Residential Rate Study for the Kansas Corporation Commission
Final Report

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Executive Summary

This report documents a residential rate study that Christensen Associates Energy Consulting, LLC (CA Energy Consulting) conducted on behalf of the Kansas Corporation Commission (KCC). The KCC is interested in studying rates that can encourage conservation and/or provide efficient rates. "Conservation" refers to providing customers with incentives to reduce energy consumption. "Efficient rates" are those that provide customers with prices that reflect the marginal cost to serve them, which in theory leads to the most efficient use of resources (e.g., electricity generators). These two goals do not always coincide. For example, a TOU rate may have low off-peak prices to reflect the fact that only low-cost generators are needed to serve off-peak loads. While this price is efficient, it provides less incentive to conserve in off-peak hours than an equivalent flat price (in which the price is the same across all hours).

We used data from Kansas City Power & Light (KCP&L), Westar Energy (Westar), and Midwest Energy (Midwest) to analyze several alternative residential rate structures. The rate structures included in the study are:

- Flat rate;
- Straight-fixed variable (SFV) rate;
- Inclining block rate (IBR);
- Time-of-use (TOU) rate; and
- Day-type TOU rate.

The flat rate is included primarily as a reference case, in which the price does not vary by time or with the level of customer use. SFV rates address the utility's incentive to promote conservation and energy efficiency by increasing the fixed monthly customer charge and reducing the throughput volumetric rate, thereby recovering all utility fixed costs through fixed charges rather than through volumetric rates. An IBR is intended to provide an incentive to conserve by increasing the rate a customer pays as its usage level increases. TOU rates are intended to provide efficient price signals by charging rates that are based on the average cost to serve customers. TOU rates therefore give customers an incentive to reduce usage during high-cost hours (e.g., summer afternoons) and increase usage during low-cost hours (e.g., overnight hours). Day-type TOU rates add a "dynamic" component to TOU rates that provides customers with a significant incentive to reduce usage on the hottest, most costly days to serve them.

Each of these rate structures affects customers differently depending on their usage levels and patterns. The relationship between bill impacts and customer usage levels is of interest because stakeholders often wish to avoid adverse bill impacts for low-income customers, and low-income customers are often believed to use less electricity than other customers. The advantages and disadvantages of each rate structure are described in the full report.

Research Approach

The following steps were used to evaluate the alternative rate structures of interest:

1) Design revenue-neutral alternative residential rates for each utility;
2) Estimate customer-level bill impacts for each rate structure at historical loads;

3) Evaluate the relationship between bill impacts and customer usage levels;
4) Simulate the changes in customer usage levels and patterns (i.e., "demand response") in response to the new rate structures; and
5) Estimate the potential for utility revenue loss (revenue attrition) due to mispricing the new rate options.

Design revenue-neutral alternative residential rates for each utility: Separate revenue-neutral rates were designed for each utility using utility-specific residential customer usage data and Southwest Power Pool (SPP) price data (to design the TOU and day-type TOU rates). The rates were designed so that they produced the same amount of total revenue as the current rate produces.

Estimate customer-level bill impacts for each rate structure at historical loads: Each customer's bill was calculated for both their current rate and each alternative rate structure using historical loads.

Evaluate the relationship between bill impacts and customer usage levels: To evaluate the relationship between bill impacts and customer usage levels, the bill impacts are displayed as scatter plots against each customer's average monthly usage (in kWh). This allows for an easy examination of how bill impacts vary with customer usage level.

Simulate customer demand response to each rate structure: Simulation was used to estimate the changes in load that could be expected from each rate structure. We used evidence from existing studies on customer price responsiveness to provide estimates of the potential magnitude of the load changes (which, depending on the rate, could be an overall increase, an overall reduction, or shifting from high- to low-cost hours) that might be expected from each rate structure.

Estimate the potential for utility revenue loss (revenue attrition) due to mispricing the new rate options: The final step was to examine the potential for utility *revenue attrition*, or lost revenues, due to self selection and demand response. Revenue attrition due to *customer self selection* can occur when the utility sets rates without accounting for the tendency of customers to select the rate that is most beneficial for them (i.e., gives them the lowest bill). Revenue attrition due to *customer demand response* can occur when the utility sets rates using historical load profiles but customers modify their usage patterns in response to the pricing signals of their new rate.

Research Implementation

We used utility-specific customer data to calculate bill impacts for each rate structure. KCP&L and Westar provided us with 2007 hourly data from their residential load research samples. Midwest did not have a load research sample, and instead provided us with 2009 monthly billing data for its residential customers.

The rates within the alternative structures were set to produce the same total revenue as the existing base residential rate for the available sample customers. Therefore, the first step in the rate design process was to calculate the total revenue (accounting for the sample weights) from the base residential rate. The assumptions used when setting the rates were (a) all customers are on the rate (i.e., there is no customer selection issue), and (b) the historical load profiles are retained (i.e., we ignore the potential effect of demand response on customers' usage and bills).

For each of the rate structures, we calculated customer-level bills using the available customer-level load data, the "base" residential rates, and the newly designed rates. We then calculated "instant" bill impacts, which are the bill impacts before the customers modify their load profiles in response to the new price signals. For ease of analysis, scatter plots of bill impacts verses customer's average monthly usage were used. For some of the rate structures, such as IBR or SFV, the bill impacts are strongly related to customer size. For others, such as TOU, this is not the case.

Research Results

Bill Impacts

Tables ES.1 through ES.3 provide results that summarize the bill impact analyses. Four statistics are provided for each utility and rate structure:

- The share of customers that experienced a bill <u>increase</u> of 10% or more on the new rate structure;
- The share of customers that experienced a bill <u>decrease</u> of 10% or more on the new rate structure;
- The average percentage bill impact for customers who use an average of 500 kWh per month or less; and
- The average percentage bill impact for customers who use an average of 2,000 kWh per month or more.

These statistics are intended to facilitate comparisons of bill impacts across rate structures and utilities. Following are the key observations from these tables:

- The flat, TOU, and day-type TOU rates do not produce large percentage load impacts for very many customers (as shown in the "Greater than 10% column").
- The bill impacts for the flat, TOU, and day-type TOU rates are not strongly related to customer usage levels (as illustrated by the similarity of the average bill impacts in the "Low Use " and "High Use" columns).

- The high customer charge in the SFV rate leads to large bill increases for low-use customers (e.g., 27.4 percent for KCP&L's low-use customers). The percentage bill decreases for high-use customers on this rate structure are smaller in magnitude (e.g., 5.7 percent for KCP&L's high-use customers).
- Despite the fact that IBR and SFV have opposite effects by customer usage levels, combining the two rate structures is not enough to offset SFV's adverse bill impacts for low-use customers.

Table ES.1: Summary of Bill Impacts by Rate Structure, *KCP&L*

Rate Structure	Share of Customers by Bill Impact Amount		Average Bill Impact by Customer Usage	
	Greater than 10%	Less than -10%	Low Use (<500 kWh/mo.)	High Use (>2,000 kWh/mo.)
Flat rate	1.3%	0.0%	0.1%	0.6%
SFV	15.1%	0.0%	27.4%	-5.7%
IBR	4.9%	0.0%	-6.6%	10.4%
IBR + SFV	3.9%	0.0%	21.2%	2.6%
TOU	0.3%	0.0%	-0.5%	-0.2%
Day-type TOU	0.3%	0.0%	-0.5%	-0.5%

Table ES.2: Summary of Bill Impacts by Rate Structure, *Westar*

Rate Structure	Share of Customers by Bill Impact Amount		Average Bill Impact by Customer Usage	
	Greater than 10%	Less than -10%	Low Use (<500 kWh/mo.)	High Use (>2,000 kWh/mo.)
Flat rate	0.0%	0.0%	-0.1%	2.6%
SFV	35.9%	6.6%	46.6%	-10.1%
IBR	5.6%	0.0%	-1.5%	8.9%
IBR + SFV	28.8%	0.0%	42.2%	-4.8%
TOU	0.0%	0.0%	0.1%	1.9%
Day-type TOU	0.0%	0.0%	1.4%	1.5%

Table ES.3: Summary of Bill Impacts by Rate Structure, *Midwest*

Rate Structure	Share of Customers by Bill Impact Amount		Average Bill Impact by Customer Usage	
	Greater than 10%	Less than -10%	Low Use (<500 kWh/mo.)	High Use (>2,000 kWh/mo.)
Flat rate	0.0%	0.0%	-2.2%	3.9%
SFV	19.5%	0.4%	20.7%	-8.8%
IBR	6.0%	0.0%	-7.3%	17.9%
IBR + SFV	13.7%	0.0%	16.7%	1.9%

The customer-level bill impacts shown above are those that occur before customers take actions to adapt to the new rate structures (e.g., by shifting or reducing load). Of course, the goal of most of these rate structures is to provide customers with incentives to change behavior. The primary incentive goal of each rate structure can be summarized as follows:

- **SFV:** Eliminates the utility's disincentive to encourage conservation and energy efficiency. As a side effect, SFV reduces the customer-level incentive to conserve because the volumetric rate has been reduced.
- **IBR:** Discourages increases in consumption levels, particularly for high-use customers who face the high tail-block price. Note that low-use customers may experience a *decrease* in their incentive to conserve because they face the relatively low initial block price.
- **TOU:** Encourages customers to shift intra-day load from peak to off-peak hours.
- **Day-type TOU:** Builds upon standard TOU by providing added incentives to reduce usage on high-cost days.

Demand Response

To evaluate the potential magnitude of the usage changes described above, we developed simple elasticity-based models to simulate the changes in usage for each of these rate structures. The results of these simulations show that SFV leads to small increases in overall usage; IBR leads to small decreases in overall usage; TOU leads to decreases in peak-period usage and increases in off-peak period usage; and day-type TOU produces larger shifts of usage from peak to off-peak periods on higher-priced days.

Revenue Attrition

Finally, the report examined the potential for utility revenue attrition (recovering less revenue than forecast) due to customer self selection and demand response. That is, when the utility sets the rates for an optional pricing program, it does not know which customers will select the rate, or how the customers who select the rate will modify their load profiles in response to the new price signals. Our analysis provided an indication of the scale of this potential problem by assuming that customers select the rate that provides them with the lowest bill (customer self selection); and by simulating customer demand response using a range of price responsiveness parameters (i.e., price elasticities). The results indicated that both types of revenue attrition (i.e., due to customer self selection and demand response) are more pronounced for SFV and IBR than they are for TOU and day-type TOU.

1. Introduction and Purpose of the Study

This report documents a residential rate study that Christensen Associates Energy Consulting, LLC (CA Energy Consulting) conducted on behalf of the Kansas Corporation Commission (KCC). The KCC is interested in studying rates that can encourage conservation and/or provide efficient rates. "Conservation" refers to providing customers with incentives to reduce energy consumption. "Efficient rates" are those that provide customers with prices that reflect the marginal cost to serve them, which in theory leads to the most efficient use of resources (e.g., electricity generators).[1] These two goals do not always coincide. For example, a TOU rate may have low off-peak prices to reflect the fact that only low-cost generators are needed to serve off-peak loads. While this price is efficient, it provides less incentive to conserve in off-peak hours than an equivalent flat price (in which the price is the same across all hours).

We used data from Kansas City Power & Light (KCP&L), Westar Energy (Westar), and Midwest Energy (Midwest) to analyze several alternative residential rate structures. The rate structures included in the study are:

- Flat rate;
- Straight-fixed variable (SFV) rate;
- Inclining block rate (IBR);
- Time-of-use (TOU) rate; and
- Day-type TOU rate.[2]

Each of these rate structures is capable of furthering progress toward encouraging conservation or efficient pricing. The advantages and disadvantages of each are described in the report.

Separate rates were designed for each utility using utility-specific residential customer usage data and Southwest Power Pool (SPP) price data (to design the TOU and day-type TOU rates).

The primary goals of the evaluation are the following:

- Design revenue-neutral alternative residential rates for each utility;
- Estimate customer-level bill impacts for each rate structure at historical loads;
- Evaluate the relationship between bill impacts and customer usage levels; and
- Estimate the potential for utility revenue loss (revenue attrition) due to mispricing the new rate options.

[1] The marginal cost of electricity in a particular hour represents the forward-looking change in the cost of generating and delivering electric power that is caused by a change in load in that hour. With the advent of competitive regional wholesale markets, hourly wholesale prices are generally interpreted as representing marginal costs. Retail prices that reflect time-based changes in wholesale costs (e.g., averaged over certain time periods) signal consumers about the cost of consuming power at those times, leading to efficient use of resources.

[2] We did not study TOU or day-type TOU rates for Midwest because they do not have a residential load research sample. Hourly load data are required to design and evaluate these rate structures.

The relationship between bill impacts and customer usage levels is of interest because stakeholders often wish to avoid adverse bill impacts for low income customers, and low income customers are often believed to use less electricity than other customers.[3]

A second goal of the evaluation is to simulate the demand response (i.e., changes in load) that could be expected from each rate structure. Some of the rate structures (e.g., day-type TOU) provide customers with the incentive to reduce load in peak periods (e.g., summer weekday afternoon hours) and we will use existing evidence on customer price responsiveness to provide estimates of the potential magnitude of the load reductions that might be expected from each rate structure.

A third goal is to examine the potential for utility *revenue attrition*, or lost revenues, due to customer self selection and demand response. Revenue attrition due to *customer self-selection* can occur when the utility sets rates without accounting for the tendency of customers to select the rate that is most beneficial for them (i.e., gives them the lowest bill). Revenue attrition due to *customer demand response* can occur when the utility sets rates using historical load profiles and customers modify their usage patterns in response to the pricing signals of their new rate.

After this introductory section, Section 2 describes each of the rate structures included in the study. Section 3 describes our methodology for designing each rate structure. Section 4 presents the estimated bill impacts for each rate structure and utility. Section 5 contains estimates of the customer load reductions and/or load shifting in response to each rate structure. Section 6 contains an analysis of the potential for utility revenue attrition due to customer self selection and demand response. Section 7 provides a summary and conclusions.

2. Description of the Rate Structures Included in the Study

In the sub-sections below, we describe each of the rate structures included in the study. For each of the new structures, we evaluate each structure according to a range of criteria:

- *Economic efficiency*: the extent to which prices reflect marginal costs.
- *Conservation incentives*: the extent to which prices encourage customers to use less energy.
- *Simplicity/transparency for customer*: reflects how easily the customer can understand the rates.
- *Stability in utility revenues and customer bills*: reflects the variability in revenues and bills as changes occur in system conditions or weather.
- *Utility administrative costs*: how costly the rate is to administer.
- *Metering requirements*: the meter technology required to bill the rate.

The rating given for each of these items is qualitative in nature. That is, the exact rating may depend on a variety of factors. The ratings given here are only intended to facilitate comparison across rate structures.

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[3] We may explore the extent to which low income customers are also low use customers in Kansas, subject to data availability and stakeholder interest.

2.1 Base residential rate

Existing utility-specific residential rates (some of which date back to 2007) were used as the basis for all bill impact analyses in the study.

KCP&L's rates are shown in Table 2.1 below. The General Use rate shown in the second column applies to 91 of the 95 customer load profiles that we used in the analysis.

Table 2.1: Base Residential Rates, *KCP&L*

Rate Component	General Use Rate	Water Heater Rate
Customer Charge ($ per customer month)	$9.07	$9.07
Summer Energy 1st 1,000 kWh ($/kWh)	$0.08899	$0.08899
Summer Energy over 1,000 kWh ($/kWh)	$0.08899	$0.08899
Winter Energy 1st 1,000 kWh ($/kWh)	$0.08037	$0.05177
Winter Energy over 1,000 kWh ($/kWh)	$0.08003	$0.07910

Westar's residential rates are shown in Table 2.2 below. In addition to the rates in the table, 10 of the 87 customers in the load research sample are on the Peak Management Rate, which has a $10 per customer-month customer charge, flat energy charge of $0.043189 per kWh, and seasonal demand charges of $1.65 per kW in the winter and $5.45 per kW in the summer. Because this rate tends to produce a lower average rate paid, the bill impacts for the Peak Management customers tend to be quite high. (There is only one rate per alternative structure that applies to all customers.) Therefore, we typically present bill impacts that assume that these customers are on the "standard" residential rate.

Table 2.2: Base Residential Rates, *Westar*

Rate Component	Winter Rate	Summer Rate
Customer Charge ($ per customer month)	$8.00	$8.00
1st 500 kWh ($/kWh)	$0.067892	$0.067892
Next 400 kWh ($/kWh)	$0.067892	$0.067892
All additional kWh ($/kWh)	$0.056045	$0.081240

Table 2.3 shows the residential rates that we used for Midwest. The have a declining block structure in the non-summer months, though the decrease in price is not large across blocks.

Table 2.3: Base Residential Rates, *Midwest*

Month	Customer Charge ($/cust.-mo.)	Energy Block 1 ($/kWh)	Energy Block 2 ($/kWh)	Energy Block 3 ($/kWh)
Jan-09	$ 13.00	$ 0.0888	$ 0.0818	$ 0.0758
Feb-09	$ 13.00	$ 0.0873	$ 0.0803	$ 0.0743
Mar-09	$ 13.00	$ 0.0874	$ 0.0804	$ 0.0744
Apr-09	$ 13.00	$ 0.0905	$ 0.0835	$ 0.0775
May-09	$ 13.00	$ 0.0904	$ 0.0834	$ 0.0774
Jun-09	$ 13.00	$ 0.0926	$ 0.0856	$ 0.0796
Jul-09	$ 13.00	$ 0.0906	n/a	n/a
Aug-09	$ 13.00	$ 0.0892	n/a	n/a
Sep-09	$ 13.00	$ 0.0872	n/a	n/a
Oct-09	$ 13.00	$ 0.0898	$ 0.0828	$ 0.0768
Nov-09	$ 13.00	$ 0.0904	$ 0.0834	$ 0.0774
Dec-09	$ 13.00	$ 0.0938	$ 0.0868	$ 0.0808

2.2 Flat rate

Description

A flat rate is the simplest tariff structure. For our analysis, this structure consists only of a single price per kWh. That is,

Monthly Bill = Flat Price ($/kWh) x Monthly Usage (kWh).

More commonly, the flat rate is combined with a monthly customer charge.[4] That is,

Bill = Customer Charge + Flat Rate ($/kWh) x Monthly Usage (kWh).

The distinguishing characteristic of a flat rate is that the marginal price to the customer does not change with the level of usage or over time.

Economic Efficiency

Rating: Low

Notes: The price does not vary with expected or actual market conditions. The price tends to reflect average costs more than marginal costs.

Conservation Incentives

Rating: Low[5]

Notes: The price does not vary with the level of usage. The price is *below* the cost to serve in high-cost hours. The price *exceeds* the cost to serve in low-cost hours.

Simplicity / Transparency for Customer

Rating: High

Notes: It is easy for a customer to determine the change in bill associated with a change in consumption, as the price does not change by time or with the level of usage.

[4] The customer charge may also be expressed as dollars per day of service.

[5] In off-peak hours, the conservation incentive could be regarded as "high" relative to the cost to serve.

Stability in Utility Revenues and Customer Bills
Rating: Medium
Notes: Revenues / bills change with usage levels, which are affected by weather, economic conditions, etc.

Utility Administrative Costs
Rating: Low
Notes: Bill calculation is easy and rates are set infrequently.

Metering Requirements
A standard energy meter is the only requirement.

2.3 Straight fixed variable (SFV) rate

Description
SFV rates are flat rates in which all fixed costs are recovered through a monthly customer charge.[6] This rate structure is intended to remove the utility's disincentive to promote conservation and energy efficiency that occurs when some or all fixed costs are recovered through volumetric rates.

Economic Efficiency
Rating: Medium
Notes: By recovering all fixed costs through the customer charge, the energy price ought to more closely approximate the marginal cost of energy. However, the energy price does not vary with expected or actual market conditions.

Conservation Incentives
Rating: Low for the customer.
Notes: The customer-level incentive to conserve is lower relative to a flat rate in which fixed costs are partly recovered through the energy price. However, the utility has an increased incentive to promote conservation, which may offset this effect.

Simplicity / Transparency for Customer
Rating: High
Notes: It is easy for a customer to determine the change in bill associated with a change in consumption, as the price does not change by time or with the level of usage.

Stability in Utility Revenues and Customer Bills
Rating: High
Notes: Revenues / bills change with usage levels, but by much less than on a standard flat rate. Utility revenues to recover fixed costs do not vary (on a per-customer basis).

Utility Administrative Costs
Rating: Low
Notes: Bill calculation is easy and rates are set infrequently.

[6] The energy rate does not need to be flat in general, but that is how we designed it for this study.

Metering Requirements
A standard energy meter is the only requirement.

2.4 Inclining block rate (IBR)

Description
Under block rates, the per-unit price of electricity changes with the level of consumption. Block rates may be used to achieve a variety of goals. *Inclining* block rates, in which the rate increases with the level of usage, may be used to encourage conservation or subsidize low-use customers.

We use a three-block rate, which is billed as follows:

> Monthly Bill = Customer Charge + Block 1 Rate ($/kWh) x Block 1 Usage (kWh)
> + Block 2 Rate ($/kWh) x Block 2 Usage (kWh)
> + Block 3 Rate ($/kWh) x Block 3 Usage (kWh)

For an inclining block rate, the rate in the first block is lower than the rate in the second block, which in turn is lower than the rate in the next block. Section 3 describes the methods used to set the block sizes and rates.

Economic Efficiency
Rating: Low
Notes: The price does not vary with expected or actual market conditions. The tail-block price is likely to exceed marginal costs in most hours of the year.

Conservation Incentives
Rating: High for high-use customers, low for low-use customers
Notes: Customers who use enough energy to reach the high-cost blocks face a high price at the margin. Low-use customers have a conservation incentive that is lower than it would be under an equivalent flat rate.

Simplicity / Transparency for Customer
Rating: Low to medium
Notes: Understanding how changes in usage affect bills requires the customer to understand (and possibly forecast) its total usage levels as well as the tariff block sizes and associated rates.

Stability in Utility Revenues and Customer Bills
Rating: Low
Notes: The high tail-block price, combined with variability in tail-block usage levels, can produce relatively high variability in utility revenues and customer bills.

Utility Administrative Costs
Rating: Low

Notes: Bill calculation is easy and rates are set infrequently. Block rates may be more difficult to implement than flat rates depending upon the capabilities of the billing system and the ability to determine appropriate block thresholds and rates.

Metering Requirements
A standard energy meter is the only requirement.

2.5 Time-of-use (TOU) rate

Description
TOU rates contain prices that vary across the hours of the day. These rates are fixed within a time-of-use period and do not respond to changing system cost conditions. The primary motivation for TOU rates is that electricity costs vary across the hours of the day in reasonably predictable ways. By establishing different rates for different periods of the day, it is possible for rates to be more reflective of average differences in the cost to serve. TOU rates provide customers with an incentive to reduce peak-period usage, perhaps by shifting it to lower-cost hours. For this study, the TOU rates have two pricing periods (peak and off-peak) per season (summer is defined as May through September and all other months are defined as non-summer).

Economic Efficiency
Rating: Medium
Notes: TOU rates account for average variations in electricity costs by hour and day type. Therefore, the rates can reflect expected marginal costs to serve by time periods. However, on any particular day, there can still be a substantial difference between, for example, the TOU peak price and the peak-period marginal energy costs on that day.

Conservation Incentives
Rating: Low in off-peak hours, higher in peak-hours
Notes: Relative to a flat rate, the incentive to conserve is higher during peak hours and lower during off-peak hours.[7]

Simplicity / Transparency for Customer
Rating: Medium
Notes: In order for a customer to understand how changes in usage affect their bill, the customer must know the relevant TOU time periods and the applicable rates. However, the schedule of rates does not change.

Stability in Utility Revenues and Customer Bills
Rating: Medium
Notes: Relative to a flat rate, TOU rates may increase the variability of utility revenues and customer bills because of the higher peak-period prices. However, costs are expected to be higher during those hours as well, so the variability of *net* revenues may not increase.

Utility Administrative Costs

[7] This assumes that the flat rate and the TOU rate are set to recover the same level of revenue. Therefore, setting the peak period rate higher than the flat rate requires the off-peak rate to be lower than the flat rate.

Rating: Low
Notes: Within each TOU pricing period, the bill calculation is simply the metered usage multiplied by the applicable rate.

Metering Requirements
A time-of-use energy meter is required.

2.6 Day-type TOU rate

Description
A day-type TOU rate allows TOU rates to vary with expected system conditions. For example, the rate may consist of three sets of summer TOU rates (we use a standard TOU rate for the non-summer months):

- "Red", or high rates that apply to a maximum of 5 summer non-holiday weekdays;
- "Yellow", or medium rates that apply to a maximum of 15 summer non-holiday days; and
- "Green", or low rates that apply to the remaining summer days.

Customers are provided with the green, yellow, and red TOU rates at the beginning of the year or season, but do not know ahead of time which of the three sets of rates will be in effect on a particular day until the preceding afternoon.

This rate structure is an extension of critical peak pricing (CPP), which typically has two day types: "critical days", in which the peak-period price is very high (sometimes $1 per kWh or more), and all other days.

Economic Efficiency
Rating: High
Notes: Rates account for variations in electricity costs by hour and day type. Day-type TOU moves beyond standard TOU rates by better aligning the rates with market conditions (on a day-ahead basis).

Conservation Incentives
Rating: Low in off-peak hours, higher in peak-hours
Notes: Relative to a flat rate, the incentive to conserve is higher during peak hours and lower during off-peak hours.

Simplicity / Transparency for Customer
Rating: Low to medium
Notes: In order for a customer to understand how changes in usage affect their bill, the customer must know the time periods during which rates apply and the applicable rates, and be prepared to obtain information on the following day’s type, as the schedule of TOU rates that applies on a particular day changes with day-ahead notice.

Stability in Utility Revenues and Customer Bills
Rating: Medium

Notes: Relative to a flat rate, Day-type TOU rates may increase the variability of utility revenues and customer bills because of the higher peak-period prices. However, costs are expected to be higher during those hours as well, so the variability of *net* revenues may not increase.

Utility Administrative Costs
Rating: Medium
Notes: The utility must develop a protocol for determining the TOU day type for the following day and communicating that information to its customers. Also, three sets of rates must be designed.

Metering Requirements
An interval meter is required.

3. Rate Design Methodology

3.1 Prepare customer usage data

KCP&L and Westar provided us with 2007 hourly data from their residential load research samples. Midwest does not have a load research sample, and instead provided us with 2009 monthly billing data for its residential customers. We examined the usage data to ensure that they provided a reasonable basis for bill comparisons under the potential alternative rate designs. In some cases for the hourly customer data, we could "clean" a relatively small number of observations (i.e., to remove data missing because of service outages or metering error) and retain the customer's data. In other cases, we excluded the customer's data entirely, typically because it appeared that the customer closed its account during the sample timeframe.

Table 3.1 provides a summary of the number of customers for whom we received data and the number of those customers that we retained for the analysis, for each utility. For Midwest, we used only M system, regular residential schedule customers. For KCP&L and Westar, we used the utility-provided sample weights to ensure that each customer was given the proper weight in the study.[8]

[8] For example, utilities often over-sample high-use customers in their load research samples, to ensure that their profile is represented in the limited number interval data that can be obtained. When using the data to calculate a class load profile, these over-sampled customers are given less weight than other customers to ensure that the profile properly represents the average class usage pattern.

Table 3.1: Number of Customers used in the Analysis, by Utility

Utility	# of Customers in Raw Data	# of Customers Retained for the Analysis
KCP&L	105	95
Westar	114	87
Midwest	4,532	3,620

3.2 Rate design summary

The rates within the alternative structures are set to produce the same total revenue as the existing base residential rate (in Section 2.1) for the available sample customers. Therefore, the first step in the rate design process is to calculate the total revenue (accounting for the sample weights) from the base residential rate. The assumptions used when setting the rates are a) all customers are on the rate (i.e., there is no customer selection issue), and b) the historical load profiles are retained (i.e., we ignore the potential effect of demand response on customers' usage and bills).

3.2.1 Flat rate

The flat rate is comparatively easy to set: we simply solve for the single rate that provides the same revenue as the base residential rate at the historical usage level. We set the customer charge at its level in the base residential rate. Table 3.2 summarizes the flat rates that were set for each utility.[9]

Table 3.2: Flat Rate ($/kWh), by Utility

Utility	Flat Rate ($/kWh)
KCP&L	$0.08570
Westar	$0.06779
Midwest	$0.08595

3.2.2 Straight-fixed variable rate

Two steps are required to set the SFV rate. First, we use cost-of-service information to obtain the amount of fixed costs per customer, which is then converted into a monthly customer charge.[10] Given the revenue implied by this customer charge, we then solve for the flat energy price that produces the same amount of total revenue (based on the sample-weighted average bill from the load research sample for KCP&L and Westar) as the base rate. Table 3.3 summarizes the SFV rates that were set for each utility.

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[9] The Westar rate assumes that no customers are on the Peak Management rate. If the appropriate customers are billed on the Peak Management rate (i.e., the customer is in the load research sample and is on the Peak Management rate), the flat rate goes down to $0.06498.

[10] It would be quite easy for us to update the results if the utilities believe that a different customer charge is required to recover all fixed costs.

Table 3.3: SFV Rates, by Utility

Utility	Customer Charge ($ per cust-mo.)	Flat Rate ($/kWh)
KCP&L	$19.72	$0.07578
Westar	$25.00	$0.05198
Midwest	$26.21	$0.06921

3.2.3 Inclining block rate

To create the Inclining Block Rates (IBR), we examined the distribution of monthly usage amounts for residential customers. We allow for three block prices in each season. The thresholds were established using the distribution of customer monthly usage values in 2007 for Westar and KCP&L and 2009 for Midwest. Within each season, we attempted to set the thresholds such that approximately one-third of the customers fall into each category (e.g., one-third of the customers have monthly usage that reaches into the second block). The block rates were set to be revenue neutral within season, where the first block price is 10% lower than the second block price, and the third block price is 25% higher than the second block price. While somewhat arbitrary, these relationships between block prices reflect the goal of increasing the customer-level incentive to conserve, at least for customers who are exposed to the higher block prices. The resulting block definitions and revenue neutral rates for each utility are shown in Tables 3.4 through 3.6.

Table 3.4: Inclining Block Definitions and Prices ($/kWh), *KCP&L*

Block Description	Block Definition	Rate
Summer First	Less than 900 kWh	$0.07934
Summer Second	900 kWh to 1,500 kWh	$0.08816
Summer Third	More than 1,500 kWh	$0.11020
Non-summer First	Less than 700 kWh	$0.07591
Non-summer Second	700 kWh to 1,000 kWh	$0.08435
Non-summer Third	More than 1,000 kWh	$0.10543

Table 3.5: Inclining Block Definitions and Prices ($/kWh), *Westar*

Block Description	Block Definition	Rate
Summer First	Less than 1,200 kWh	$0.06736
Summer Second	1,200 kWh to 1,800 kWh	$0.07485
Summer Third	More than 1,800 kWh	$0.09356
Non-summer First	Less than 600 kWh	$0.05518
Non-summer Second	600 kWh to 1,000 kWh	$0.06132
Non-summer Third	More than 1,000 kWh	$0.07665

Table 3.6: Inclining Block Definitions and Prices ($/kWh), *Midwest*

Block Description	Block Definition	Rate
Summer First	Less than 800 kWh	$0.08211
Summer Second	800 kWh to 1,300 kWh	$0.09123
Summer Third	More than 1,300 kWh	$0.11404
Non-summer First	Less than 500 kWh	$0.07668
Non-summer Second	500 kWh to 800 kWh	$0.08520
Non-summer Third	More than 800 kWh	$0.10649

An alternative, and possibly more effective, method for defining block sizes is to make them customer specific, based on each customer's historical usage levels. This method is currently being tested in a residential pilot program at Commonwealth Edison. While it is administratively more complicated, this method has the potential to provide every customer with an increased incentive to reduce usage (relative to current or flat rates), while maintaining revenue neutrality for all customers at their historical usage pattern. Under "standard" inclining block pricing (in which everyone has the same block definitions), low-use customers are likely to experience *reductions* in their incentive to conserve and their bills decrease. In contrast, high-use customers are likely to experience bill increases, along with greater incentives to conserve. We do not explicitly analyze IBR with customer-specific blocks in this study, but we may examine them in greater depth if there is sufficient interest from the stakeholders.

3.2.4 Time-of-use rate

We set TOU rates for KCP&L and Westar. The lack of hourly load data at Midwest left us unable to examine time-differentiated rates for their residential customers.

Under the assumption that TOU rates should reflect expected differences in marginal costs by time period, and that wholesale market prices signal those marginal costs, we used 2007 hourly data on Southwest Power Pool (SPP) prices in the design of TOU rates. We combined that data with the load research sample data to determine the TOU seasons, pricing periods, and price ratios across pricing periods. The goal is to create pricing periods that contain hours that are most alike in terms of marginal costs (e.g., hours of high costs and low costs), and therefore produce peak to off-peak price ratios that reflect the greatest difference between costs by time period. We set the summer season to be May through September and the non-summer season to be all other months. During the summer season, the peak hours are from 11:00 a.m. to 7:00 p.m. During the non-summer season, the peak hours are from 6 a.m. to 10 p.m. Weekends and holidays have the same TOU pricing periods as non-holiday weekdays. Note that these are broader peak periods than we prefer to select, particularly in the non-summer months. While the periods match the patterns of the SPP data, broad peak periods have the disadvantage of reducing the customers' ability to reduce peak load and/or shift load to off-peak hours.

As with the other rates, we set the TOU rates to be revenue neutral to the base rate (prior to any demand response). To do this, we assumed that the price ratios across TOU pricing periods equal the ratio of SPP prices across pricing periods (using 2007 SPP data). We then solved for the set of rates (given the ratios) that obtains revenue neutrality.[11] Tables 3.7 and 3.8 show the resulting TOU rates for each utility.

Table 3.7: TOU Periods and Prices ($/kWh), *KCP&L*

TOU Pricing Period	Hours	Rate
Summer Peak	11 a.m. to 7 p.m.	$0.11135
Summer Off-peak	7 p.m. to 11 a.m.	$0.07134
Non-summer Peak	6 a.m. to 10 p.m.	$0.09362
Non-summer Off-peak	10 p.m. to 6 a.m.	$0.05849

Table 3.8: TOU Periods and Prices ($/kWh), *Westar*

TOU Pricing Period	Hours	Rate
Summer Peak	11 a.m. to 7 p.m.	$0.08777
Summer Off-peak	7 p.m. to 11 a.m.	$0.05648
Non-summer Peak	6 a.m. to 10 p.m.	$0.07422
Non-summer Off-peak	10 p.m. to 6 a.m.	$0.04617

3.2.5 Day-type TOU rate

Day-type TOU rates allow prices to vary with day-ahead notice during the summer months, and therefore better reflect wholesale costs, particularly on the relatively few high-load and high-cost days during the summer. The non-summer TOU rates and all peak and off-peak hour definitions are identical to the values presented in Section 3.2.4. Three sets of TOU rates are set:

- "Red", or high rates, which apply on up to five summer days;
- "Yellow", or moderate rates, which apply on up to fifteen summer days; and
- "Green", or low rates, which apply on all of the remaining summer days.

The day types were set using SPP prices, where the five highest-price (defined as the average peak-period price) weekdays are defined as "Red", the next fifteen highest-price weekdays are defined as "Yellow", and the remaining days are defined as "Green".

The 2007 SPP prices that we used are not high enough (even on the highest-price days) to create a significant amount of differentiation between the prices on the different day types, as might be seen in some years. Therefore, to illustrate a price structure more reflective of a wider distribution of wholesale prices, we have set the Red and Yellow prices to relatively high levels and high ratios of peak to off-peak prices (compared to 2007 values), and solved for the Green prices that obtain revenue neutrality to the base residential rates. The Green prices are set using the peak to off-peak price ratio observed in the SPP prices for the Green days. Tables 3.9 and 3.10 contain the summer day-type TOU prices for KCP&L and Westar, respectively.[12]

[11] This is not the only method that can be used to create revenue neutral TOU rates. For example, the peak rate could be set at the expected market marginal cost with the off-peak rate set to obtain revenue neutrality.
[12] Utilities in some states have developed rates similar to day-type TOU (e.g., critical-peak pricing, or CPP) in which peak prices on "critical" days include an allocation of avoided *capacity* costs as well as energy costs, thus resulting in substantially higher critical-day peak prices, on the order of $1.00/kWh or more.

Table 3.9: Day-type TOU Prices by Day Type ($/kWh), *KCP&L*

Day Type	Peak	Off-peak
Red (5 days)	$0.24000	$0.08000
Yellow (15 days)	$0.15000	$0.07500
Green (all other days)	$0.10284	$0.06745

Table 3.10: Day-type TOU Prices by Day Type ($/kWh), *Westar*

Day Type	Peak	Off-peak
Red (5 days)	$0.24000	$0.08000
Yellow (15 days)	$0.15000	$0.07500
Green (all other days)	$0.07538	$0.04967

4. Bill Impacts

For each of the rate structures, we calculated customer-level bills using the available customer-level load data, the "base" residential rates, and each of the rates described in Section 3. We then calculated bill impacts at the customers' historical usage patterns, before accounting for any possible modification in customers' load profiles in response to the new price signals.

The bill impacts are displayed as scatter plots against each customer's average monthly usage (in kWh). This allows for an easy examination of both the range of magnitude of the bill impacts, as well as how the bill impacts vary with customer usage. For some of the rate structures, such as IBR or SFV, the bill impacts are strongly related to customer usage. For others, such as TOU, this is not the case, as bill impacts are related to differences in percentage of usage in peak periods.

The relationship between bill impacts and customer usage may be of interest because customer usage is often equated with customer income levels, where smaller customers are believed to have lower income levels. Therefore, bill impacts that adversely affect low-use customers are believed to reflect adverse outcomes for low-income customers. Utilities typically do not have customer income data, so it is not a straightforward exercise to determine whether this relationship between income and usage actually exists. However, some studies have attempted to make use of Census data to explore the link between usage and income. One example is a recent article that examined the redistribution of income that occurs under inclining block rates.[13] We could consider implementing a similar analysis as an extension of this work if there is sufficient interest from the stakeholders.

The sub-sections below present bill impacts for each utility's residential customers, ordered by rate structure.

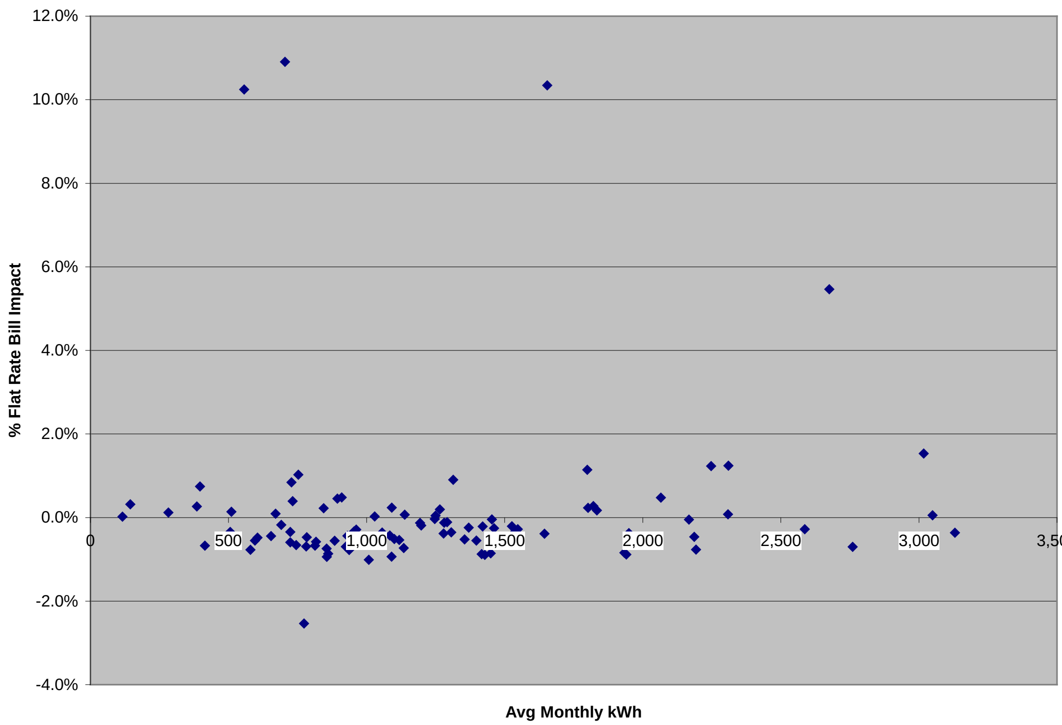
4.1 Flat rate

Figures 4.1 through 4.4 show the customer-level bill impacts for the flat rates shown in Table 3.2. For KCP&L (shown in Figure 4.1), there are four customers who have

[13] Borenstein, Severin. "The Redistributional Impact of Non-Linear Electricity Pricing", Energy Institute at Haas Working Paper Series, March 2010.

significantly higher bill impacts than the other customers (i.e., approximately 10 percent, where the bill impact for majority of customers is between +/- 2 percent). These customers are on the space heating rate, which offers lower winter rates than the standard residential rate. Because one flat rate is set to apply to all of the residential customers, the space heating customers experience a more adverse bill impact than the others.

Figure 4.1: Percentage Flat Rate Bill Impacts, *KCP&L*



A similar situation is present for Westar, shown in Figure 4.2. In this case, ten of the load research sample customers are on the Peak Management Rate, which contains a single energy price and a demand charge. The average price on this rate is significantly below the average price on the standard residential rate, so these customers experience a large bill increase when they are migrated to the flat rate. Because these customers are such outliers relative to the standard residential customers, for the remainder of the analysis we treat them as standard rate customers, and calculate their base bills at the standard rate. This is shown in Figure 4.3.

Figure 4.2: Percentage Flat Rate Bill Impacts, *Westar with Peak Management*

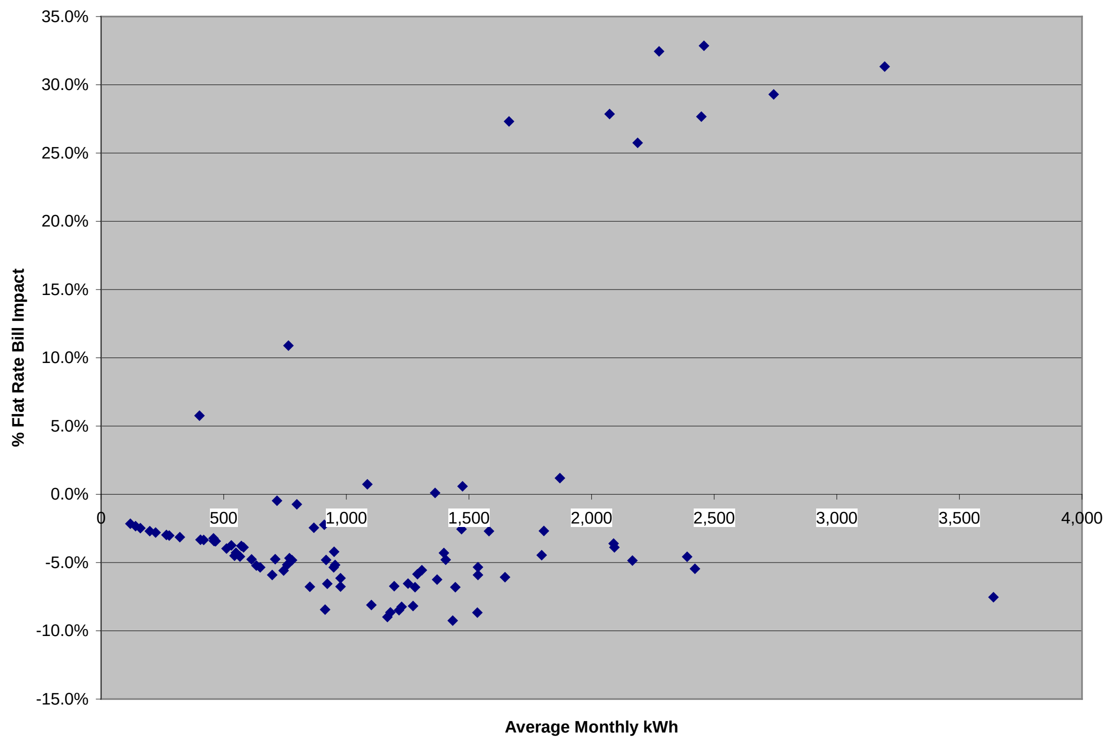


Figure 4.3: Percentage Flat Rate Bill Impacts, *Westar*

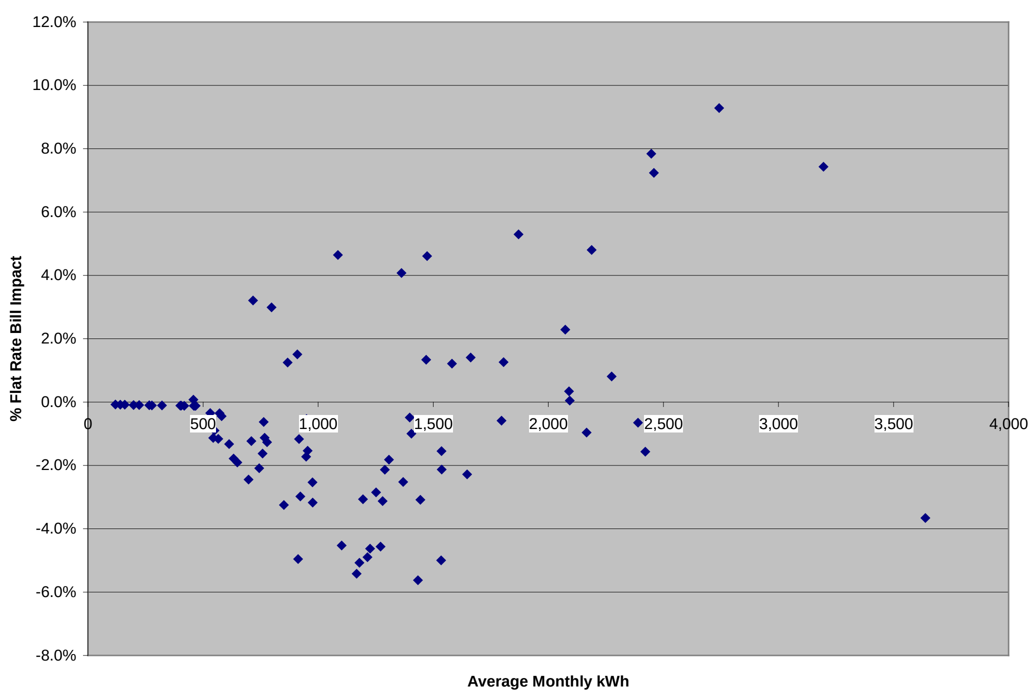
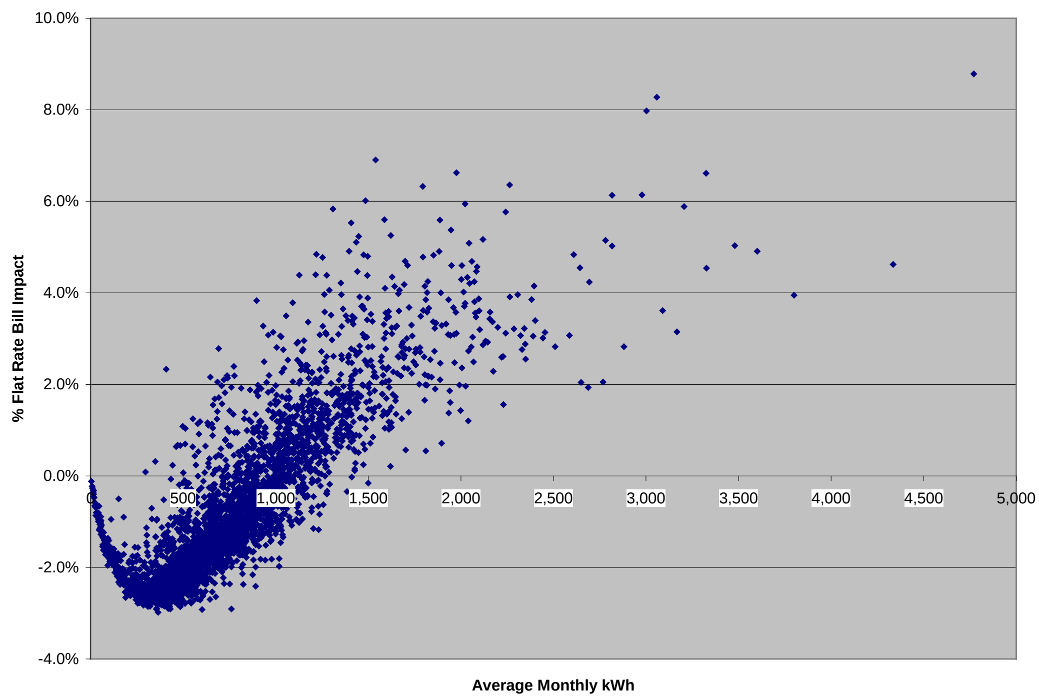


Figure 4.4 shows the bill impacts for Midwest's residential customers. Notice that data for many more customers are available (because we use billing data and not hourly data), which may provide a more complete picture of the distribution of bill impacts.

Figure 4.4: Percentage Flat Rate Bill Impacts, *Midwest*



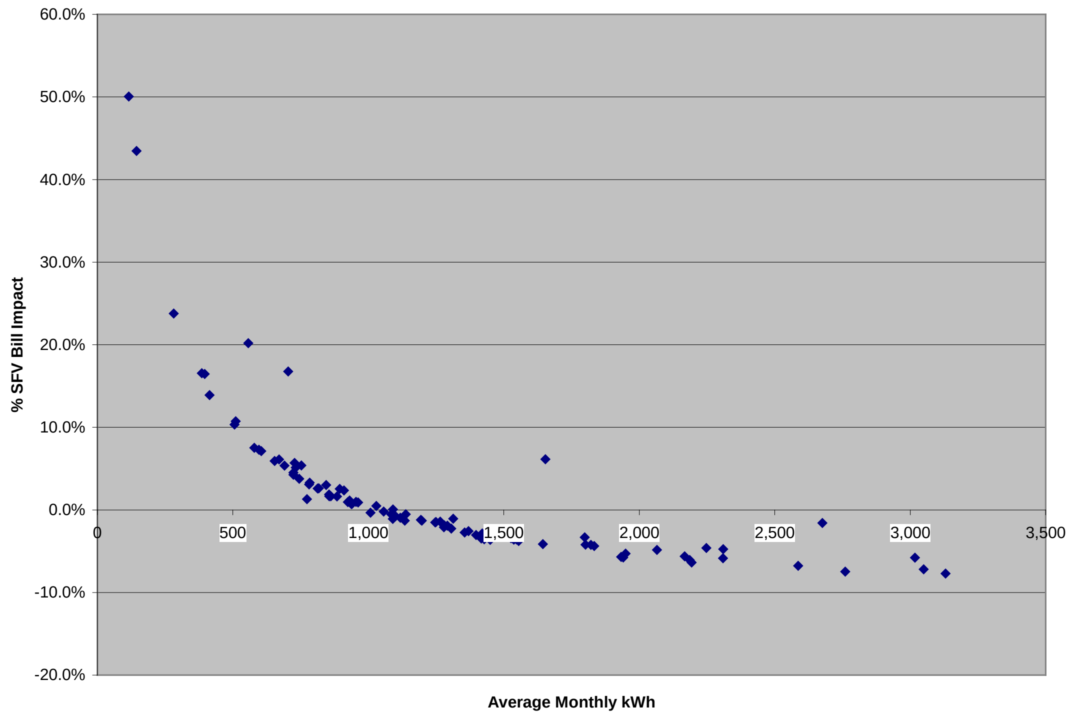
For Midwest, the bill impacts are strongly related to customer size, with bill decreases for small customers and bill increases for large customers. This is because Midwest's base residential rate has a declining block structure in nine of the twelve months of the year, and the tail block rate is 1.3 cents/kWh lower than the rate in the first block. This effect is not as pronounced for KCP&L and Westar. For KCP&L most of the customers are on a rate that has seasonal differentiation with a declining block in the winter months, but the magnitude of the decline is trivial ($0.00034 per kWh). For Westar, the effect of the declining block rates in the winter months is offset by the use of inclining block rates in the summer months.

4.2 Straight fixed variable rate

Figures 4.5 through 4.7 show the bill impacts for straight fixed variables rates in Table 3.3. These have the same structure as the flat rates presented in Section 4.1, but with higher customer charges set to cover all fixed costs. The basic story is the same for all three utilities: because of the increase in the customer charge, low-use customers experience bill increases and high-use customers experience bill decreases. The magnitude of the bill increases for low-use customers varies somewhat across utilities. One way to quantify this is the share of customers who experience a bill increase of more than 20 percent, which is 20 percent for Westar, 9.4 percent for Midwest, and 3.2 percent for KCP&L.[14]

While Westar has the highest share of customers who experience an especially adverse bill impact, it also has the highest share of customers who experience significant bill *reductions* on SFV. Approximately 6 percent of Westar's customers experience more than a 10 percent bill decrease on SFV. In contrast, none of KCP&L's customers and only 0.4 percent of Midwest's customers achieve that level of bill reduction on SFV.[15]

Figure 4.5: Percentage SFV Rate Bill Impacts, *KCP&L*



[14] The shares are calculated using the customer sample weights, as opposed to simply using the share of customers in the available sample.

[15] We are aware of a few utilities that have attempted to reduce the adverse effect of higher customer charges on low-use customers by instituting a graduated customer charge, on the theory that the amount of fixed costs that customers cause the utility to incur are related to their usage level.

Figure 4.6: Percentage SFV Rate Bill Impacts, *Westar*

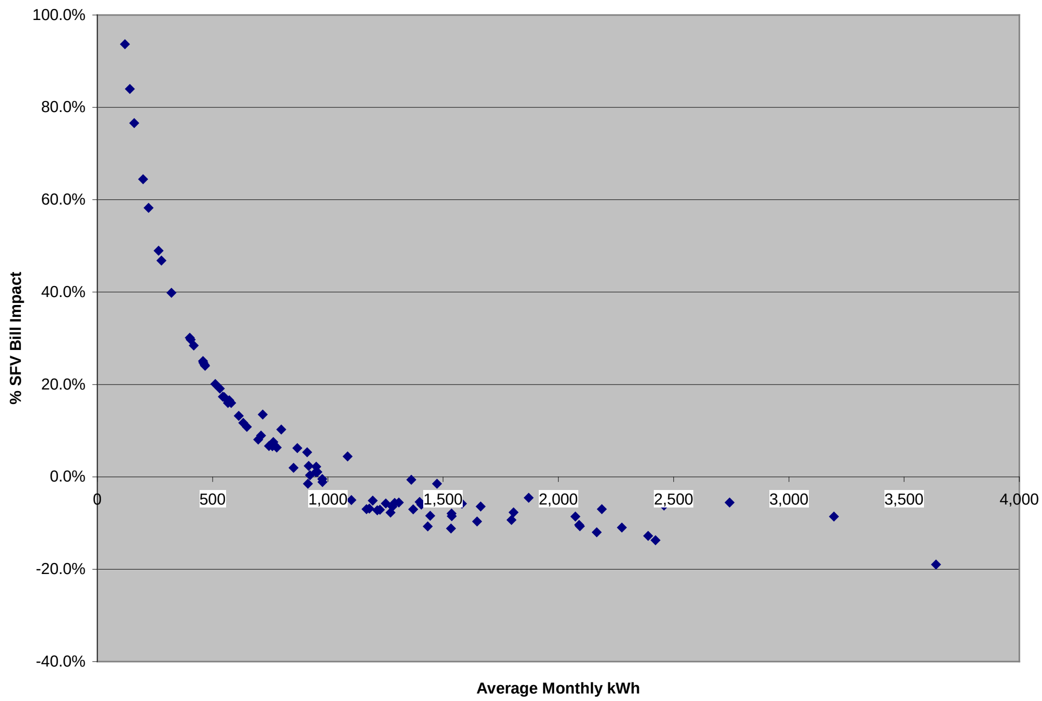
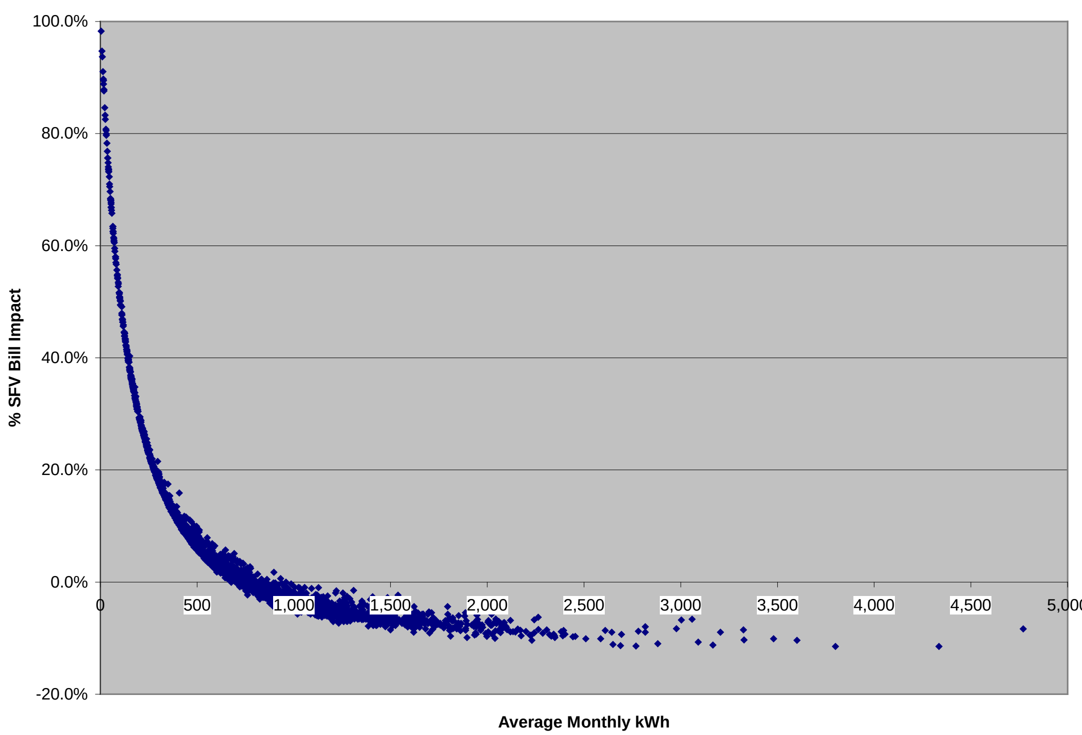


Figure 4.7: Percentage SFV Rate Bill Impacts, *Midwest*



4.3 Inclining block rates

The bill impacts associated with the inclining block rates introduced in Tables 3.4 through 3.6 are shown in Figures 4.8 through 4.10. IBR, in which the rate increases with the usage level, produces bill impacts that benefit low-use customers at the expense of high-use customers. This is the opposite of the effect of SFV rates.

Figure 4.8: Percentage IBR Bill Impacts, *KCP&L*

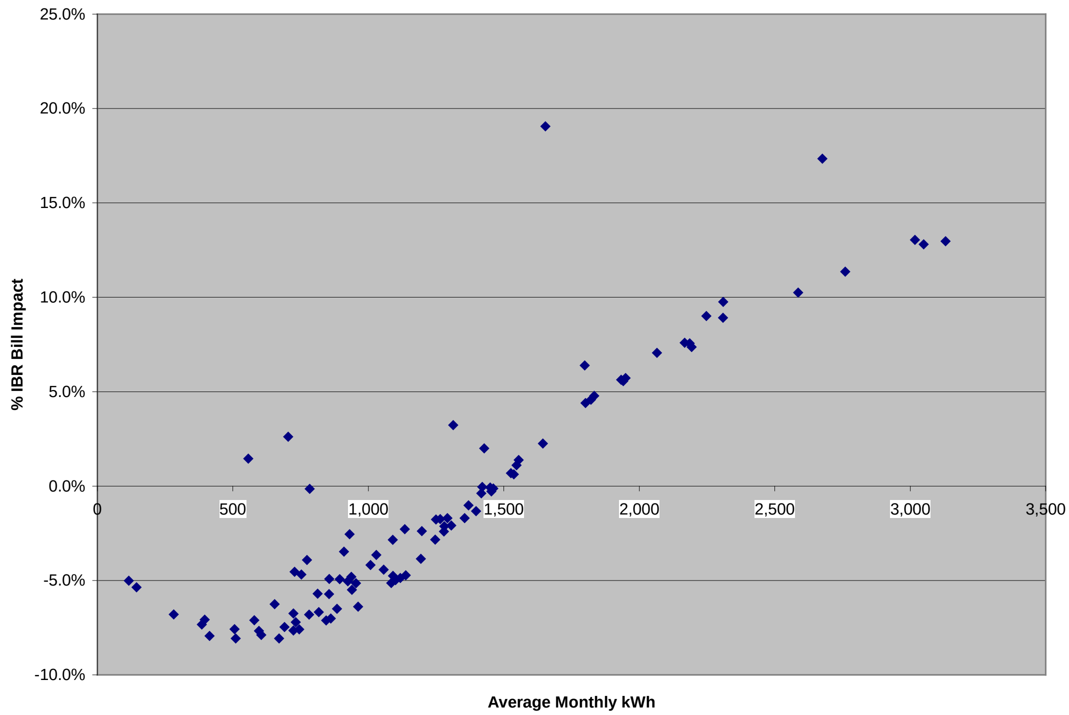


Figure 4.9: Percentage IBR Bill Impacts, *Westar*

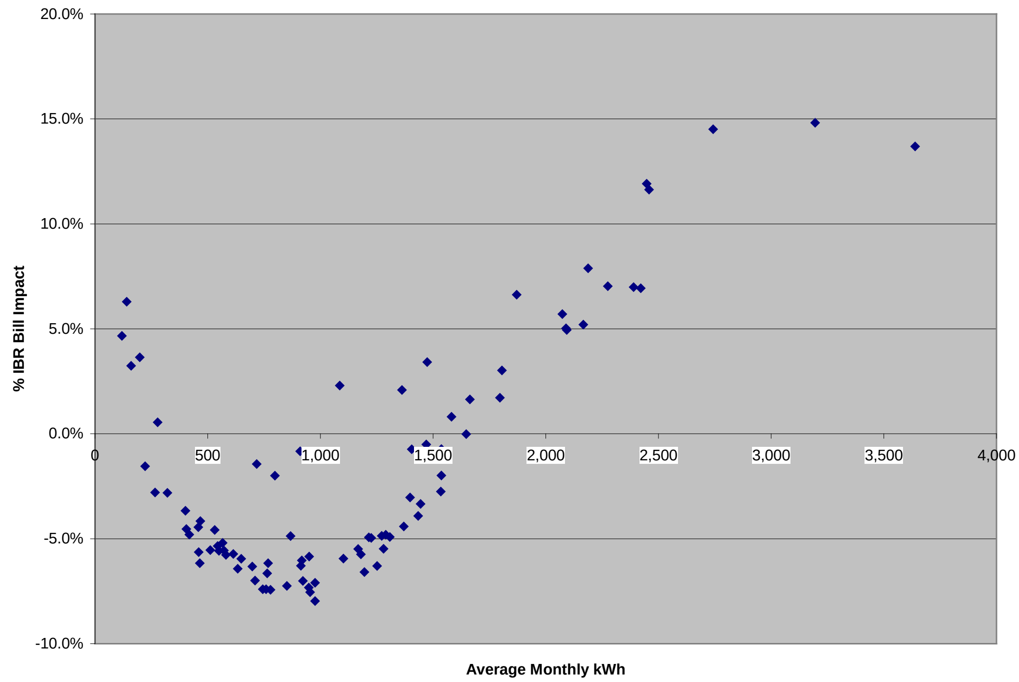
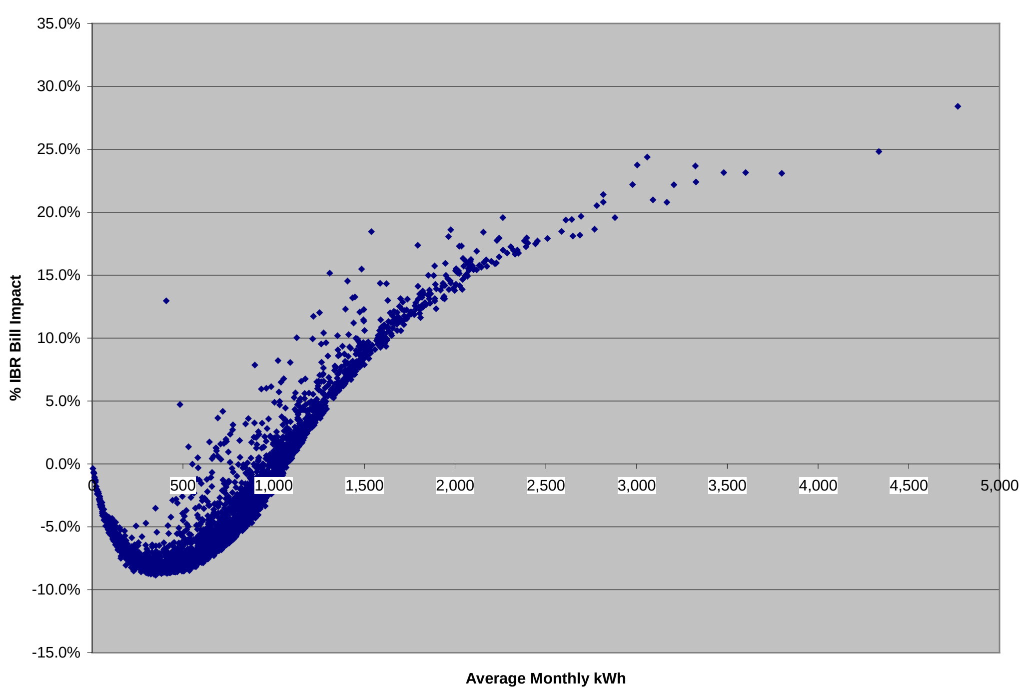


Figure 4.10: Percentage IBR Bill Impacts, *Midwest*



The distribution of the percentage bill impacts is similar for the three utilities. Table 4.1 shows the share of customers on the high and low end of the bill impacts. Across all three utilities, approximately five percent of the customers experience a bill increase of at least ten percent on IBR (these are the large customers), while 40 to 50 percent of the customers experience at least a five percent decrease (these are low-use customers).

Table 4.1: Share of High and Low Bill Impacts, by Utility

Utility	Share with 10% or higher	Share with -5% or lower
KCP&L	4.9%	45.8%
Westar	5.6%	42.1%
Midwest	6.0%	50.0%

The "break-even" usage level (where the bill impact is zero) is approximately 1,500 kWh per month for KCP&L and Westar and 1,000 kWh per month for Midwest.

4.4 IBR and SFV

It is useful to note that the alternative rate structures are not mutually exclusive. For example, we can combine the SFV and IBR structures by simply increasing the customer charge on IBR and re-calculating the rates to obtain revenue neutrality. This is an intuitively appealing combination because of the potential for offsetting bill impacts. For example, SFV tends to increase bills for low-use customers while IBR tends to reduce them.

Figures 4.11 through 4.13 show the resulting bill impacts of a combined SFV/IBR rate. The results indicate that the SFV bill impacts "dominate" the IBR bill impacts for low-use customers. That is, for low-use customers, the higher customer charge produces larger effects than the reduction in the initial block price.

Interestingly, for KCP&L and Midwest, the combination of SFV and IBR also produces adverse bill impacts for the largest customers. The "middle class" of customers, with usage ranging from approximately 750 to 1,500 kWh per month, tends to benefit from this combination of rate structures.

Figure 4.11: Percentage IBR+SFV Bill Impacts, *KCP&L*

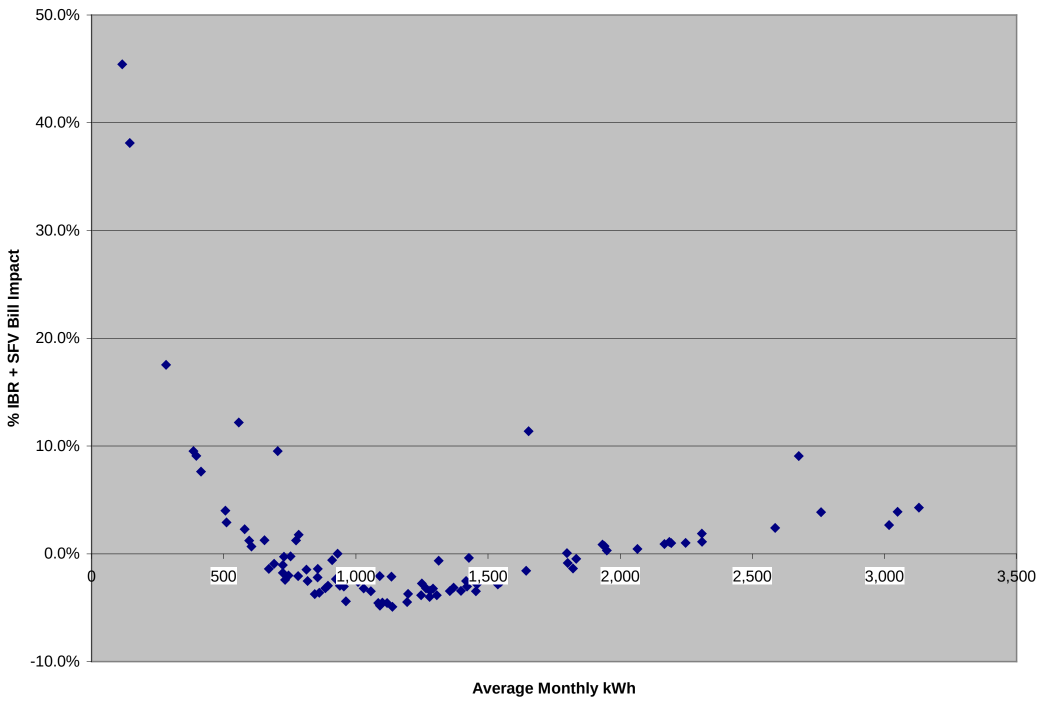


Figure 4.12: Percentage IBR+SFV Bill Impacts, *Westar*

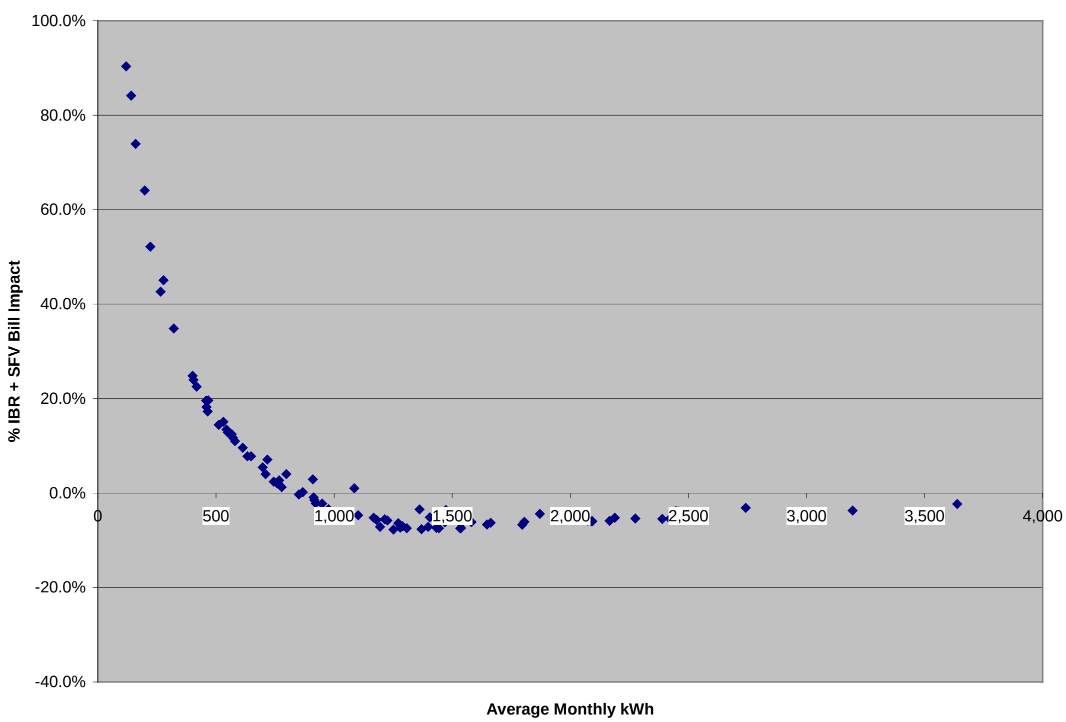
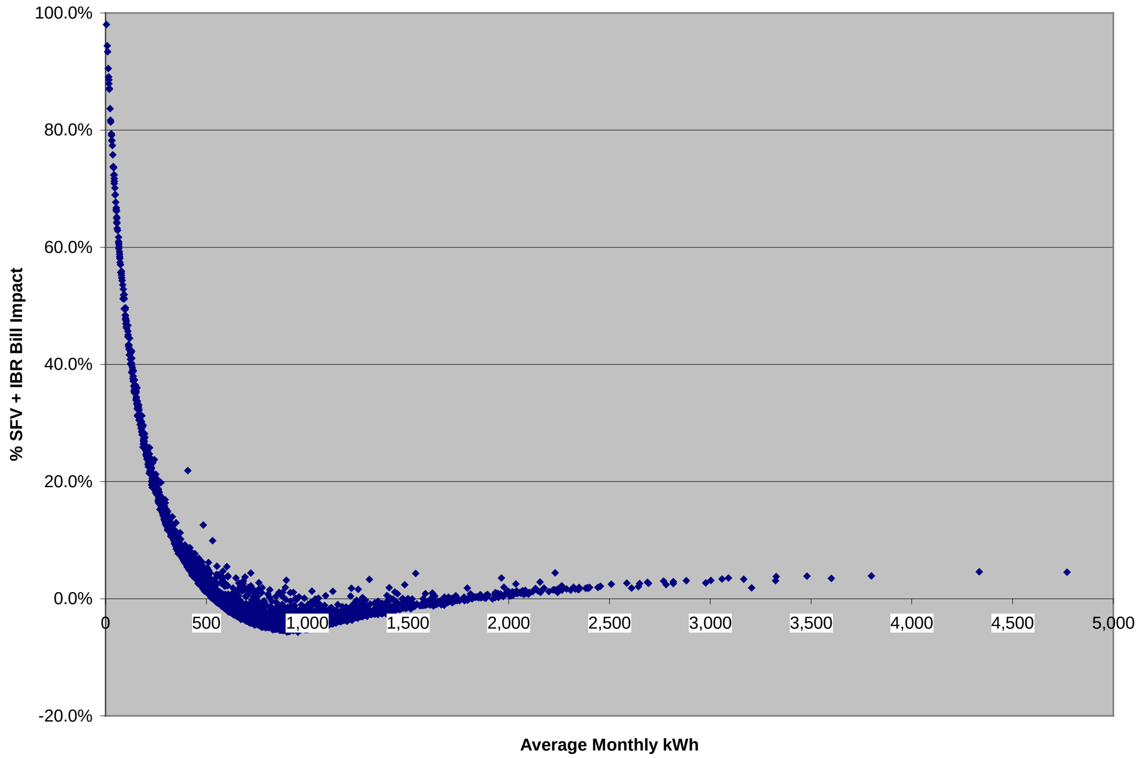


Figure 4.13: Percentage IBR+SFV Bill Impacts, *Midwest*



4.5 Time-of-use rates

The bill impacts associated with the TOU rates in Tables 3.7 and 3.8 are shown in Figures 4.14 and 4.15. Note that we cannot analyze TOU rates for Midwest because they do not have the hourly usage data required to bill the rate (i.e., to obtain sales by pricing period).

The bill impacts associated with TOU rates are related to the *timing* of a customer's usage (e.g., the share of usage that is in peak hours) rather than the *amount* of the customer's usage, as is the case for SFV and IBR. The distributions of bill impacts in the figures reflect this difference, showing no strong relationship between bill impacts and customer usage levels.

The magnitude of the bill impacts for TOU rates is lower than we observed for SFV and IBR. The vast majority of the bill impacts are within +/- 5 percent, with 98 percent of KCP&L's customers and 90 percent of Westar's customers falling within that range.

Figure 4.14: Percentage TOU Bill Impacts, *KCP&L*

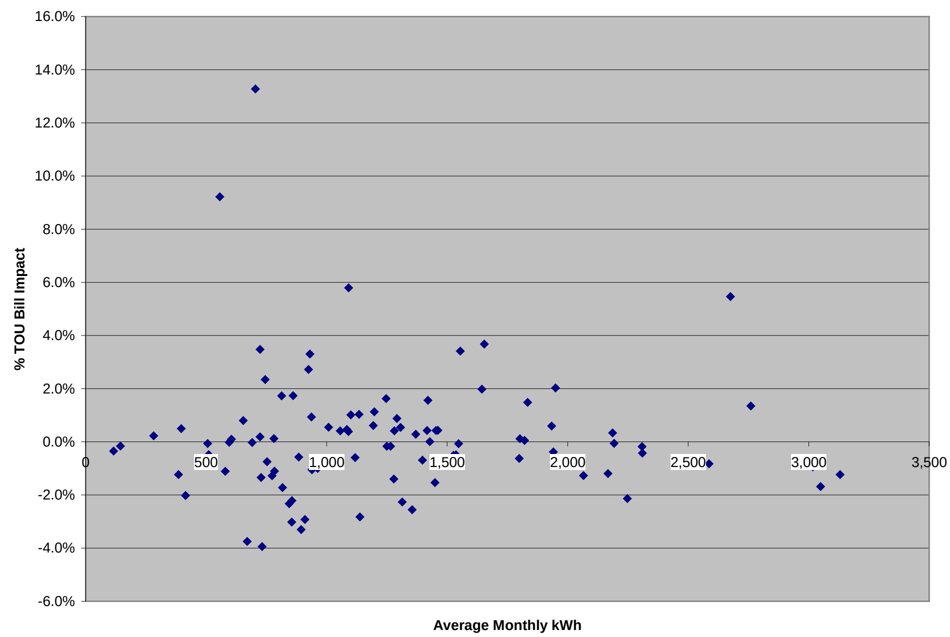
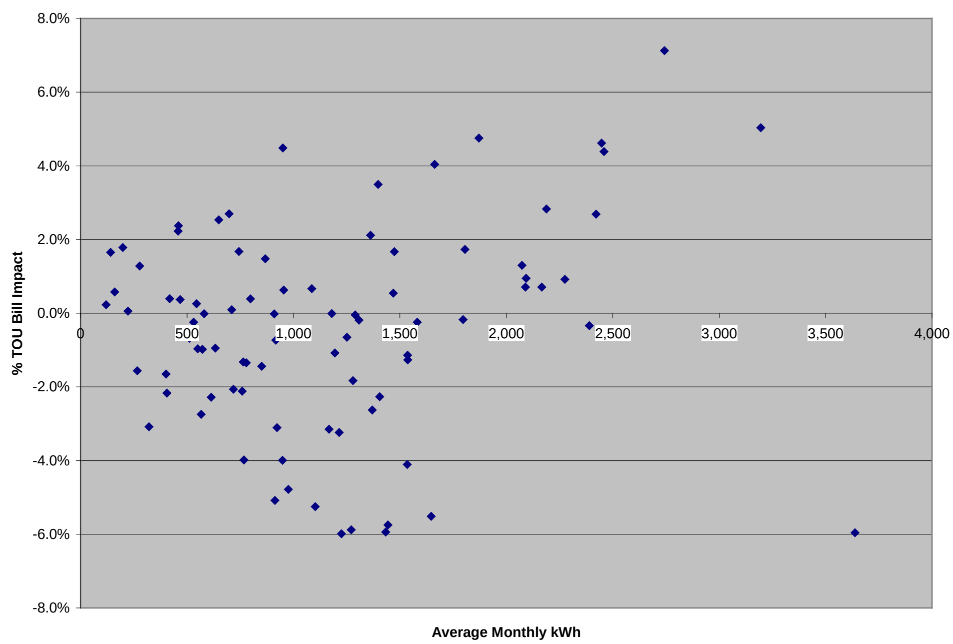


Figure 4.15: Percentage TOU Bill Impacts, *Westar*



4.6 Day-type TOU rates

The bill impacts associated with the day-type TOU rates in Tables 3.9 and 3.10 are shown in Figures 4.16 and 4.17. As was the case with TOU rates, we are not able to analyze this rate structure for Midwest.

This rate structure builds upon the TOU rates to provide higher price signals on days in which the wholesale market prices are the highest. Therefore, a customer's bill impact (prior to demand response) will depend upon the level of usage on these high-cost days. Because wholesale market prices are driven by electricity demand, and air conditioning load is often a significant driver of demand, it is reasonable to suppose that the customers whose load is most weather dependent will have the most adverse bill impact on day-type TOU rates (because they tend to use the most on the hottest, highest cost days).

The figures show that, as with TOU rates, the day-type TOU bill impacts are not strongly related to customer size. In fact, the bill impacts are quite similar to the TOU bill impacts. The correlation between the TOU and day-type TOU bill impacts is 0.98 for KCP&L and 0.92 for Westar. This indicates that, for the most part, a customer who is helped (or harmed) by TOU rates will also be helped (or harmed) by day-type TOU rates.

Figure 4.16: Percentage Day-Type TOU Bill Impacts, *KCP&L*

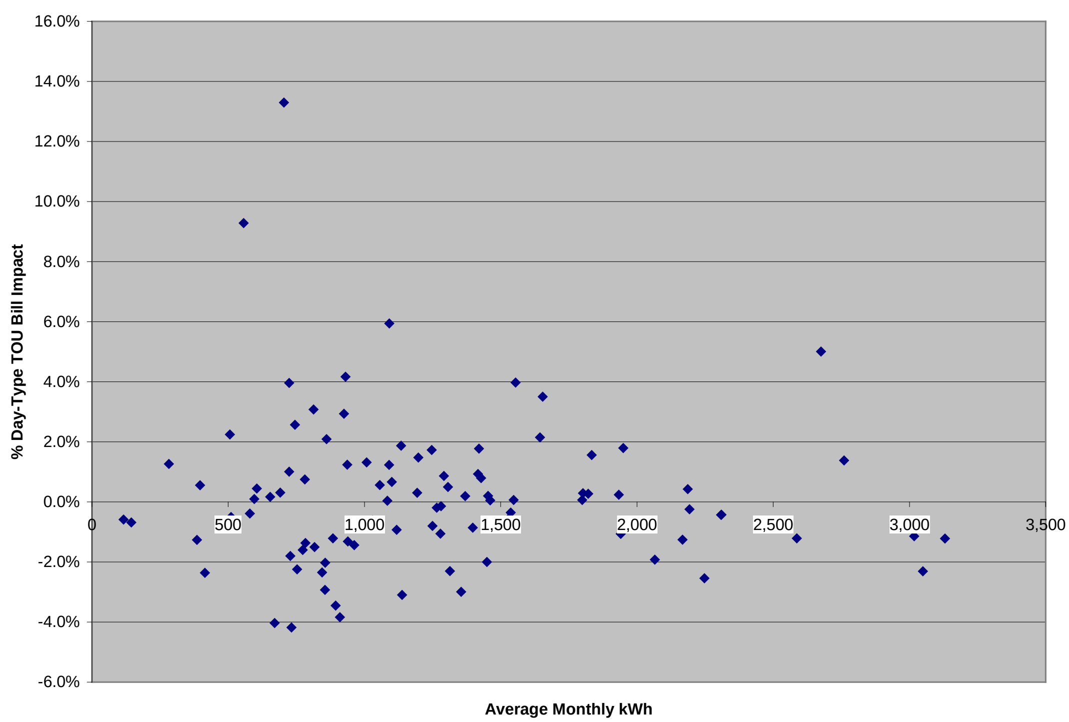
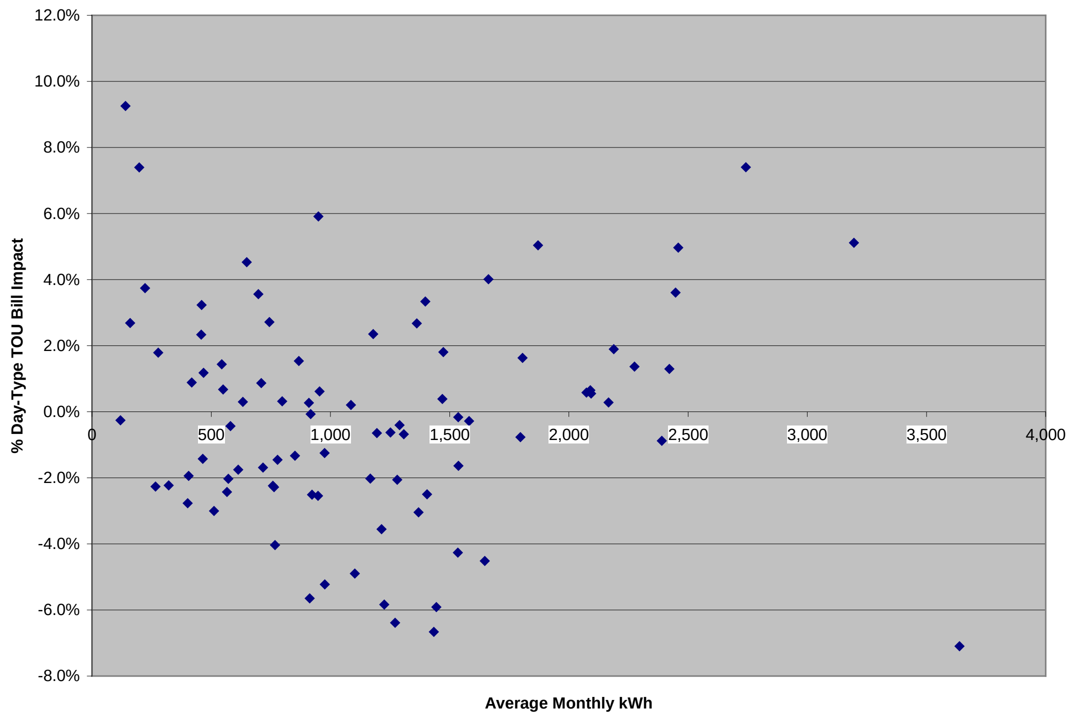


Figure 4.17: Percentage Day-Type TOU Bill Impacts, *Westar*



4.7 Summary of bill impacts

Tables 4.2 through 4.4 provide information that summarizes the figures presented in the previous sub-sections. Four statistics are provided for each utility and rate structure:

- The share of customers that experienced a bill increase of 10% or more on the new rate structure;
- The share of customers that experienced a bill decrease of 10% or more on the new rate structure;
- The average percentage bill impact for customers who use an average of 500 kWh per month or less; and
- The average percentage bill impact for customers who use an average of 2,000 kWh per month or more.

These statistics are intended to facilitate comparisons of bill impacts across rate structures and utilities. Following are the key observations from these tables:

- The flat, TOU, and day-type TOU rates do not produce large percentage load impacts for very many customers (as shown in the "Greater than 10% column").
- The bill impacts for the flat, TOU, and day-type TOU rates are not strongly related to customer usage levels (as illustrated by the similarity of the average bill impacts in the "Low Use " and "High Use" columns).
- The high customer charge in the SFV rate leads to large bill increases for low-use customers (e.g., 27.4 percent for KCP&L's low-use customers). The percentage bill decreases for high-use customers on this rate structure are smaller in magnitude (e.g., 5.7 percent for KCP&L's high-use customers).

- Despite the fact that IBR and SFV have opposite effects by customer usage levels, combining the two rate structures is not enough to offset SFV's adverse bill impacts for low-use customers.

Table 4.2: Summary of Bill Impacts by Rate Structure, *KCP&L*

Rate Structure	Share of Customers by Bill Impact Amount		Average Bill Impact by Customer Usage	
	Greater than 10%	Less than -10%	Low Use (<500 kWh/mo.)	High Use (>2,000 kWh/mo.)
Flat rate	1.3%	0.0%	0.1%	0.6%
SFV	15.1%	0.0%	27.4%	-5.7%
IBR	4.9%	0.0%	-6.6%	10.4%
IBR + SFV	3.9%	0.0%	21.2%	2.6%
TOU	0.3%	0.0%	-0.5%	-0.2%
Day-type TOU	0.3%	0.0%	-0.5%	-0.5%

Table 4.3: Summary of Bill Impacts by Rate Structure, *Westar*

Rate Structure	Share of Customers by Bill Impact Amount		Average Bill Impact by Customer Usage	
	Greater than 10%	Less than -10%	Low Use (<500 kWh/mo.)	High Use (>2,000 kWh/mo.)
Flat rate	0.0%	0.0%	-0.1%	2.6%
SFV	35.9%	6.6%	46.6%	-10.1%
IBR	5.6%	0.0%	-1.5%	8.9%
IBR + SFV	28.8%	0.0%	42.2%	-4.8%
TOU	0.0%	0.0%	0.1%	1.9%
Day-type TOU	0.0%	0.0%	1.4%	1.5%

Table 4.4: Summary of Bill Impacts by Rate Structure, *Midwest*

Rate Structure	Share of Customers by Bill Impact Amount		Average Bill Impact by Customer Usage	
	Greater than 10%	Less than -10%	Low Use (<500 kWh/mo.)	High Use (>2,000 kWh/mo.)
Flat rate	0.0%	0.0%	-2.2%	3.9%
SFV	19.5%	0.4%	20.7%	-8.8%
IBR	6.0%	0.0%	-7.3%	17.9%
IBR + SFV	13.7%	0.0%	16.7%	1.9%

5. Load Response

The previous section examined the customer-level bill impacts that occur before customers take actions to adapt to the new rate structures (e.g., by shifting or reducing load). Of course, the goal of most of these rate structures is to provide customers with incentives to change their behavior. The primary incentive goal of each rate structure can be summarized as follows:[16]

[16] The flat rate is provided for comparison purposes and not because it has especially appealing incentives.

- **SFV:** Eliminates the utility's disincentive to encourage conservation and energy efficiency. As a side effect, SFV reduces the customer-level incentive to conserve because the volumetric rate has been reduced.
- **IBR:** Discourages increases in consumption levels, particularly for high-use customers who face the high tail-block price. Note that low-use customers may experience a *decrease* in their incentive to conserve because they face the relatively low initial block price.
- **TOU:** Encourages customers to shift intra-day load from peak to off-peak hours.
- **Day-type TOU:** Builds upon standard TOU by providing added incentives to reduce usage on high-cost days.

In the sub-sections that follow, we present approximate load impacts (or demand response) that might be expected under each of the rate structures.

5.1 SFV

When a utility makes a transition from standard rates to SFV rates, the customer charge is increased and the energy price is decreased. This reduction in the energy price reduces the return that customers get from investing in energy efficiency (e.g., a saved kWh used to reduce their bill by 8 cents, but under SFV it is only reduced by 6 cents). It also reduces the incremental cost associated with increasing usage (e.g., by reducing the thermostat setting in summer).

We simulated the expected effects of this incentive change using a simple demand model:

$$\% \text{ change in usage} = \varepsilon_d * \% \text{ change in marginal rate}$$

In this model, ε_d is the price elasticity of demand, which we have assumed to be -0.20. This value is consistent with values that have been estimated in the literature.[17] We determined the marginal rate for each customer on the base rate. This was done separately for each season using the average monthly usage across the months and taking into account the existing block rates, if applicable. The "base" marginal rate was then compared to the SFV rate to obtain the percentage change in the marginal rate. The percentage change in usage was then obtained by multiplying the percentage change in the marginal rate by the elasticity of demand. The results are shown in Table 5.1.

[17] For example, a RAND study from 2005 titled "Regional Differences in the Price-Elasticity of Demand for Energy" by Bernstein and Griffin estimated long-run and short-run elasticities of electricity demand for residential customers by region. For the West North Central region (which includes Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas) the long-run price elasticity was -0.244 and the short-run price elasticity was -0.163.

Table 5.1: Percentage Changes in Usage by Season and Utility, *SFV*

Utility	Summer	Winter
KCP&L	+3.0%	+1.1%
Westar	+6.8%	+2.5%
Midwest	+4.5%	+2.6%

In summer, increases in usage induced by the lower SFV rates range from 3.0 to 6.8 percent. The increases are smaller in winter, ranging from 1.1 to 2.6 percent. These load changes do not include effects associated with any increases in conservation activities that may be induced by the change in utility incentives. That is, SFV removes the utility's disincentive to promote energy and conservation, so more conservation may occur due to increased utility involvement in demand-side management activities. However, accomplishing this incentive change through SFV has the side effect of reducing customer-level incentives to conserve.

5.2 IBR

The effect of IBR on customer usage levels was analyzed using the same method described above for SFV rates. In this case, we also determined the marginal IBR block rate for each customer and season. In general, small customers (who face a low marginal rate) have a reduced incentive to conserve under IBR, while large customers (who face a high marginal rate) have an increased incentive to conserve. Table 5.2 shows the results of our load response simulations (again assuming a -0.20 elasticity of demand).

Table 5.2: Percentage Changes in Usage by Season and Utility, *IBR*

Utility	Summer	Winter
KCP&L	-2.3%	-3.4%
Westar	-0.3%	-3.7%
Midwest	-2.8%	-3.9%

The results indicate larger reductions in winter than summer months (these results could be reversed by modifying the rate designs), with winter usage reductions ranging from 3.4 to 3.9 percent; and summer usage reductions ranging from 0.3 to 2.8 percent.

5.3 TOU

The model used to simulate load response to TOU and Day-type TOU rates was different from the model used to simulate load response to SFV and IBR. In this case, we focus on the customer's incentive to shift load from peak to off-peak hours. The magnitude of the load shifting is described by the elasticity of substitution (ε_s), which we assume to be 0.10. The load response is modeled as follows:

$$QR_{TOU} = \exp\{\ln(QR_{base}) - \varepsilon_s \text{ x } \ln(PR_{TOU})\}$$

In this equation, QR_{TOU} is the ratio of peak to off-peak usage on the TOU rate, QR_{base} is the ratio of peak to off-peak usage on the base rate, ε_s is the elasticity of substitution, and PR_{TOU} is the ratio of peak to off-peak prices on the TOU rate.[18] Table 5.3 shows the results of the simulations for each season and utility.

Table 5.3: Percentage Changes in Usage by TOU Pricing Period and Utility

Season	TOU Period	KCP&L	Westar
Summer	Peak	-2.6%	-2.5%
	Off-peak	+1.8%	+1.9%
Winter	Peak	-1.4%	-1.4%
	Off-peak	+3.4%	+3.4%

Notice that across all seasons and both utilities, the TOU rates produce a decrease in peak-period usage and an increase in off-peak usage. Summer peak usage declines by approximately 2.5 percent, while off-peak usage increases by about 1.9 percent. In winter, the reduction in peak usage is smaller, at about 1.4 percent. Off-peak usage goes up by about 3.4 percent.

These results illustrate how, in theory, TOU rates can lead to a more efficient use of resources (by shifting usage from higher-cost peak to off-peak hours), but not necessarily to an overall reduction in usage. However, in practice there may be reductions in peak usage that are not shifted to off-peak hours. For example, a customer who turns off lights during peak hours is not likely to want to compensate by turning on more lights during off-peak hours.

5.4 Day-Type TOU

As with "standard" TOU rates, day-type TOU rates are intended to produce reductions in peak-period usage, with the distinction that day-type TOU rates charge higher rates on days with a higher cost to serve. In theory, this produces higher levels of demand response during the times of greatest need and highest avoided cost.

We apply the same model and assumptions used to simulate demand response to standard TOU rates to the day-type TOU rates. Because the winter rates do not differ between the two types of TOU rates, we do not summarize the winter demand response again in this section. Table 5.4 presents the simulated demand response by day type and utility for the summer months.

[18] The ratio of peak to off-peak prices on the base rate is always 1.0, so the base rates drop out of the equation.

Table 5.4: Percentage Changes in Usage by Day-type TOU Day Type

Utility	TOU Period	Green	Yellow	Red
KCP&L	Peak	-2.5%	-4.1%	-6.5%
	Off-peak	+1.7%	+2.8%	+4.4%
Westar	Peak	-2.4%	-4.0%	-6.3%
	Off-peak	+1.8%	+2.9%	+4.5%

As expected, more demand response occurs on the high-price days than on the low-price days. For example, for KCP&L we simulate a 6.5 percent reduction in peak-period sales on "Red" days, but only a 2.5 percent reduction in peak-period sales on "Green" days. The increases in off-peak usage are also correspondingly higher on the high-cost days, because the model assumes that peak-period load reductions are shifted to off-peak hours.

6. Potential for Utility Revenue Attrition

When a utility introduces one or more optional rates, it cannot be certain which customers will choose to participate in each rate, or how they will modify their usage patterns in response to the price signals offered by the chosen rate. The absence of experience with the new rate options creates two primary sources of error when setting the rates: 1) uncertainty regarding the participants in each rate option; and 2) uncertainty regarding the load profile of the participating customers.

When the utility sets rates, a failure to account for the fact that customers will tend to select the rate that is most beneficial to them ("customer self selection") and then respond to the new rate by modifying their usage patterns ("customer demand response") can lead to the recovery of less revenue than expected, or *revenue attrition*. In this section, we examine the potential level of utility lost revenues due to each of these factors.

6.1 Revenue attrition due to customer self selection

When customers are offered the choice between rates, their rate selection may be influenced by any number of factors, including:

- *Whether they are an instant winner or loser*: customers may benefit from a particular rate structure because of their current usage pattern. For example, a customer may be able to experience an immediate bill reduction by switching from a flat rate to a TOU rate if they use relatively little energy during peak hours.
- *Price responsiveness*: customers who are able to shift usage across time periods or reduce usage on short notice may be more willing to select a rate structure in which the price varies across hours.
- *Risk aversion*: some customers may be more willing than others to be exposed to changing energy prices.
- *"Hassle" costs*: customers may not want to take the time to understand more complex rates. For example, customer response to a TOU rate requires that customers be aware of the TOU pricing periods, whereas some customers may simply want to pay the same rate all the time, even if doing so requires paying a premium.

Because the utility does not have full knowledge of the factors that influence customer choice, it does not have the ability to perfectly predict which customers will select each rate. The assumptions the utility uses when designing a rate may be violated as customers select rates, because the customer types and aggregate load profile served by a rate may differ from the assumed values. This can produce *revenue attrition*, which is a loss of utility revenues due to customer rate choices. The lost revenue persists until the next rate case, at which time the utility can price each rate correctly based on the actual, instead of expected, participants and loads.

Our analysis attempts to provide an upper bound of the revenue attrition that KCP&L, Westar, and Midwest Energy may experience due to customer self selection when SFV, IBR, TOU and day-type TOU rates are each introduced as an optional rate. The assumptions we use to price each rate are as follows:

- All applicable customers adopt the rate; and
- Customers do not engage in demand response (i.e., historical loads are used).

Customer choice is simulated assuming that each customer selects the rate option that provides them with the lowest bill.

In practice, the utility can improve upon the two pricing assumptions by basing rates on its *expectation* of customer enrollments and demand response (provided that the assumptions and modeling are accepted by the Commission). In addition, the customer choice assumption is extreme because customers may not select the rate with the lowest bill. For example, customers who may save on a TOU rate on average may nevertheless select a flat rate because they do not want to keep track of the TOU pricing periods. For these reasons, the results presented here provide an *overestimate* of revenue attrition due to customer self selection. However, we believe that the results are instructive regarding the potential scale of the issue from a utility perspective.

Table 6.1 shows the revenue attrition as a percentage of revenues from the current rates, by utility and rate structure. The results represent the percentage revenue attrition when each rate is introduced as the sole alternative to the current rate.

Table 6.1: Revenue Attrition Due to Customer Self Selection

Utility	Rate Structure			
	SFV	IBR	TOU	Day-Type TOU
Midwest	-2.9%	-3.1%	n/a	n/a
KCP&L	-2.3%	-2.9%	-0.6%	-0.8%
Westar	-5.1%	-3.0%	-1.2%	-1.3%

The magnitude of the revenue attrition is modest for the TOU and day-type TOU rates, with utility losses ranging from 0.6 percent to 1.3 percent of current revenue. Revenue attrition is considerably higher for the SFV and IBR rates, with losses ranging from 2.3 percent to 5.1 percent of current revenue.

These results are consistent with the bill impacts shown in Section 4 in that larger revenue attrition is observed for rates with more dispersed bill impacts (i.e., SFV and IBR). For example, SFV tends to harm low-use customers. Therefore, when given the choice between their current rate and SFV, low-use customers will tend to remain on their current rate. However, the high-use customers that benefit from SFV will leave the current rate, leading the utility to lose revenue from those customers. The findings therefore indicate the importance of accounting for customer self selection when pricing SFV and TOU rates.

6.2 Revenue attrition due to customer demand response

In this section, we examine the potential for utility revenue attrition due to customer demand response. That is, if the utility sets its rates using historical loads instead of loads that anticipate the load response of the customers, the utility may lose revenues as customers shift usage from high-priced to low-priced periods. For this analysis, we assume that all customers are on the new rate (e.g., TOU or IBR) and examine the utility revenues lost as customers modify their usage level and pattern in response to the new rate. The demand response model applied for each rate structure is described in Section 5.

Because the results depend upon the customers' level of price responsiveness, we simulated outcomes using a range of elasticity assumptions. Table 6.2 shows the elasticities used for the "expected" scenario; the "high", or very price responsive scenario; and the "low", or not very price responsive scenario. The elasticities of demand were derived from the RAND study described in footnote 18. The elasticities of substitution were based on results from the California Statewide Pricing Pilot, which examined customer load shifting due to TOU and critical peak pricing rate programs.[19]

Table 6.2: Elasticity Assumptions by Rate and Scenario

Scenario	Elasticity of Demand (SFV and IBR)	Elasticity of Substitution (TOU and Day-Type TOU)
Expected	-0.20	0.10
High	-0.40	0.15
Low	-0.10	0.05

Tables 6.3 through 6.5 show the results for the expected, high, and low elasticity scenarios, respectively. Notice that SFV rates actually lead to the utility recovering *more* revenue than it did under current rates. Because SFV reduces energy rates, it costs customers less to increase their usage than it did under current rates. They respond to this reduction in the *marginal price* by increasing their usage level, which, in turn, leads to an increase in utility revenues.

IBR leads to a reduction in utility revenue as high-use customers reduce usage in response to the high tail-block price signal. Note that, because the first block price is lower than the current rate, IBR gives low-use customers an incentive to increase usage. However, the

[19] "Impact Evaluation of the California Statewide Pricing Pilot", Charles River Associates, 2005, pages 91 and 97.

effect for low-use customers is outweighed by the effect for high-use customers, leading to an overall reduction in utility revenues.

TOU and day-type TOU rates lead to small reductions in utility revenues as customers shift usage from peak to off-peak pricing periods. The reduction in revenues from the peak-period usage reductions exceeds the increase in revenues from the increase in off-peak period usage increases, reducing total utility revenues. However, the magnitude of the revenue attrition due to these rates is small, ranging from 0.3 to 0.8 percent of current revenue.

Table 6.3: Revenue Attrition Due to Customer Demand Response, *Expected Elasticity*

Utility	Rate Structure			
	SFV	IBR	TOU	Day-Type TOU
Midwest	2.2%	-3.7%	n/a	n/a
KCP&L	1.6%	-3.2%	-0.4%	-0.5%
Westar	2.9%	-4.6%	-0.4%	-0.5%

Table 6.4: Revenue Attrition Due to Customer Demand Response, *High Elasticity*

Utility	Rate Structure			
	SFV	IBR	TOU	Day-Type TOU
Midwest	4.4%	-7.3%	n/a	n/a
KCP&L	3.3%	-6.4%	-0.6%	-0.8%
Westar	5.9%	-7.0%	-0.6%	-0.8%

Table 6.5: Revenue Attrition Due to Customer Demand Response, *Low Elasticity*

Utility	Rate Structure			
	SFV	IBR	TOU	Day-Type TOU
Midwest	1.1%	-1.9%	n/a	n/a
KCP&L	0.8%	-1.6%	-0.2%	-0.3%
Westar	1.5%	-3.3%	-0.2%	-0.3%

In summary, the results show the importance of accounting for revenue attrition due to customer demand response for SFV and IBR rates, but indicate that the issue is not significant for the TOU and day-type TOU rates.

7. Summary and Conclusions

This report analyzed the effects associated with changing residential rate structures for residential customers at KCP&L, Westar, and Midwest Energy. The study includes five rate structures:

- *Flat rates*, which charge the same rate in all hours;
- *Straight-fixed variable (SFV) rates*, in which the customer charge is increased to recover all fixed costs;
- *Inclining-block rates (IBR)*, in which the rate increases with the level of usage;
- *Time-of-use (TOU) rates*, in which the rate varies by time of day; and
- *Day-type TOU rates*, in which the rate varies by time of day and with system conditions.

For each rate structure and utility, we designed a rate that is revenue neutral based on the representative samples of customers available to us. We then calculated customer-level bill impacts and presented figures that illustrate the relationship between the percentage bill impact and the customer usage level (or size). We found a strong relationship between customer size and bill impacts for some of the rate structures:

- SFV rates increase bills for low-use customers and decrease bills for high-use customers;
- IBR rates tend to decrease bills for low-use customers and increase bills for high-use customers; and
- A combination of SFV and IBR produces bill impacts that more closely resemble the SFV bill impacts.

TOU and day-type TOU bill impacts are not strongly related to customer size. Rather, they tend to benefit customers with relatively less usage during peak hours.

The *range* of bill impacts (highest to lowest) was significantly higher for SFV and IBR than for TOU and day-type TOU rates. For example, the percentage bill impact on KCP&L's SFV rate ranged from -7.7 percent to 50.1 percent; while the bill impacts on its TOU rate ranged from -3.9 percent to 13.3 percent.

In addition to analyzing bill impacts, we conducted a high-level simulation of the overall usage and load impacts that may be expected to occur for each rate structure. Because SFV and IBR change the rate in all hours, they are modeled as affecting *overall* load changes, with SFV tending to increase usage[20] and IBR tending to decrease usage. Because TOU and day-type TOU rates change by time of day, we modeled the effects of these rates as shifts of usage from peak to off-peak periods.

Finally, the report examined the potential for utility revenue attrition (recovering less revenue than forecast) due to customer self selection and demand response. That is, when the utility sets the rates for an optional pricing program, it does not know which customers

[20] The load change from SFV does not include any effects associated with increases in utility-assisted conservation efforts. A primary goal of SFV is to remove the utility's disincentive to promote conservation.

will select the rate, or how the customers who select the rate will modify their load profiles in response to the new price signals. Our analysis provided an indication of the scale of this potential problem by assuming that customers select the rate that provides them with the lowest bill (customer self selection); and by simulating customer demand response using a range of price responsiveness parameters (i.e., price elasticities). The results indicated that both types of revenue attrition (i.e., due to customer self selection and demand response) are more pronounced for SVF and IBR than they are for TOU and day-type TOU.