Electricity Retail Rate Design in a Decarbonizing Economy: An Analysis of Time-of-use and Critical Peak Pricing

Tim Schittekatte,[a] Dharik Mallapragada,[b] Paul L. Joskow,[c] and Richard Schmalensee[d]

Currently, U.S. residential and small commercial electricity consumers are typically billed based on nearly flat rates, i.e., a constant price per kWh of electricity consumed accounts for most of their bills. Ongoing developments in the power system, both on the supply and demand sides, increase the efficiency loss of not transmitting time-varying prices and "scarcity" conditions in wholesale markets to end users. In practice, the pass-through of widely varying hourly spot prices is not popular among consumers; consumers highly value price predictability and sudden increases in bills often becomes a political problem. In this work, we investigate the question of how to better reflect the time-varying conditions in the wholesale electricity markets in residential and small commercial retail rates while balancing consumer preference for price predictability and bill stability.

We focus on two popular "second-best" rate designs: time-of-use rates (TOU) and critical peak pricing (CPP). The existing literature has been skeptical about the value of TOU rates, typically finding that they capture only about one-fifth of the efficiency gains of dynamic retail pricing that passes along wholesale spot price. We introduce alternative criteria to assess the performance of TOU rates, complemented or not with CPP. The proposed criteria are tailored to a context with increasing penetration of both intermittent generation and easily shiftable loads within a day such as the charging of electric vehicles and the cycling of heat pumps, air conditioners, and electric water heaters. The criteria can be split into two groups: time series analysis and simulation models with different characterizations of load flexibility. We compute results using data from three US power systems for 2011-2020: CAISO, ERCOT and ISO-NE. The TOU rates for a particular year are calibrated based on the preceding three years of wholesale prices. CPP is proxied by the replacement of the TOU rates by the observed wholesale price for a limited number of the highest priced hours per year; we assume full consumer response to these high prices, which would likely require load control mechanisms rather than price signals alone.

The results from the time series analysis confirm other recent analyses that the out-of-sample *annual Pearson* correlations between TOU rates and spot prices are low. However, show that these correlations improve significantly when recognizing a limited number of high spot-price "scarcity" hours replacing the respective TOU rate in those hours either with spot prices or compatible load control mechanisms. An important finding is that out-of-sample *daily Spearman rank* correlations of TOU rates and spot prices are relatively high and that rank correlations are especially high during summer when load is highest for all three systems. This implies that, conditional upon power system characteristics and their specific design, TOU tariffs can provide a high proportion of socially efficient load-shifting incentives. The simulations confirm that well-designed TOU rates can reasonably replicate the load-shifting incentives of spot pricing. Scarcity price events often occur within "peak" TOU periods. Accordingly, TOU rates alone give flexible load incentives to

a Corresponding author. MIT Energy Initiative, Massachusetts Institute of Technology, Address: 50 Ames St, Cambridge, MA 02142, USA. E-mail: Schtim@mit.edu

b MIT Energy Initiative, Massachusetts Institute of Technology

c Department of Economics, Massachusetts Institute of Technology

d MIT Sloan School of Management and Department of Economics, Massachusetts Institute of Technology

reduce load during scarcity price events. In any case, there is significant value in mobilizing additional demand reduction during those moments by complementing TOU rates with a CPP program.

We conclude that well-designed TOU rates, especially when accompanied with a CPP program involving load control during infrequent scarcity price events, are more attractive from an efficiency perspective than the existing literature suggests. As a result, TOU rates accompanied by CPP offer a valuable intermediate step towards improved electricity retail rates that balance efficiency considerations and consumer/political pressures for price predictability and bill stability. An important question, which we plan to investigate, is whether the presented results still hold in systems with significantly higher penetration of intermittent wind and solar generation and storage.