.g., avoided meter reading costs). The second cost is the loss of economic welfare associated with reducing usage during a high-cost period (curtailment) or shifting usage to a lower cost period ("hassle factor").[6]

A number of key parameters need to be defined when designing a time-varying rate. How many different pricing periods will be offered? What will be the price level in each of those periods? When will the periods occur? How and when will customers be notified of an upcoming dynamic pricing event? Will the time-varying rate be offered in combination with any other rate structure, such as inclining block (also called tiered or inverted block) rates that charge customers more per unit (kilowatt-hour) for higher levels of usage? While practices in time-varying rate design are still evolving – particularly for the mass market – some general criteria for effective rate design can be established based on theory, intuition and field experience.

Well-designed pilots are critical to proving the benefits of time-varying rates. Before deploying time-varying rates at scale, conducting pilots with a limited number of customers will help to understand what works and what does not. Prudent pilot design involves several key steps, including choosing the right type of pilot, defining the specific rates to be tested, establishing two comparable groups of customers (one enrolled in the new rates and the other serving as a "baseline" for comparison purposes), and identifying the most effective ways to recruit participants into the pilot.

We have learned a lot about time-varying rates through recent pilots. For example, weather, end-use saturation, price level, sociodemographic characteristics, and other factors all affect the degree to which customers shift load in response to time-varying rates. Load shifting increases as the strength of the price signal increases, but at a decreasing rate. Low-income customers have been found to be price responsive, although not always as responsive as the average residential customer. Impacts of time-varying rates have persisted for several years and over consecutive pricing events. And enabling technologies, such as smart thermostats, have been shown to incrementally boost price response.

New research will further inform our understanding. There are still important questions about time-varying rates that remain partially or entirely unanswered. What are customer preferences for the various rate options? Do rebates for curtailment produce the same level of price response as higher prices during peak hours (and lower prices during other hours)? Do time-varying rates lead to energy conservation? Do time-varying prices lead to fuel switching and the use of distributed generation? What is the impact of enhanced energy information on peak consumption? New research will help to answer questions such as these.

There are options for facilitating the transition to time-varying rates. Changing the way electricity has been priced for decades will not be easy. However, several tools exist to assist with the transition to time-varying rates. For example, an intensive, research-based marketing and education effort will help customers to understand the benefits and opportunities of time-varying rates. Temporary bill protection would help customers to learn about the rate first-hand, without being exposed to the risk of higher bills. Improved information about their electricity consumption patterns could provide customers with actionable ways to shift load and lower their bills. And rate designs such as two-part pricing would provide customers with the flexibility to manage the level of price volatility to which they are exposed.

6 Note that this loss of welfare should be treated similarly across all demand-side programs that may produce such an effect, and not just limited to time-varying rates.

1. Introduction

For the vast majority of electricity consumers, metering technology has remained effectively unchanged over the past 100 years. With the exception of the largest commercial and industrial facilities, most consumers are equipped with simple electromechanical meters which must be read manually. Due to the high cost of this manual approach to meter reading, meters are typically read no more frequently than once per month. This has acted as a constraint on the types of rates that an electricity provider can offer. “Flat” or “fixed” rates[7] are essentially the only option available, along with some possible alternate variations (such as the ability to increase the price as consumption increases over the course of the billing period). The lack of granularity in electricity consumption data has prevented all but a limited set of time-varying rates from being provided to all but the largest customers. However, the “digital revolution” of the past few decades has produced a new, increasingly cost-effective form of metering that is beginning to change this picture entirely.

Today, smart meters are being deployed increasingly around the globe. Roughly 64 million smart meters are currently in place and 825 million are expected to be installed over the coming decade.[8] Among many potential benefits offered by this new technology is the ability to provide innovative pricing schemes to retail electricity customers that help to foster more responsive customer demand. While traditional electromechanical meters are read manually and on an infrequent basis, smart meters record and digitally communicate electricity consumption data on frequent intervals (e.g., 15 minutes or hourly), thereby allowing for the provision of rates that vary by time of day. These new rates that are enabled by smart meters are referred to collectively in this report as “time-varying rates.”

The benefits of time-varying rates have played a pivotal role in justifying investment in smart metering technology. While some smart metering investments can be justified purely on the basis of operational savings (e.g., avoided meter reading costs), many utilities have required the additional benefits of time-varying rates - such as avoided resource costs - to show that the investment would produce a net benefit to consumers. Achieving these benefits, however, requires careful planning, intelligent rate design, and a thorough understanding of the important issues that are emerging as smart meters and time-varying rates are beginning to be deployed internationally.

The purpose of this report is to provide regulators and policymakers around the globe with a resource that highlights important issues in time-varying rate design and deployment. The report also summarizes recent implementation experience with international time-varying rate offerings.

Why offer time-varying rates?

Time-varying rates represent an opportunity to improve over traditional “flat” rates that do not vary by time of day, by providing societal and consumer benefits. Potential benefits of time-varying rates include:

- **Avoided or deferred resource costs:** With prices that are higher during peak hours and lower during off-peak hours, time-varying rates encourage customers to shift consumption away from peak hours and therefore reduce system peak demand. This avoids the need to invest in expensive new peaking plants that are built to maintain a reserve margin but otherwise operate during very few hours of the year. Peak demand reductions can also lead to deferred transmission and distribution (T&D) costs that are peak-driven.[9]

7 A “flat” rate design refers to one with a uniform price per kilowatt-hour for all consumption regardless of when the consumption occurs.

8 Based on data provided by eMeter.

9 Faruqui, Hledik, Newell, & Pfeifenberger, 2007

- **Reduced wholesale market prices:** A reduction in demand during high-priced hours could reduce wholesale market prices in those hours - a benefit to all market participants.[10]

- **Fairness in retail pricing:** One notion of fairness is that cost-causers should bear their proportionate burden of costs on the system. If the underlying cost of providing electricity varies over time, then time-varying rates provide a better match between costs and bills. Under a flat rate structure, customers who consume more electricity during high-cost hours (i.e., peak hours) effectively rely on customers who consume less during those hours to ensure that all costs are recovered in rates. During time periods when costs are high, traditional flat rate structures result in an effective customer cross-subsidy relative to a well-formed time-varying rate alternative (i.e., the additional costs imposed by one group of customers are borne by other customers.)

- **Customer bill reductions:** In the short run, time-varying rates offer participants an opportunity to reduce their electricity bills by shifting consumption to hours that are priced lower than their otherwise applicable flat rate. In the long run, time-varying rates should improve the system load factor and lead to a lower revenue requirement, compared to what it would be without the demand response from time-varying rates.

- **Facilitating deployment of distributed resources:** Time-varying rates improve the economic attractiveness of certain types of distributed resources such as rooftop solar and energy storage, which allow owners to avoid consuming electricity during higher priced peak hours. Time-varying rates may also be a way to encourage more efficient charging of electric vehicles.[11]

- **Environmental benefits:** If time-varying rates reduce consumption or shift it to hours when power plants with lower emissions rates are on the margin, they can result in a net environmental benefit. This will depend on the specific characteristics of the system in which the time-varying rates are being offered.[12] To the extent that time-varying rates play a role in facilitating the integration of renewable resources, there would be associated environmental benefits as well.

Time-varying rates are not a new concept. In fact, this approach to pricing is already utilized in many other industries. Airlines, hotels, and car rental companies are some of the most common examples of industries that dynamically vary prices in response to fluctuations in demand. Commuter trains and subways often vary the price by time of day (e.g., Washington, D.C.'s Metro, which has three tiers of pricing). Some bridge and road tolls vary by time of day, such as the Bay Bridge in San Francisco and congestion charging on major roads in parts of London. Parking meters typically apply a charge only during times of high demand (generally during business hours), and in some emerging pilots the price of a parking meter is a function of the number of meters in the network that are being used. Sports teams are beginning to vary the price of tickets depending on the quality of the opponent, time of game, and other factors. In other words, the concept of time-varying rates is something that many electric utility customers already experience on a near-daily basis.

The scope of this report

While there are many potential benefits of time-varying rates, there are also significant challenges to be addressed in their implementation. For example, what are the most effective rate designs? How should the rates be developed? How should they be deployed to encourage customer adoption? These and many other issues must be addressed through careful planning before deployment. To provide guidance based on industry observation and experience, this report addresses several key topics and is organized as follows:

Section 2 provides a description and assessment of the advantages and disadvantages of the various time-varying rate options.

10 The Brattle Group, 2007

11 Faruqui, Hledik, Levy, & Madian, 2011

12 See sidebar for further discussion of potential environmental benefits.

Section 3 includes a discussion of criteria for time-varying rate design, pricing pilot design, and methods for addressing barriers to time-varying rate deployment.

Section 4 provides an overview of international experience with time-varying rate implementation, including a survey of time-varying rate pilots and lessons learned from these studies.

Section 5 includes full-deployment case studies for the United States, France, China, and Vietnam.

Section 6 presents a blueprint for full-scale time-varying rate deployment.

Section 7 concludes with a synthesis of the key points in the preceding sections, as well as insights for future research needs.

This report does not focus on rate designs that could be offered in the absence of an upgrade from a traditional electromechanical meter. For example, the report does not include inclining block rates, which are commonly used as an alternative to a flat rate to promote conservation and do not require a smart meter. Seasonal rates, which vary by time of year but not by time of day, are another example of rates that do not require advanced metering. Principles for designing and offering these types of rates are the focus of another paper titled Rate Design Using Traditional Meters. We do, however, discuss issues related to integrating these rates with time-varying rates.

The report includes static time-of-use (TOU) rates as well as dynamic rates, which both require an upgrade from a traditional, one-period electromechanical meter. TOU rates are different than dynamic rates because they are not "dispatchable," instead adhering to a schedule established in the retail tariff. With true dynamic pricing, on the other hand, the timing, price levels, or both are only made available to the customer on a day-ahead or day-of basis. While this distinction is important, both forms of time-varying rates are included in this report.

The scope of the report includes time-varying rates for all customer classes. We have a particular focus on time-varying rate issues for the residential class, which has only recently begun to receive the metering technology necessary to offer time-varying rates. As a result, many of the emerging issues and new research on time-varying rates are centered on the customers in this segment.

The Environmental Impact Of Time-Varying Rates

With growing concern over the sustainability of worldwide electricity consumption, there is interest among some policymakers about the potential environmental benefits of time-varying rates. Generally, the conservation impact of time-varying rates on the environment is expected to be small. This is mostly because high prices that would induce significant changes in a customer's electricity consumption are encountered during relatively few hours per year. For example, a critical peak pricing (CPP) design exposes customers to a higher price during only 50 to 100 hours of the year, and customers receive a discounted rate during other hours. Further, recent studies have found that while time-varying rates induce significant reductions in electricity demand during peak periods, much of that reduction is offset by increases in consumption during periods when the price is discounted. The result is little or no conservation effect from time-varying rates alone.[13]

Still, there may be environmental benefits from time-varying rates. Even in the absence of a net reduction in consumption, load shifting could result in a net emissions reduction, depending on the characteristics of the applicable generating resource mix.[14] Further, time-varying rates may encourage greater adoption and facilitate the integration of variable renewable energy resources. Basic categories of environmental impacts from time-varying rates are discussed below.[15]

Change in greenhouse gas (GHG) emissions: Whether there is a net reduction in GHG emissions from time-varying rates depends on the emissions rate of the marginal unit during peak and off-peak hours. For example, if load were shifted from hours when an inefficient oil- or natural gas-fired peaker was on the margin to hours when a more efficient gas-fired combined cycle unit was on the margin, one could expect a net decrease in GHG emissions. However, in a different service territory, there might be a gas-fired peaker on the margin during peak hours and a coal plant on the margin during off-peak hours. In this situation, an increase in GHG emissions could arise. One study of different regions in the U.S. found that the impact could range from a decrease of 0.9 percent to an increase of 0.3 percent.[16]

Change in criteria and hazardous air pollutants: Peak period load reductions from time-varying rates could also reduce other types of generator emissions such as criteria and hazardous air pollutants. In the U.S., these reductions would be particularly valuable in designated non-attainment areas where predetermined emissions levels cannot be exceeded.

Minimization of impact to wildlife and sensitive ecosystems: To the extent that peak demand reductions result in avoided investment in new generation capacity or T&D capacity, the result would be a smaller geographical footprint of the grid. This would reduce the impact to wildlife, habitat, and sensitive ecosystems.

Facilitating adoption of renewable resources: Time-varying rates could facilitate the adoption of renewable sources of energy. For example, a strong TOU rate could improve the economics of a rooftop solar system to the extent that the peak period aligns with the time of highest output from the system. Additionally, to the extent that time-varying rates result in more flexible demand, particularly through the adoption of technologies that automate load changes in response to prices, this could be valuable for integrating variable renewable energy resources.[17] However, the integration benefit still remains to be proven on a large scale.

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13 This is the finding of recent time-varying rate pilots in California, Maryland, and Connecticut. However, a survey of much older TOU pilots did find that, on average, the rate design induced some conservation. See King, & De-lurey, 2005.

14 Some market operators publish information on the emission rate of marginal generating units, which would allow for this analysis to be conducted. For example, PJM (in the eastern United States) publishes this information on a monthly basis for peak and off-peak periods: http://www.pjm.com/documents/~/media/documents/reports/co2-emissions-report.ashx.

15 For details, see Environmental Defense Fund, 2009

16 Hledik, 2009. Also see Pratt, et al., 2010

17 Cappers, Mills, Goldman, Wiser, Eto, 2011