THE COSTS AND BENEFITS OF REAL-TIME PRICING

An empirical investigation into consumer bills using hourly energy data and prices

The Citizens Utility Board (CUB)
Environmental Defense Fund (EDF)

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Introduction

The recent availability of extensive energy-use data allows a more accurate analysis of alternative electricity rate structures. This paper, what we hope will be the first in a series by the Citizens Utility Board (CUB) and Environmental Defense Fund (EDF), focuses on the impact of hourly prices on consumer bills.

Economists often argue for the system-wide benefits of dynamic electricity pricing, in which customers pay for power through time-variant rates. Samuel Newell and Ahmad Faruqui from the Brattle Group make the standard case for dynamic pricing in comments to the New York Independent System Operator. They write:

> Dynamic rates would encourage consumers to adjust energy usage to take advantage of lower priced energy in low demand hours and to limit consumption in higher demand high priced hours. As a result, consumers … benefit from a more efficient electric system. Demand for electricity is uneven. Consumption in the top one percent of the hours of the year accounts for more than 10 percent of system peak demand. Actions taken to reduce electric demand during this relatively small number of peak hours can significantly reduce total annual electricity costs. Dynamic pricing targets these peak loads, reducing the need for expensive additional reserve generation and transmission capacity.[1]

Indeed, according to Brattle, "even a 5-percent reduction in peak demand in the United States could lower consumer energy costs by at least $3 billion a year."[2] Peak-load reductions also offer environmental benefits, most obviously in the form of reduced emissions from fossil-fueled peaker plants.

Currently, the vast majority of utility consumers pay an average price for electricity that changes little (if at all) over the course of the year. There are two main reasons for the predominance of flat rates. First, policymakers typically maintain that average-price rate designs create value by smoothing-out market volatility, providing certainty and stability, and avoiding potential bill shocks, particularly for low-income customers. Second, while dynamic pricing advocates talk about the importance of 'price responsiveness' or 'taking action to lower peak demand,' what happens to a customer who doesn't respond to prices? True, if enough consumers act to lower peak demand, over time total systemic costs should decline and this would benefit everyone. However, if the benefits of dynamic pricing require action by the customer, the *costs* of this action may outweigh any potential benefits from moving to time-variant rates.

Average, flat-rate pricing, then, is akin to a form of insurance, where a premium is paid to hedge against market volatility and price spikes. Until recently, quantifying the cost of this premium for individual

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[1] Newell, S., & Faruqui, A. (2009). *Dynamic Pricing: Potential Wholesale Market Benefits in NewYork State*. http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCQQFjAA&url=http%3A%2F%2Fwww.nyiso.com%2Fpublic%2Fwebdocs%2Fmarkets_operations%2Fdocuments%2FLegal_and_Regulatory%2FNY_PSC_Filings%2F2009%2FCase_09M0074_NYISO_Supp_Cmmts_Report_12_17_09.pdf&ei=Ph7PU6HdH4ypyAS4m4KQDg&usg=AFQjCNFFa6uBF_yvuveOtcKjrRdXNEWYQ&sig2=yBQzbtkIEvxSneEiFzZrGw&bvm=bv.71667212,d.aWw

[2] Ahmad Faruqui, Ryan Hledik, Sam Newell, Johannes Pfeifenberger, "The Power of Five Percent," *The Electricity Journal*, Volume 20, Issue 8, October 2007.

consumers has been challenging due to the limited number of studies involving hourly customer usage data. As a result, it has been difficult to make analytical progress, and the debate over dynamic pricing often relies on theories rather than empirical evidence. This is unfortunate for many reasons, not the least of which is that lowering peak demand becomes even more important with transportation electrification on the horizon, as system costs may increase significantly unless electric vehicles charge at the right times. Price signals are likely the simplest and lowest-cost way to accomplish this end.[3]

Now, the availability of anonymous energy-usage data from hundreds of thousands of advanced meters allows for new research that can more thoroughly investigate the costs and benefits of average, flat-rate pricing versus dynamic-pricing models, such as real-time pricing. This white paper does so by focusing on Illinois, the only state in the nation where the two largest utilities — Ameren Illinois and Commonwealth Edison (ComEd), which serve about 90 percent of the state's customers — offer comprehensive, opt-in dynamic "real-time pricing" programs for residential customers. Under real-time pricing, electricity rates vary by the hour, according to wholesale electricity markets.

In 2017, Illinois also approved an innovative tariff[4] allowing access to sets of anonymous usage data, which protects customer privacy while allowing researchers access to scrubbed, 30-minute household energy usage data at the ZIP+4 level. The existence of both a real-time pricing program and a formal channel for sharing anonymous energy-usage data have made Illinois a promising frontier for new research. This white paper offers one example: By comparing how residential customers of ComEd, the electric utility for much of northern Illinois, would have fared in 2016 on real-time pricing vs. traditional flat rates, *without making any behavior changes*, the paper begins to quantify the costs of the insurance provided for by flat rates.

Our analysis shows that roughly 97 percent of ComEd customers would have saved money through real-time pricing in 2016 without changing behavior, with a net average savings of $86.63 annually. In percentage terms, ComEd customers would have saved an average of 13.2 percent through the real-time pricing program. Focusing on the top 5 percent of savers produces more dramatic results: These customers would have saved an average of $104 per year, or 31 percent on their overall bills. Flatter load shape, as one might expect, turns out to be the main differentiator between the top 5 percent (mean savings: 31 percent) and the bottom 5 percent (mean savings: 0 percent).[5] The data show no significant differences between low-income and other customers.

Several clarifications are useful. While the 2016 data set is large and includes a higher percentage of low-income customers than the overall service territory, it is not necessarily representative of the rural areas in the ComEd service territory. Running the analysis over multiple years – and with a larger number of utilities – is also necessary to further inform policy development.

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[3] Cohen, Martin R. The ABCs of EVs, A Guide for Policymakers and Consumer Advocates. Citizens Utility Board, 2017.

[4] Final Order at 9, 17. ICC Docket No. 13-0506 (Jan. 28, 2014) [A] "15/15 Rule" whereby utilities would provide 12 months of customer usage data of at least 15 customers organized by groups of customers within the same ZIP +4 area after stripping any identifiable information (name, address, account number, etc.). (Id.). A single customer's load must not comprise more than 15% of the customer group. If the number of customers in the dataset is below 15, or if a single customer's load is more than 15% of the total data, utilities must expand the geographic area, moving to a ZIP+2 level for example. CUB explains that if expanding the geographic area reaches the 15 customer threshold, but a customer still comprises 15% or more of the usage data, that customer is simply dropped from the dataset. (Id.). If the 15 customer requirement is not met after the first expansion of the zip code, the sample size is expanded to the ZIP level.

[5] Generally, the flatter the load shape, the higher the savings.

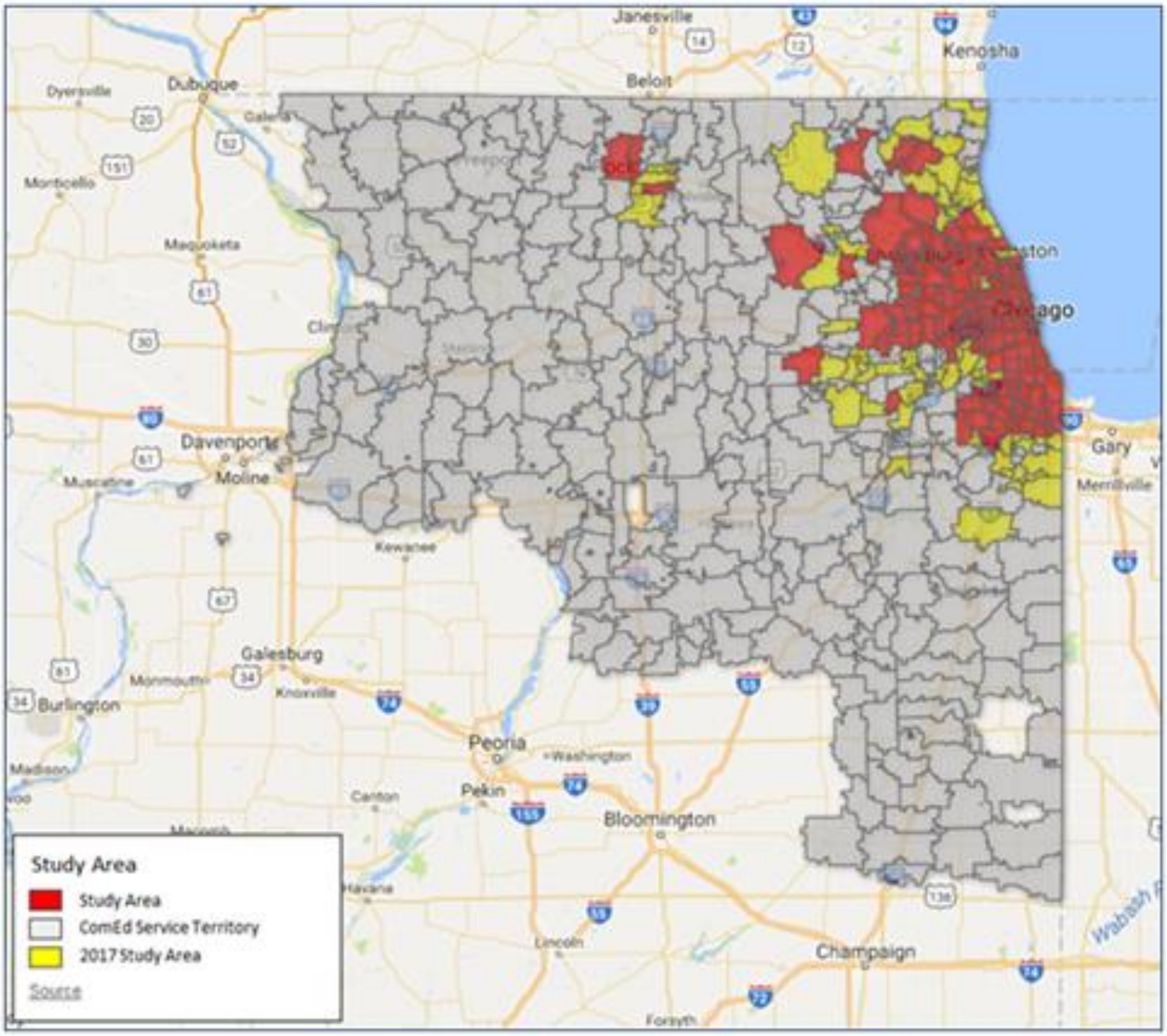

Figure 1: Study Area
ComEd's AMI deployment began in Chicago's Maywood area and has extended outward. This study includes customers who had smart meters as of Jan. 1, 2016. The next iteration will include customers with smart meters as of Jan. 2017.

Nevertheless, the fact that ComEd customers would have benefited nearly universally from real-time pricing during 2016 indicates that this program can be a consumer asset on a much larger scale and across a far larger territory than it has been deployed to date. To reinforce that point, consider the following:

- The cost of average, flat-rate supply service for individual consumers was significantly higher than the hourly market price in 2016. ComEd customers on the utility's default, flat-rate supply price as a whole paid, on average, over 13 percent more than they would have on real-time pricing.

- Given what we know from numerous pilots and programs that price signals induce customer response, the systemic costs of average, flat-rate pricing over time are higher still, even before the environmental benefits of reducing peak demand are considered.[6]

- On average, low-income customers showed little variation from the rest of the population, with the only statistically significant difference being an additional 1 percent savings on average.

The genesis for these findings was Illinois' seminal decision to share anonymous energy-use data with researchers, which unleashed new analytical capabilities that will continue to bear fruit in subsequent studies our organizations will conduct. We urge all states to adopt similar data access protocols that will promote the public interest.

Beyond that pivotal reform, the Conclusion section below outlines a series of policy recommendations that collectively form a blueprint for broadening access to, and participation in, the cost-savings opportunities inherent in dynamic pricing.

Methodology

Using actual energy-usage data, this study analyzes how customers who are currently under a traditional, average electricity pricing structure would have fared under ComEd's existing Hourly Pricing program, a residential real-time pricing initiative. Rather than rely on estimates or small samples, this analysis compares the bills of 344,717 ComEd customers—roughly 10 percent of the company's residential customers—in every month of 2016, which is the largest data set ever for a study of this kind. Each monthly data set contains half-hourly interval volumes for each anonymous customer.

The data include customers' 9-digit ZIP+4 codes, allowing for fine-grained geographical analysis. For this iteration of the study, ZIP codes were tagged according to income (low and moderate income areas) and location (suburban and within Chicago). Low and moderate income areas were determined using Census data; areas tagged as low income had 50 percent or more residents with annual incomes of $12,300[7] or less, and moderate income areas had 50 percent or more residents with annual incomes of $19,680[8] or less.

In addition, individual customers' subclass is identified in the data. ComEd assigns subclasses to residential customer based on single family versus multi-family status, and whether or not customers heat their homes with gas or electric space heating. This leads to four separate residential subclasses (listed in order of prevalence in the study group): single family non-electric space heat (SFNH), multi-family non-electric space heat (MFNH), multi-family electric space heat (MFH), and single family space heat (SFH).

[6] See. e.g., Faruqui, A. and J. Palmer (2011): *Dynamic Pricing and its Discontents* https://sites.hks.harvard.edu/hepg/Papers/Faruqui_Dynamic%20Pricing%20of%20Electricity%20and%20its%20Discontents.pdf
[7] 50% of Federal Poverty Level for family of four
[8] 80% of Federal Poverty Level for family of four

Both flat and hourly rate designs include multiple line-item rates, many of which vary on a monthly basis. The first step to estimating annual savings is to find the savings for each month. Annual savings are the sum of a customer's monthly savings.

Monthly savings are then estimated by calculating a customer's monthly charges, based on her actual energy usage, arising from each component of the flat rate and hourly pricing structures.

Flat Rate Pricing

ComEd's flat energy price is made up of two separate $/kWh charges, one for energy supply and capacity charges and one for transmission.

> • *Supply*: Customers taking ComEd's flat supply rate use energy procured by the Illinois Power Agency (IPA), based on load projections provided by the utilities. The IPA, which has a statutory obligation to procure power at the lowest possible cost for consumers, secures the bulk of this supply in annual auctions, in which it selects bids for blocks of energy one, two, and three years out, with the statutory goal of ensuring affordable, stable energy prices over time. The $/kWh energy charge is calculated for each month by dividing the cost of this energy by projected usage.
>
> • *Capacity*: As a member of PJM Interconnection[9], ComEd is responsible for a required level of scheduled capacity. Capacity costs are also included in the supply charge. ComEd procures capacity as a pass-through cost directly from PJM. The capacity requirement is calculated as the ComEd grid's average total load during PJM's five annual peak hours. This figure is often referred to as a coincident peak, meaning a subsidiary entity's average load during the peak usage of the larger grid from which it draws power (as opposed to that own entity's peak load, which is referred to as non-coincident peak). Residential customers on flat-rate pricing are charged the class average capacity cost, which is collected on a per/kWh basis.
>
> • *Transmission*: Transmission services are purchased from PJM directly, and are calculated based on the coincident peak of ComEd's grid, meaning the average total load of ComEd customers during its five annual peak hours. This cost is collected as a separate $/kWh line item on customer bills.[10]

Hourly Pricing

Rather than bundling energy, capacity, and transmission costs into volumetric charges, ComEd's Hourly Pricing program unpacks these components and collects them via their own specific mechanisms, the most important being the hourly energy rate.

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[9] PJM Interconnection is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and the District of Columbia. See: http://www.pjm.com/about-pjm/who-we-are.aspx

[10] Because transmission and the bundled supply rate are both collected on the same number of monthly kWh, they are combined and treated as a single $/kWh rate in the study.

• *Supply*: Hourly Pricing customers pay a $/kWh supply rate that changes hourly based on the ComEd Zonal Locational Marginal Price (LMP) from the PJM wholesale market. This is the average real-time, or "spot," energy price available at ComEd's PJM hubs.

• *Capacity*: Capacity costs are recovered from Hourly customers according to a $/kW rate that is applied to a customer's individual capacity obligation. This capacity obligation is calculated as the customer's coincident peak, during both PJM's five peak hours and ComEd's five peak hours, from the previous year.

• *Transmission*: Transmission costs are recovered through a $/kWh rate that is fixed monthly.

• *Administrative Costs*: This is a flat fee that recovers the administrative costs ComEd incurs to run the Hourly Pricing program, which by law is administered by an independent third party.

• *Miscellaneous Procurement Costs*: While flat rate energy is procured by the IPA, ComEd must carry out hourly procurement for these customers. This $/kWh rate recovers miscellaneous costs of conducting this activity. [11]

For each hour of the year, the difference between the flat rate and the Hourly Pricing $/kWh components was determined by subtracting the Hourly rates from the monthly flat rate. By multiplying these hourly $/kWh "spreads" by a customer's corresponding hourly usage, the study calculated that customer's variable savings for that month.

This savings figure reflects the difference in supply and transmission rates, but does not account for the capacity and fixed administrative charges for Hourly Customers. By subtracting the fixed monthly fee and capacity charge (equal to the applicable monthly capacity rate multiplied by individual capacity obligation[12]) from variable savings, the study estimates the total savings a customer would have realized in that month from real-time pricing.

Findings

Time-variant pricing is designed to incentivize customers to move a portion of their usage away from peak times to take advantage of lower electricity prices and to reduce pollution. However, one key finding from this study is that even without adjusting daily usage patterns, 97 percent of smart meter customers would have saved money if they were participating in the Hourly Pricing program. This proportion is consistent across income groups.

[11] Because the transmission and miscellaneous procurement rates are both collected on monthly kWh, they are combined and treated as a single $/kWh rate in the study.

[12] Individual capacity obligations are estimated based on 2016 peak usage.

Figure 2: Summary Results

Summary Saving Statistics	All Customers	Top 5% of Savers	Bottom 5% of Savers
Avg. Annual Savings	$86.63	$103.76	$0.62
Median Savings	$69.78	$68.42	$0.77
Avg. % Savings	13.2%	31%	0%
Median % Savings	12.6%	28.8%	0.3%
Total Annual Savings	$29.8 mm	$3.95 mm	$10,121

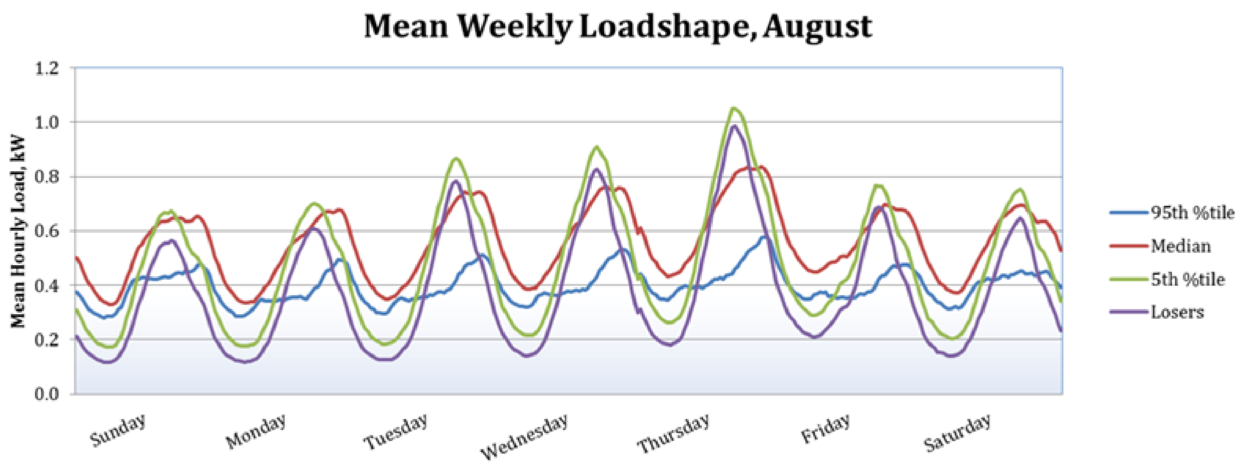
On the whole, customers in this study would have saved a total of $29.8 million were they on ComEd's Hourly Pricing program in 2016. The average customer savings would have totaled $86.63 over the course of the year, or 13.2 percent of their annual bill. The customers with the highest levels of savings[13] would have cut their annual costs by an average of 31 percent, or $104 in annual savings.

Customers with the lowest level of percentage savings broke even, on average. The median customer in the bottom 5th percentile saved an estimated $0.77 for the year. Of the small fraction of customers who would have seen higher bills on hourly pricing, the median customer lost an estimated $6.23 on the year; 90 percent of such customers would have lost less than 5.3 percent compared to their annual bill.

Accounting for annual usage, estimated capacity obligation, space heating and single vs. multi-family housing, the biggest and most significant factors impacting annual dollar savings are usage and capacity obligations.[14] This means using an extra 50 kWh a month increases a consumer's estimated dollar savings by $13.93. Estimated capacity obligation also has a significant impact on dollar savings; according to the analysis, lowering one's annual capacity obligation by 0.5 kilowatt (kW) increases estimated dollar savings by $17.49.

One reason such a large proportion of customers would have saved money under real-time pricing in 2016 is the significant difference between the flat rate energy price and the 2016 LMPs. This may, in part, be due to the lingering effects of the "polar vortex" in 2014—although there will always be at least some discrepancy between hourly prices and future hedged average pricing. The weighted average energy price customers would have paid is $22.06 per megawatt-hour (MWh). For the average customer to have broken even that year—after removing capacity, transmission, and fixed charge differences—the average LMP would had to have been $42.60/MWh, a 93 percent increase.

[13] 95th percentile by percentage of total bill
[14] See Appendix 2 for regression model statistics



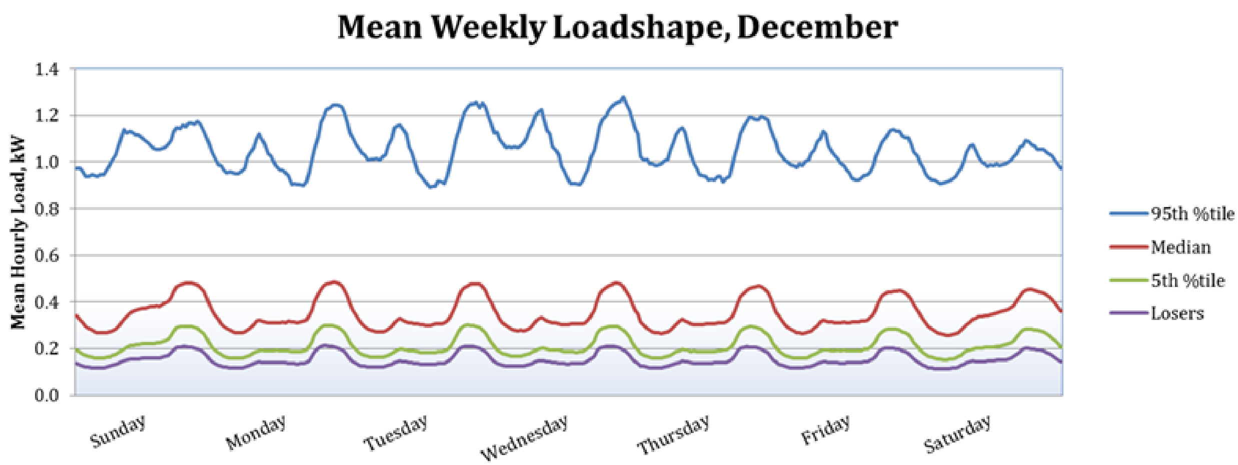
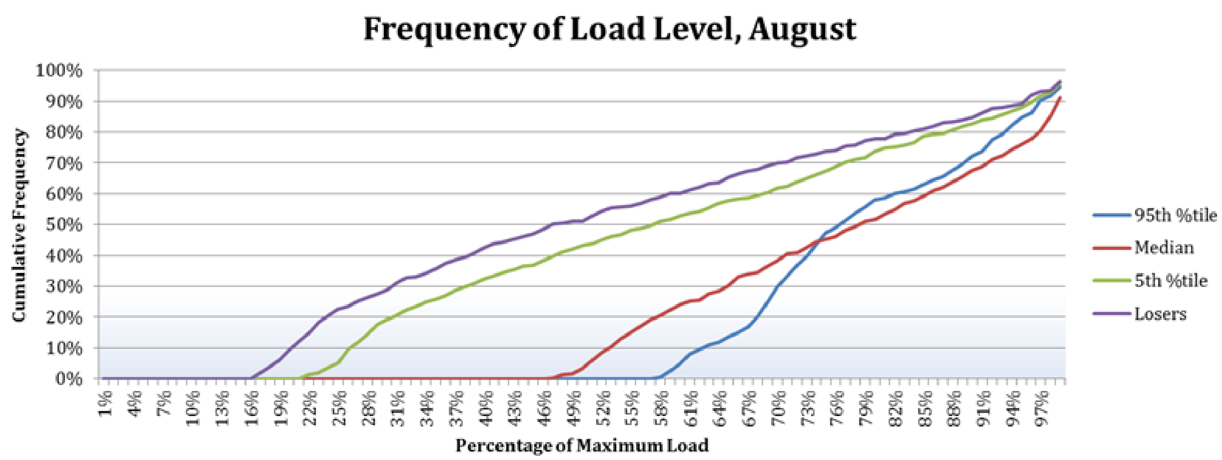


Figure 3: Representative Mean Weekly Loadshapes
In summer months, high- and low-saving customers have similar load levels, with high-saving customers exhibiting shallower peaks and troughs. In winter months, high-saving customers had higher load, but lower percentage variation in loadshape.

When evaluated on a percent-of-bill basis, a customer's load shape has a significant effect on savings. Figure 3 compares weekly load curves of the 95^{th}, 50^{th}, and 5^{th} percentile customers by percent-of-bill savings during the summer and winter. While customers with high percentage savings, on average, used more in December, average load was comparable in August. However, even in the summer month, customers with high percentage savings exhibit more rounded peaks and minimum loads.

This difference is evident when examining the frequency of customer load. Figure 4 compares the cumulative frequency of half-hourly observations that different customer groups use each percentage of their peak load. Flatter frequency curves with lower x-intercepts indicate those customers spend more time at lower percentage levels of their peak load, suggesting higher and steeper usage peaks and troughs. By contrast, steeper frequency curves that begin farther to the right on the x-axis indicate customers who have a lower percentage variation between their peaks and troughs, and flatter overall load shape. In every month of the year, 95^{th} percentile-saving customers exhibit the steepest frequency curves, followed by median customers, and then 5^{th} percentile and non-saving customers. This suggests a strong correlation between higher percentage savings and flatter load shape.



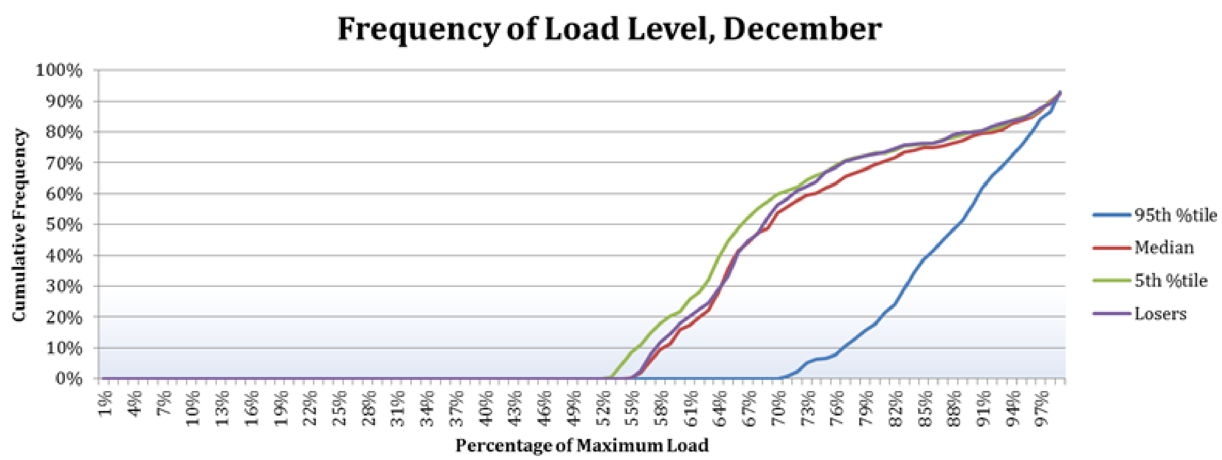


Figure 4: Cumulative Frequency of Load Levels

These cumulative frequency curves represent the proportion of time customers spend at each percentage of their maximum load. Curves that rise at higher percentages, or that are beneath other curves, exhibit flatter overall loadshape.

To support this observation, this study's regression model — using annual usage, capacity obligation, space heat and single/multi-family regressors to estimate percentage of annual total bill savings — predicts a higher impact from capacity obligation than usage. Using a specific example, an average customer who lowered her capacity obligation by 0.5 kW would see increased savings of 3.9 percent, while increasing usage by 162 kWh per month, a comparable level of variation from mean usage, would increase savings by only 0.3 percent.

As for low-income customers, their average annual usage and bills are less, but not by a statistically significant margin. Likewise, their dollar savings were slightly lower, but not significantly so. The only statistically significant difference is in percentage of total bill savings: on average, customers in low-income areas saved 1 percent more on their annual bills than the general population.

Overall, estimated percentage savings were found to be evenly distributed throughout the study area. Figure 5 illustrates average percentage savings and dollar savings per capita by ZIP code. Customers estimated to have little or negative savings from hourly pricing were also evenly distributed. Figure 6 shows the ratio of non-savers per capita in each ZIP code.

Figure 5: Distribution of Savings

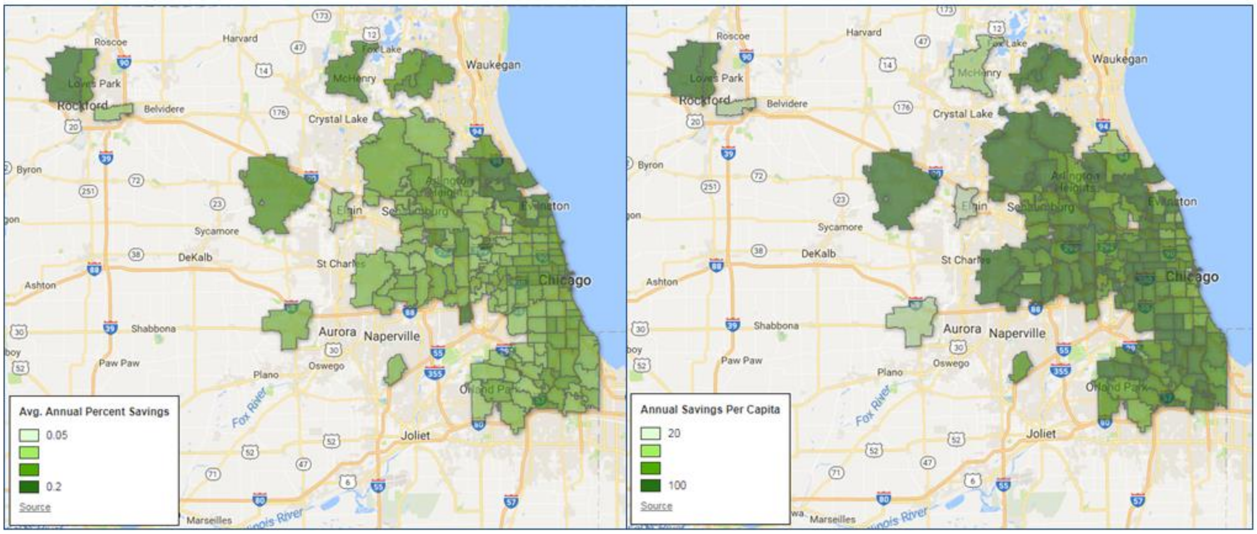
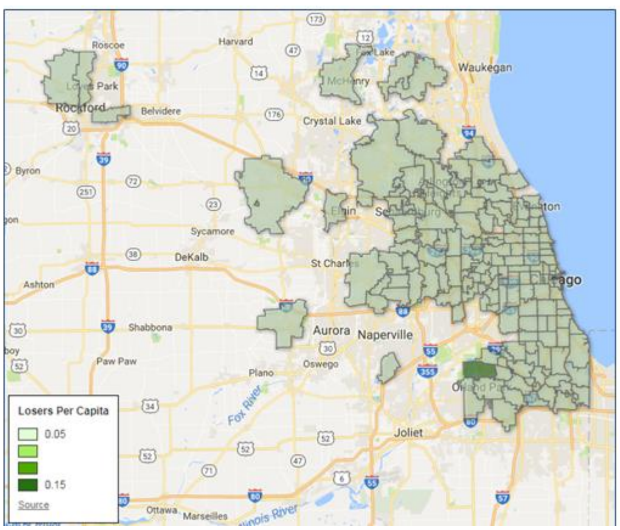


Figure 6: Distribution of Non-Savers



Conclusions

Policy developments over the last decade set the stage for research on dynamic pricing. In 2011, the Illinois General Assembly passed legislation allowing major electric utilities to install digital advanced electric meters in more than 4 million households across Illinois. These smart meters collect an unprecedented amount of energy usage data. ComEd's anonymous data tariff, filed in 2017, gives researchers access to those numbers in aggregate and anonymous data sets.

Conventional wisdom holds that for the residential customer, saving money under real-time pricing or other dynamic rate designs depends on using less energy during high-price times of the day, such as summer afternoons and fall mornings and evenings. The concern among many policymakers and consumer advocates has been that if customers do not – or cannot – shift their usage patterns and consume significant energy during a spike in prices, they may see a corresponding increase in their monthly bill. Therefore, it was expected that a customer's projected level of savings would be most closely correlated to differences in their load shape, or usage patterns. While customers with flatter load shapes saved more under hourly pricing, even peakier load shapes showed savings.

These findings should prompt robust discussion and more study to determine if the conventional wisdom on real-time pricing may be wrong, and that the real-time dynamic-pricing structure could be beneficial to a much larger number of consumers. There are reasons to question whether other years would produce different results. ComEd's flat rate is based on the price of energy and capacity procured as many as three years out. This approach leaves room for a significant spread between forward market prices for these products and spot prices. In 2016, portions of the energy and capacity being consumed were procured in the aftermath of the 2014 "polar vortex," which increased forward-price expectations, particularly in capacity markets. If market conditions had more closely followed expectations, there would likely have been less difference between the two rates.

Also, while the 2016 data set is unprecedented in size and includes a higher percentage of low-income customers than the overall service territory, it is not necessarily representative of rural areas in the ComEd service territory. We recommend further analysis, running over multiple years – and with a larger number of utilities.

However, the findings—that nearly all ComEd residential customers would have benefited from real-time pricing in 2016—should stimulate discussion on whether this dynamic-pricing program could be a consumer asset on a much larger scale and across a far larger territory than it occupies currently.

The analysis suggests that the hedge premium embedded in the costs of average, flat-rate pricing for individual consumers is significant. In 2016, ComEd customers as a whole paid over 13 percent more than they would have on real-time pricing. Given that we know from numerous pilots and programs that price signals induce customer response and could prompt even larger savings, the systemic costs of average, flat-rate pricing over time are higher still, even before other societal and environmental benefits of reducing peak demand are considered.

Based on the results of this research to date, we further recommend that states:

1. **Allow Access to Anonymous Energy-Usage Data.** In order to better evaluate how alternative rate structures can benefit consumers, states should allow access to scrubbed household energy-usage interval data at the ZIP+4 level.

2. **Adopt Opt-In Real-Time Pricing.** As the data in Illinois demonstrate, real-time pricing can yield substantial cost savings for residential electricity consumers. Therefore, we recommend that other states investigate offering the program as a discretionary alternative to flat-rate pricing, affording all customers the opportunity to shift consumption to lower-cost periods of the day. We do offer a caveat: While Illinois may present a blueprint of real-time programs for other restructured states, one size never fits all. Other states may have a dramatically different energy landscape that requires different solutions. Our hope is that these findings prompt exploration and thoughtful planning in each state on other pricing models and how to maximize benefits for consumers and the power grid.

3. **Investigate a Transition to Opt-Out Real-Time Pricing**. Policymakers should explore the comparative costs and benefits of introducing dynamic pricing for customers on an opt-out basis, rather than as a passive "opt-in" elective. For instance, our analysis of Illinois data suggests that an opt-out program could be marketed to customers most likely to enjoy prolific savings with real-time pricing—if accompanied by data analysis and the availability of smart devices that alert customers of, and perhaps even respond to, imminent price spikes.
4. **Investigate Various Dynamic Pricing Structures.** Real-time pricing is a proven money-saver in Illinois[15], but there are other incarnations of dynamic pricing, such as "time-of-use" rates – where prices vary during the day, but in fewer time intervals – that warrant consideration.

5. **Focus On Helping Consumers Lower Their "Coincident Peak."** Coincident Peak is a measure of an individual customer's usage when the electric grid is operating at peak demand. Even though coincident peak represents only a handful of hours over the course of a year, research suggests it is a significant factor in elevated electricity costs for households. Therefore, states should investigate promoting and launching creative programs—a demand-response smart thermostat program, for example—that will help automate energy efficiency and peak control efforts in the home.

[15] *Since the program began, Hourly Pricing participants have saved more than 15 percent off the electricity supply portion of their electricity bill, in contrast to what they would have paid with ComEd's fixed-price rate.* Elevate Energy. ComEd's Hourly Pricing Program. Retrieved from https://www.elevateenergy.org/home-savings/comed-rrtp/

Further Research

This whitepaper was made possible by two policy decisions. First, Illinois is the only state in the nation where the two biggest utilities—Ameren Illinois and ComEd —offer comprehensive, opt-in residential real-time pricing programs. Under state law, these programs must be run by an independent third party, and both are managed by Elevate Energy, a nonprofit organization. Elevate says the ComEd program, which began in 2007, has saved participants an average of 15 percent off the supply portion of their electricity bills.

Second, state regulators in 2017 also approved an innovative anonymous data access tariff, which protects customer privacy while allowing researchers access to scrubbed, thirty-minute household energy usage data at the ZIP+4 level. We encourage other states to adopt these policies.

Whether the benefits of average, flat-rate pricing exceed the costs in the final analysis depends upon how representative 2016 was for consumers. Because the dataset isn't necessarily representative of the entire state, further analysis is needed to determine the expected results of a return of the "polar vortex" – or other conditions precipitating spikes in short-term wholesale market prices – in order to draw broader conclusions regarding the benefits of dynamic pricing.

The price difference that allowed for widespread savings was the product of numerous factors, and could differ significantly in other years with slightly different market conditions. Evolutions in forward energy and capacity markets, low fuel costs, and weak demand growth create uncertainty for the block procurement process that generates ComEd's default service energy prices. It is possible that years with lower-priced ComEd supply would produce lower, or even negative, savings results, compared to the costs of real-time pricing.

Future studies will apply this methodology to 2017 usage data; this and continual updates will render a fuller understanding of the consistency of this opportunity for consumers. Looking backwards, it would also be instructive to analyze ComEd hourly LMPs and IPA procurement results, even without comprehensive usage data, to see how often these particular pricing conditions occur.

Another critical reason to continue this research in following years is the yearly expansion of the data set, in both footprint and number of customers. More users allow for more confident conclusions, but more importantly, inclusion of areas farther from Chicago creates more diversity in the dataset, allowing the analysis to control for more demographic and geographic variables. Further expanded analysis should yield conclusions that can be applied more broadly beyond Chicagoans and their immediate neighbors.

Appendix 1: Simulation Formulae

$$P_c = ComEd\ Price\ to\ Compare\ (energy + capacity + trans., \$\ per\ kWh)$$
$$U_h = Customer\ usage\ (kWh)$$
$$L_h = ComEd\ Zone\ LMP\ (from\ PJM)$$
$$T_m = Hourly\ program\ transmission\ rate\ (\$\ per\ kWh)$$
$$C_h = Hourly\ program\ capacity\ charge\ (\$\ per\ kW)$$
$$O_z = Personal\ capacity\ obligation\ (kW)$$
$$M_m = Hourly\ program\ misc. rate\ (\$\ per\ kWh)$$
$$F_m = Hourly\ program\ flat\ monthly\ fee\ (\$\ per\ Month)$$
$$n = days\ in\ month$$

Daily Savings

$$S_d = \sum_{1}^{24} [U_h * (P_c - (L_h + T_m + M_m))]$$

Monthly Savings

$$S_m = \sum_{1}^{n} [S_d] - C_h * O_z - F_m$$

Capacity Obligation Assumptions

- Hourly customers are assigned capacity obligations based on prior year average usage during 5 PJM peak hours and 5 ComEd peak hours, expressed in kW
- Without prior year usage data, individual capacity obligations were estimated based on usage during the study year peak hours, and scaled to the proportional difference between 2015 and 2016 peaks for ComEd and PJM.

$$PJ_{1-5} = Sum\ of\ individual\ usage\ during\ 5\ PJM\ 2016\ peaks$$
$$CE_{1-5} = Sum\ of\ individual\ usage\ during\ 5\ ComEd\ 2016\ peaks$$
$$PJs = Scalar\ equal\ to\ 2015\ PJM\ peak\ divided\ by\ 2016\ PJM\ peak$$
$$CEs = Scalar\ equal\ to\ 2015\ ComEd\ peak\ divided\ by\ 2016\ PJM\ peak$$
$$O_z = \frac{PJs * \left({PJ_{1-5}}/{5}\right) + CEs * \left({CE_{1-5}}/{5}\right)}{2}$$

Appendix 2: Regression Results

Annual Dollar Savings Model

Independent Variables	*β*	*SE*	*t*	*95% Conf. Interval*	
Annual Usage (kWh)	0.0232	2.48E-05	936.35	0.0232	0.0233
Capacity Obligation (kW)	-34.98	0.0754	-463.72	-35.13	-34.83
Space Heat (binary)	43.52	0.288	150.98	42.96	44.09
Single Family (binary)	8.45	0.136	62.21	8.19	8.72
constant	12.25	0.105	116.63	12.05	12.46
r^2			0.7887		

Percent of Bill Savings Model

Independent Variables	*β*	*SE*	*t*	*95% Conf. Interval*	
Annual Usage (kWh)	1.67E-05	4.73E-08	352.51	1.66E-05	1.68E-05
Capacity Obligation (kW)	-0.0595	1.39E-04	-427.65	-0.0598	-0.0592
Space Heat (binary)	0.0523	4.96E-04	105.51	0.0514	0.0533
Single Family (binary)	0.00296	2.34E-04	12.64	0.0025	0.0034
constant	12.63	1.84E-04	687.01	0.1259	0.1267
r^2			0.4397		