Business & Technology Advisory

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NRECA
America's Electric Cooperatives

Retail Rate Scenarios and Modeling for Beneficial Electrification Programs

Key Findings

- Promoting electrification in American homes represents an enormous opportunity to decarbonize the economy.
- Many co-ops are actively implementing beneficial electrification programs. These programs offer different incentives and rates to help achieve their goals.
- Informing retail consumers through price signals in the wholesale rate can promote savings throughout the energy supply chain, and reduce the unintended effect of cross subsidization within the rate class.
- Cooperatives may benefit from more rigorous analysis, such as using AMI interval data and modeling techniques to measure the impact of existing programs and predict potential outcomes.

What has changed?

Beneficial electrification holds the potential to be a win-win-win opportunity, if consumers electrify equipment that is currently fossil fuel-powered in a manner that adds value throughout the energy supply chain. The retail rate structure is an essential tool that provides information to enable consumers to choose behaviors that can positively impact the value proposition. To unlock the benefit of electrification, price signals provided to the end-use consumer must reflect costs associated with delivering energy at the time of use. While case studies and anecdotes can be helpful, there is now enough data to conduct a thorough scenario analysis to identify consumer response to the application of innovative rate structures.

Mid-Carolina Electric Cooperative (MCEC) and NRECA's Business and Technology Strategies Department worked together to analyze the impact of implementing a three-part (customer, energy, demand) rate structure for its residential and small commercial consumer-members. Using AMI interval data, the analysis evaluated the impact that a time-of-use demand charge has on the electrification of transportation and cooking in the residential rate class.

Profile of Mid-Carolina Electric Cooperative

Mid-Carolina Electric Cooperative (MCEC) is one of the largest of South Carolina's electric distribution cooperatives, serving some 47,000 members (over 57,000 accounts) with 4,300 miles of power lines across five counties. All of its power is sourced through Central Electric Power Cooperative, a generation and transmission cooperative (G&T), which secures power from Santee Cooper (a public power entity owned by the

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State of South Carolina) and Duke Energy for all twenty of South Carolina distribution cooperatives. Wholesale power costs are by far the largest component of 'MCEC's cost of service to members, accounting for 70% of the total.

Project Background

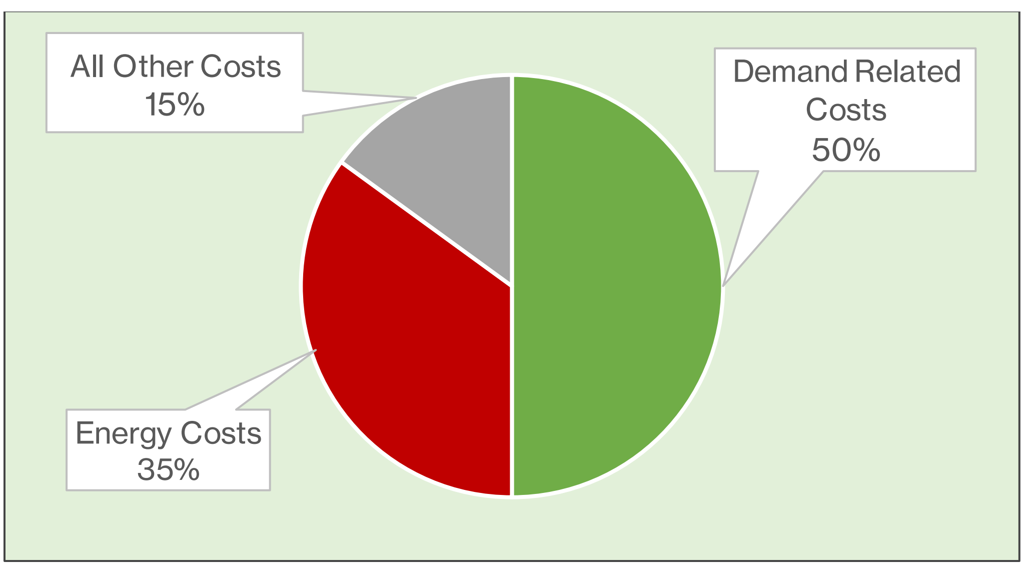
In 2014, the State of South Carolina Legislature enacted a law requiring electric cooperatives in the State to investigate the extent of cost shifting attributable to distributed energy resources (DER) within then-current rate structures. Specifically:

> **-ACT 236 in 2014** *...TO PROVIDE THAT EACH ELECTRIC COOPERATIVE SHALL INVESTIGATE THE RELATIONSHIP BETWEEN FIXED COSTS, FIXED CHARGES, AND THE EXTENT OF COST SHIFTING THAT IS ATTRIBUTABLE TO DISTRIBUTED ENERGY RESOURCES ...*

At that time, MCEC was facing flat energy sales resulting from the Great Recession of 2007-2009 and the success of robust energy efficiency programs. The co-op could also see the impact of distributed energy resources (DER) on the horizon. (For additional details on the MCEC case study see Case Study: Mid-Carolina Electric Cooperative's Residential Demand Rate.)

An in-depth analysis by the cooperative's staff revealed several considerations related to its energy-only, two-part rate (comprised of a volumetric rate per kWh plus a fixed account charge). The primary challenge was that the energy-based retail rate did not align with its wholesale power or internal costs. This misalignment was amplified by the G&T's relatively high coincident peak demand charge. A cost-of-service study indicated that roughly half of the cooperative's costs were related to demand and one-third were related to energy. See Figure 1 below.

Figure 1: MCEC's Cost Structure



The misalignment between retail and wholesale rates meant that consumers with high energy use subsidized consumers with low energy use. In the MCEC service territory, high energy consumption is typified by inefficient manufactured homes, while weekend lakefront homes tend to have low energy consumption. When demand costs are collected by the energy charge, high usage consumers pay a disproportionate share of fixed costs for reliability, while low usage consumers pay less.

The final factor influencing MCEC's consideration of a three-part rate structure for its residential and small commercial consumers was that with no price signal, the load profiles of these consumer segments disproportionately contributed to the cooperative's coincident peak. The cooperative planned to introduce a price signal to encourage members to use less energy when the system peak was expected to occur, and costs to serve were high.

In February 2016, MCEC implemented the three-part rate structure. The new rate was designed to be revenue neutral. They introduced a seasonal on-peak demand charge of $12.00 per kW and lowered the energy charge to $.05 per kWh (from $0.115 per kWh). They also transitioned the customer charge to a daily charge to reflect variations in the length of billing cycles. See Figure 2.

Figure 2: MCEC's New 2016 Rate Structure

	Rate	Per
Account Charge	$0.95	Day
Energy Charge	$0.05	kWh
On-Peak Demand Charge		$12.00
Season	Time	Months
Winter	6:00 AM to 9:00 AM	November 1 to March 31
Summer	4:00 PM to 7:00 PM	April 1 to October 31

Because the wholesale coincident demand charge could occur at any time of the day, limiting the on-peak demand window to three hours introduced risk to the cooperative. However, careful analysis of historical data and current hourly AMI data indicated that the risk was small relative to the benefit. Thirty years of data showed the peak almost always occurred during a three-hour window in the winter and summer months. The narrow on-peak window simplified messaging about the rate by providing a clear target for consumers.

Methodology – Post Rate Implementation Analysis

AMI data

MCEC provided three years of hourly AMI data for 2,000 residential consumers, with data spanning January 2, 2015 through December 31, 2017. The three-part rate took effect on February 1, 2016. Using hourly meter readings enabled account analysis by calendar month, eliminating the issue of meter reading cycles that might span periods with notably different weather patterns. Said another way, the weather is identical for all rate impact and margin calculations.

Rate comparison

This study sought to understand consumer behavior change in response to the price signal of the three-part rate. The analysis determined each customer's monthly bill under both the two-part rate in effect before the transition and the three-part rate that took effect on February 1, 2016 for all 36 months of the study period. This analysis demonstrated the impact of the rate change on each customer before and after introducing the price signal.

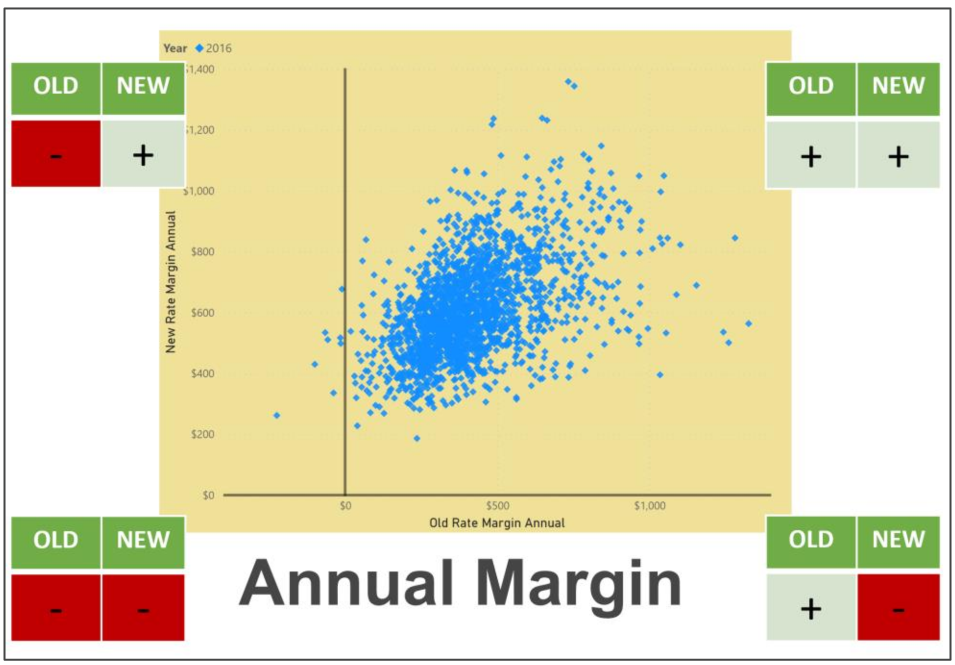
Furthermore, with two years of data after the implementation, it was possible to observe a reversion to prior use patterns among some consumers in year two after an initial behavior shift in year one. In contrast, some consumers continued to improve their response to the new rate structure and increased their savings from year one.

Wholesale Power Cost and Gross Margin

MCEC's G&T is Central Electric Power Cooperative, Inc. (CEPCI), which provides power to 20 distribution cooperatives in South Carolina. CEPCI's wholesale rate is a seasonal, time of day, demand and energy rate. CEPCI calculates the demand charge based on MCEC's contribution to the regional peak for both the transmission system and the generation fleet independently. A 60-minute demand window, based on the clock hour, determines the peak demand. The gross margin calculation required a disaggregation of the wholesale rate into an effective energy rate for each hour of the month. Applying the effective wholesale rate to each consumer hourly allows for calculating the gross margin for every consumer.

The following scatterplot shows the impact of the new rate on the annual gross margin for each account in the study. If a point lies to the left of the vertical axis, then the consumer's usage pattern created a negative margin for the co-op under the energy-only rate. Since all the points are above the horizontal axis, all the consumers produced a positive margin under the three-part rate.

Figure 3: Impact of New Rate on Annual Gross Margin



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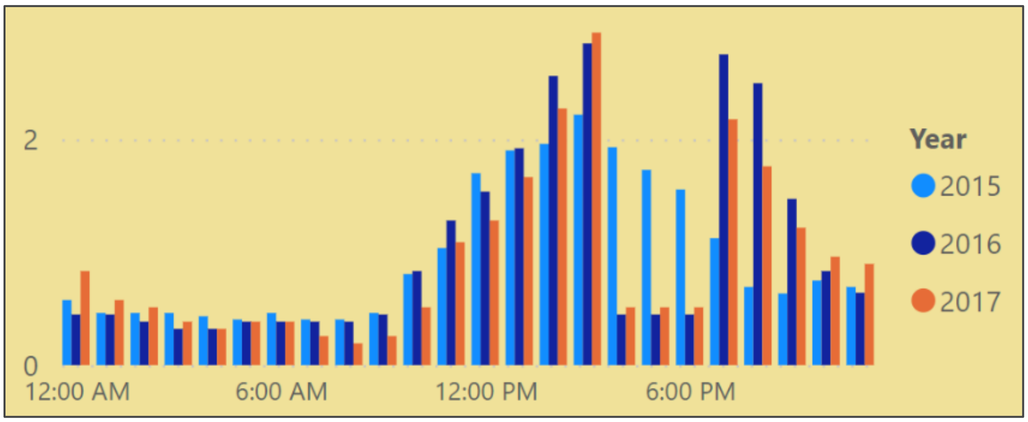
Impact on the Consumer

The analysis reveals that between 10% and 20% of consumers significantly changed their behavior in response to the price signal provided by the on-peak demand charge. Consumer response largely fell into two modes. One group shifted consumption outside the on-peak window, while the second group reduced consumption throughout the day. See Figures 4 and 5.

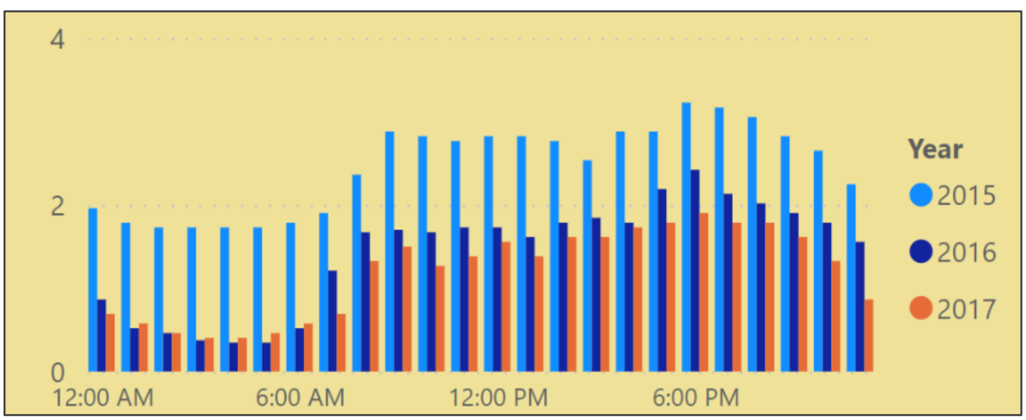
One way to measure a consumer's response to the price signal is to calculate the percentage of total energy consumption during the three-hour on-peak window and quantify the difference before and after the change. The energy-shift metric ranked all consumers in the sample by how much energy they moved off-peak. The two deciles that moved the most energy use outside the peak window achieved a median 17% reduction in on-peak energy consumption.

Figure 4: Individual Customer No.1 Median Hourly Usage



The graph above shows one residential account's median hourly energy usage during the summer months. This consumer responds in a text-book fashion to the three-part rate by pre-cooling the home before the peak window and increasing energy consumption once the low kWh rate resumes outside the on-peak window.

Figure 5: Individual Customer No. 2 Median Hourly Usage



In contrast, the second case, shown here, implemented an around-the-clock conservation strategy.

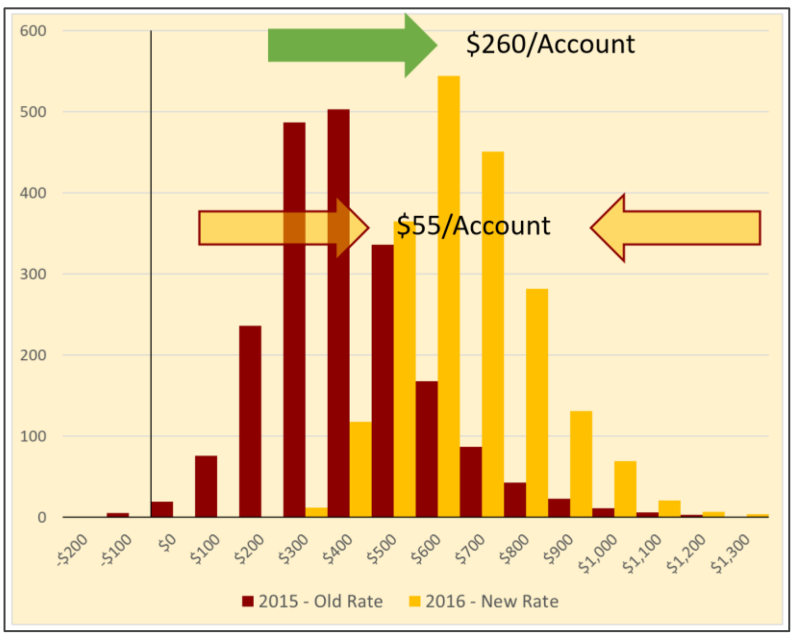
While a conservation strategy effectively reduced the consumer's bill, it missed the benefit of the significantly lower energy charge during off-peak hours. The segment of consumers that adopted the conservation strategy paid lower demand and energy charges. This group of consumers represent an opportunity for outreach and education about the new rate structure, emphasizing the significantly lower power costs outside the on-peak window.

A couple of the key benefits for consumers achieved through MCEC's three-part rate include:

- **Cross-subsidization reduced.**

  Inherently, retail rate structures create cross-subsidies within and across rate classes. One measure of the level of cross-subsidies present in a rate design is the standard deviation of the annual gross margin within the rate class. The standard deviation measures the range of gross margin centered on the average. This analysis calculates the gross margin for every account in the sample for 2015 and 2016 using both retail rate structures. For 2015, the gross margin standard deviation per account was $213.63, and in 2016 only $157.92. This 26% decrease indicates that the new rate design substantially reduced cross-subsidies within the residential rate class. Another gauge is that in 2015 some accounts in the sample had a negative gross margin for the entire year. A negative gross margin indicates that other members of the rate class subsidize these accounts. Under the three-part rate in 2016, however, none of the locations in the sample had a negative annual gross margin.

Figure 6: Change in Gross Margin from 2015 to 2016



These two histograms show the change in the gross margin of the residential rate class from 2015 to 2016. The shift to the right indicates that the average margin per consumer increased by $260. The narrowing of the distribution by $55 tells us that the margin is collected more evenly. Again note that no consumer produced a negative margin in 2016.

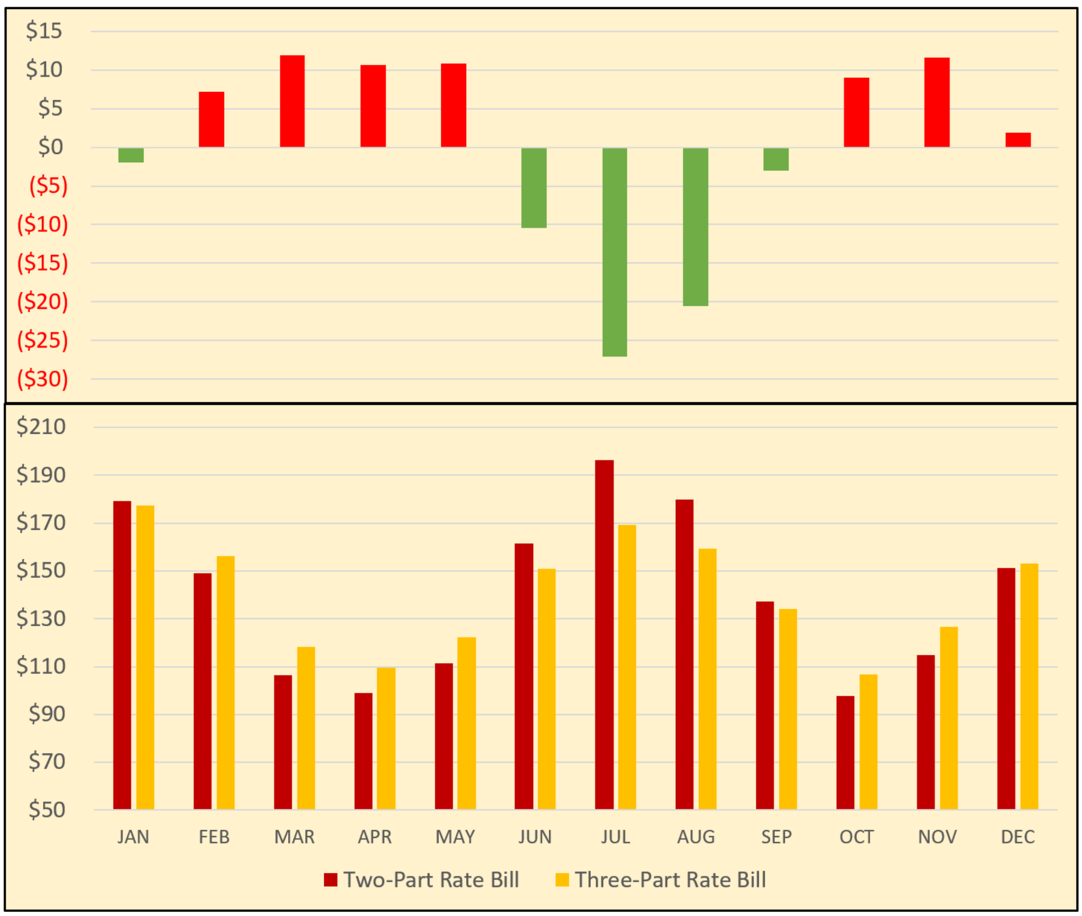
- **Affordability improved - less variation from high to low monthly bills.**

  The traditional measure of impact on a rate class is energy burden, measured by the household energy cost as a percentage of income. This perspective fails to capture the difficulty consumers experience when seasonal variability of energy bills overwhelms their monthly budget. This three-part rate design mitigates some of the seasonal variability by collecting more revenue in the shoulder months and lowering the summer and winter bills. Reducing the variability of monthly energy bills helps consumers manage their energy budget.

During 2016, the median residential bill for consumers in the sample during July and August declined under the three-part rate compared to the two-part rate. Moreover, the ratio of the highest monthly bill, January, to the lowest monthly bill, April, declined from 2.00 to 1.76 or 12.5%.

The following two graphs show the impact on consumers' monthly bills. The top graph shows the change in the bill, indicating that the additional revenue collected under this rate occurs mainly in the low-use shoulder months, while revenue collected in high usage months is lower under the three-part rate than the two-part rate. Note: this example is adjusted to make the two rates revenue neutral.

Figure 7: Impact on Customer's Monthly Bills



Impact on the Cooperative

Some of the main benefits achieved for the cooperative through MCEC's three-part rate include:

- **Gross margin risk eliminated.**

  This analysis leveraged the cooperative's AMI and wholesale billing data to calculate the hourly gross margin for each account.

  Gross Margin = Retail Electric Revenue – Wholesale Power Cost

  Implementation of the on-peak demand charge created better alignment between the wholesale power and retail rate structures, and virtually eliminated the occurrence of accounts with a negative gross margin during any given month. When calculated annually, the cooperative's gross margin was positive for every location in the sample.

- **Capital construction projects deferred.**

  Sending the on-peak price signal reduced MCEC's peak demand, allowing the cooperative to defer capital construction projects. One example cited by MCEC was the deferral of the construction of a substation for five years. This one project produced approximately $300,000 in savings for the membership.

- **Beneficial Electrification**

  The study evaluated two use cases, transportation, and residential cooking, to measure the impact of the three-part rate on beneficial electrification.

  Transportation Analysis

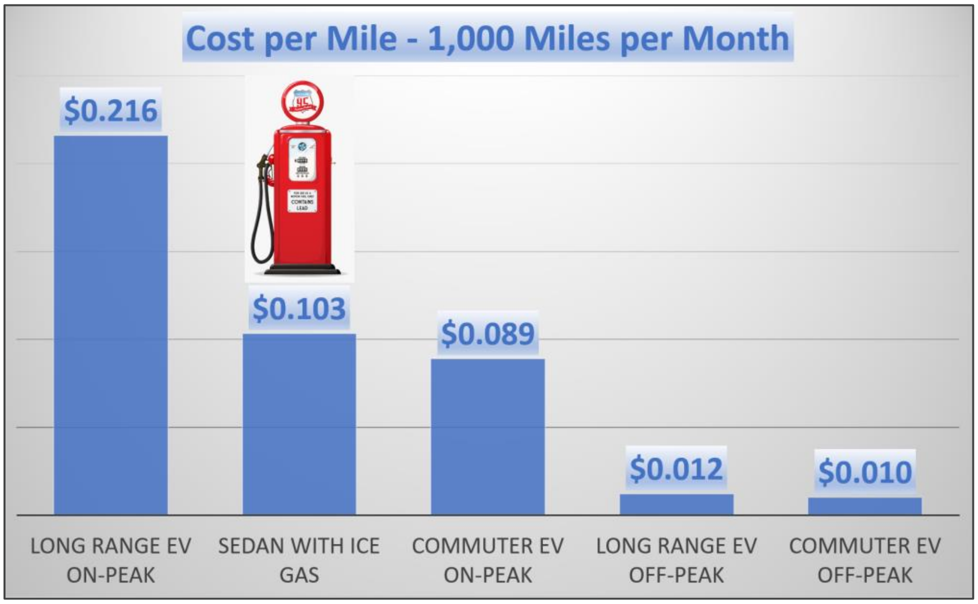
  The analysis considered three vehicle options for the transportation case:

  - a long-range electric vehicle (EV) with a peak demand charging rate of 17kW,
  - a commuter EV with a peak demand charging rate of 6.6kW, and[1]
  - a mid-size sedan with an internal combustion engine (ICE) with a fuel efficiency of 31 MPG.

  The base case assumes the owner drives 1,000 miles per month. The traditional ICE-powered sedan will cost the owner $0.103 per mile, if gasoline is $3.20 per gallon. The analysis considered two scenarios for EVs by comparing on-peak and off-peak charging. The long-range vehicle costs $0.216 per mile to operate when charged on-peak, and only $0.012 per mile when charged off-peak. Even when charged on-peak, the commuter EV costs less to drive than the ICE vehicle. The commuter EV charged on-peak costs $0.089 per mile and $0.010 per mile when charged off-peak. See Figure 8.

[1] For this example, we used a Tesla Model 3 for the long-range EV, a Nissan Leaf for the commuter EV, and a Nissan Altima for the ICE.

Figure 8: EV Cost vs. Gas Vehicle

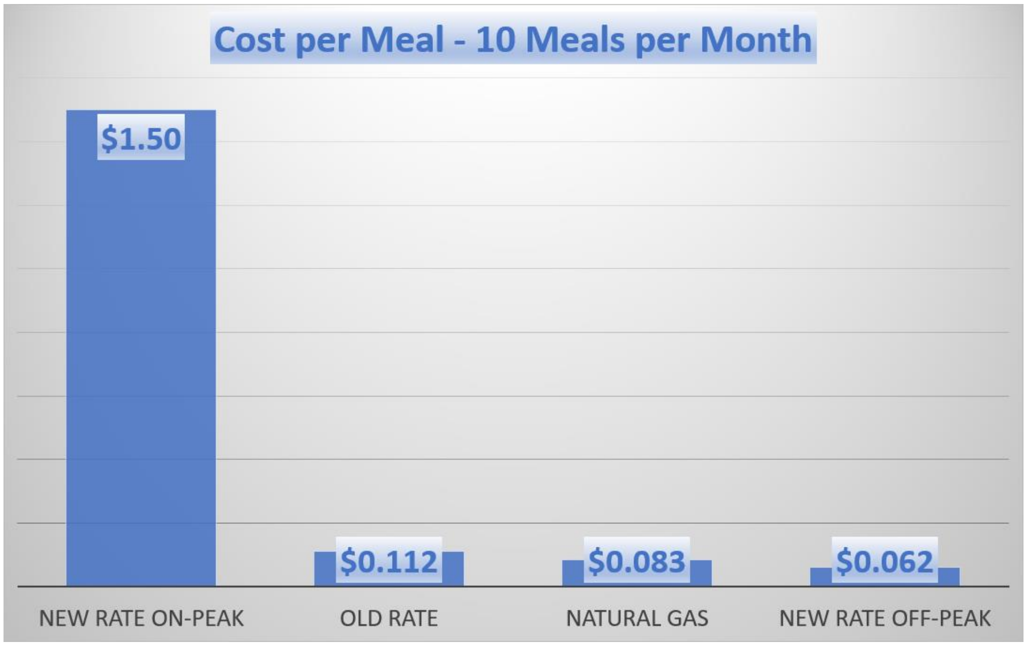


This rate sends a strong price signal to charge EVs off-peak; however, the choice remains with the consumer. The ability to program the tariff into the vehicle's smartphone app can provide a usefu; resource to inform the consumer of the rate impacts, but ultimately the consumer's preference of cost versus convenience is met with no intervention by the utility.

Cooking Analysis

The case for cooking with gas versus electric stoves is not as economic under the three-part rate. Cooking on-peak will cost between $1.00 and $2.00 per meal compared to $0.05 to $0.10 using natural gas. See Figure 9:

Figure 9: Cost per Meal: Gas vs. Electric



This analysis assumes the electric stove will add 1.2kW to the consumer's billed demand each month, adding $14.40 in demand charges to the bill. The demand charge is averaged across ten meals during a typical month.

Other Electrification

The available data did not enable the direct analysis of water heating or home heating electrification. As mentioned earlier, consumers who chose to modify their behavior in response to the three-part rate could lower their power cost on a per unit and total basis. According to Matt Porth, MCEC's Manager of Energy Services and Government Relations, many consumers have installed water heater timers and have significantly reduced their monthly bill by approximately twenty dollars, making the cost on par with natural gas water heaters. However, it should be noted that electric prices are generally less volatile that natural gas prices.[2]

For the homes in this study, those heated with an electric furnace paid 6.4% more per kWh than homes heated with a heat pump due to higher demand to operate the electric furnace. Because homes heating with natural gas had a nearly identical per kWh power cost to those with a heat pump, replacing the gas furnace with an efficient heat pump should not impact the unit cost of electricity.

Conclusion

Promoting electrification in American homes represents an enormous opportunity to decarbonize the economy and increase energy sales. However, if a cooperative's residential load dominates its load profile, increasing the electricity use in a home introduces risks in the form of increased wholesale power cost and equipment loading. There are many ways to mitigate the risks; this article demonstrates that sending an accurate price signal eliminates the margin risk, while shifting the cooperative's load profile to reduce peak demand and loading on lines and equipment. Many load management and demand response programs capture savings on the wholesale bill, then spread those savings across the membership. Using rates to send a price signal allows members to make informed choices between cost and convenience/comfort, which results in lower costs for those who respond with behavior changes, while protecting the cooperative's margin and other consumers from subsidizing the new load. Additionally, some benefits accrue to all consumer-members through lower costs.

Faced with risks from distributed energy resources and new electric loads, the leadership team recognized the need for change. Through a detailed analysis of historical AMI and wholesale billing data, the leadership team clarified their understanding of the challenges with the existing two-part rate. With this knowledge, MCEC established a goal that is easy to communicate and founded on the principles of the cooperative. The new goal, "to create a more fair and equitable rate structure by aligning the retail rate with wholesale costs," empowered the cooperative to take the challenging step of introducing a demand charge for their residential and small commercial consumer-members. As a result, MCEC successfully implemented a three-part demand and energy rate and minimized the impact on most consumers through careful design. Armed with data and the courage of their convictions, MCEC educated the membership and successfully transitioned to a rate structure that yielded benefits across the energy supply chain. By calculating the cooperative's gross margin for individual consumers using hourly AMI and wholesale cost data, this analysis validates MCEC's

[2] June CPI, Source: U.S. Bureau of Labor Statistics

pricing strategy. It shows a reduction in cross subsidization and that consumer behavior changed to benefit both the individual consumer and the membership.

The new rate promotes the electrification of transportation and protects the cooperative's margin without complicated and expensive load control systems. More importantly, it places the consumer in the driver's seat on when and how to charge their electric vehicle.

Additional Resources

"Advancing Energy Access for All: Case Study: Mid-Carolina Electric Cooperative's Residential Demand Rate", Business and Technology Advisory, February 2020: https://www.cooperative.com/programs-services/bts/energy-access/Documents/Secure/Advisory-Advancing-Energy-Access-MCEC-Case-Study-Feb-2020.pdf

"The Role of Innovative Rate Structures in Increased Adoption of Beneficial Electrification Programs", Business and Technology Report, March 2021: https://www.cooperative.com/programs-services/bts/Documents/Secure/Reports/Report-Innovative-Rates-for-Beneficial-Electrification-March-2021.pdf

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