Residential Winners and Losers behind the Energy versus Customer Charge Debate

For customers who do not have meters with maximum monthly demand reading capability and/or do not have demand charges, a long-running debate persists regarding the amount of demand-related costs that should be recovered through the energy charge versus the fixed monthly customer charge. The evidence suggests that it is correct to collect a portion of the demand-related capacity costs through the kWh energy charge.

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I. Introduction

A longstanding debate persists over the design of electric rates when customers do not have meters with maximum (kW) demand reading capability. When metering is limited to measurement of energy (kWh) consumption, rate design is similarly limited to the use of a fixed monthly fee, commonly referred to as a customer charge, and some type of energy charge ($/kWh) design, which may or may not vary based on a customer's total monthly kWh consumption. At one extreme in this debate are those who advocate a straight-fixed-variable (SFV) rate design under which all fixed costs are recovered through the customer charge and only variable costs (e.g., fuel expense) are recovered through the energy charge. Under the SFV rate design, a fixed cost is any cost that is not sensitive to changes in the kWh level consumed/produced. A fixed cost is a cost that is either

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sensitive to increases in the system's ability to produce instantaneous kW (referred to as a ''demand-related cost'') or is sensitive to connecting customers to the system (referred to as a ''customer-related costs''). Because electric utilities are extremely fixed-cost-intensive, a SFV rate design will typically result in a very large customer charge. Larger customer charges are associated with smaller energy charges. Moreover, the larger the customer charge, the lower the bills for above-average consumers of electricity and the higher the bills for below-average consumers. Rate designs that have relatively large customer charges also result in less volatile revenue streams.

At the other extreme of the debate are those who advocate the lowest customer charge acceptable to the regulator. The smaller the customer charge, the lower the bills for below-average consumers of electricity. Therefore, small-customer advocates tend to want low customer charges. The lower the customer charge, the higher the energy charge, which also tends to be supported by those advocating energy conservation. Inevitably, for rate classes that do not have meters with maximum (kW) demand reading capability (referred to as ''demand meters''), the high-versus-low-customer-charge debate centers on how the demand-related costs should be recovered. Absent a demand meter, a customer's bill cannot include a demand charge, which arguably is the rate element that should be used to recover demand-related costs. Absent a demand meter, demand-related costs must therefore be recovered through the customer and/or energy charges. Those who advocate a low customer charge are inevitably arguing that the demand-related costs (and perhaps even a portion of the customer-related costs) should be recovered through the energy charge. Those who advocate a large customer charge are inevitably arguing that the demand-related costs (as well as all of the customer-related costs) should be recovered through the customer charge. One's position in the debate is typically determined by whose subjective interests one is representing – below-average user interests, environmental interests, above-average user interests, or company revenue stability interests. We will show, however, that the portion of the demand-related costs that should be recovered through the customer versus the energy charge can be determined in an objective cost-justified manner.

A Coase two-part tariff will typically result in a very large customer charge.

Regulatory economists have long recognized the efficiency of implementing a Coase two-part tariff whereby the volumetric rate is set equal to marginal cost and the fixed monthly fee recovers the shortfall in revenue due to the pricing below average cost (Coase, 1946).[1] As is the case with the SFV rate design, a Coase two-part tariff will typically result in a very large customer charge. Nowhere in this high-versus-low-customer-charge debate have we seen a recognition that higher energy consumption tends to imply higher maximum demand during the month. Therefore, a case may be made that a portion of the demand-related fixed costs are more appropriately recovered through the energy charge and not the customer charge as suggested by the SFV or the Coase two-part tariff rate designs. We propose a simple methodology for the determination of that portion of demand-related costs that should be recovered through the energy charge. The positive and significant correlation between household electricity kWh usage and maximum household demand for capacity (kW) suggests that neither of the polar arguments is correct. Utilizing statistical relationships between kWh (or average demand) and maximum monthly kW based on load research data at the household level, we develop a methodology by which one can objectively determine the portion of demand-related costs that

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should be recovered through the energy charge and the remaining portion for recovery through the customer charge.

Arguably, the starting point for objectively analyzing this issue is to presume that a demand charge would be first-best and then determine what is second-best in the absence of a demand charge.

II. Classification of Costs

Rate class cost-of-service studies in electric rate cases assign and allocate costs to each rate class in a transparent and systematic fashion. The steps in a cost-of-service study involve what are referred to as functionalization, classification, and allocation. The allocation step is the final phase of the study where costs are assigned to each rate class. Allocation is made easier and more accurate, however, if costs are classified prior to the allocation step. The classification step assigns a cost into one of three categories that reflect measurable cost-defining service characteristics; i.e., categories that reflect what influences cost. The three classification categories are: (1) customer-related costs (costs that are sensitive to connecting customers to the network); (2) demand- (or capacity-) related costs (costs that are sensitive to providing kW of capacity required to satisfying instantaneous demand or load); and (3) energy-related costs (costs that are sensitive to providing kWh of energy). The classification step typically follows the functionalization step wherein costs are separated into operating function categories such as generation, transmission, and distribution as well as customer meters and services.

Energy-related costs are all generation-related such as fuel and variable operations and maintenance expenses such as lubricants and pollution abatement additives. Demand-related costs are generation, transmission, and distribution capacity-related costs. Customer-related costs are costs that are sensitive only to adding customers to the network irrespective of what the customers' loads are such as adding a standard residential service line, transformer costs, billing costs, and metering services. As mentioned above, both demand-related and customer-related costs are conventionally viewed as being ''fixed'' in that they are not sensitive to producing kWh of energy. While this may be true, these two cost classifications, however, are sensitive to completely different services provided by the utility; therefore, it is inappropriate to simply comingle them into the same ''fixed-cost'' category and essentially treat them as the same type of cost for rate-design purposes. Demand-related costs are sensitive to the utility serving customers' (peak and average) loads while customer-related costs are sensitive to simply connecting a customer to the network irrespective of the customer's load. Customer-related costs are positive even when kW demand and kWh are zero.

The steps in a cost-of-service study involve what are referred to as functionalization, classification, and allocation.

Arguably, demand-related costs should be recovered through a ($/kW) demand charge, which is applied to a customer's (kW) maximum demand (or load) while customer-related costs should be recovered through a fixed ($/customer per month) customer charge. In situations wherein customers do not have demand meters, the utility is forced to recover demand-related costs through the customer and/or energy charges. Just because demand-related costs are sensitive to kWh energy usage, however, does not imply that all these costs should be recovered through the fixed monthly customer charge. If a customer's load can be shown to be highly correlated with that customer's energy usage, then there is a strong cost justification for recovering some of the

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demand-related costs through the energy charge.

III. The Data

Our sample includes 43 households with monthly maximum demand (kW) and monthly energy (kWh) usage measured for each household in the sample during calendar year 2011 for an electric utility in Alaska. The raw data are 15-min interval demand data for all such intervals during each month for each household. These raw data were collected as part of a load research study performed on behalf of an electric utility in Alaska in preparation for an actual rate case and cost study allocation purposes.[2] Table 1 provides summary descriptive statistics for the relevant variables.

Table 1: Descriptive Statistics for Household Electricity Sample Data

No. of households				43
No. of monthly obs.				325

	Max	Min	Mean	Std. Dev
Monthly kW Max	16.2	0.392	6.00	2.49
Monthly kWh	3232	49	832	618
Monthly household load factor	0.636	0.031	0.197	0.126
Corr. coef. kW-kWh	0.618			

Table 2: Regression Results: kW = $a + b \times$ kWh

Regression Statistics	
Multiple R	0.618101357
R square	0.382049288
Adjusted R square	0.380136128
Standard error	1.963999418
Observations	325

ANOVA

	Df	*SS*	*MS*	*F*
Regression	1	770.2838433	770.28384	199.6954
Residual	323	1245.905869	3.8572937	
Total	324	2016.189712		

	Coefficients	Standard Error	*t* Stat	*P* Value
Intercept	3.926620415	0.182697893	21.492423	3.04E−64
X variable 1	0.002491542	0.000176313	14.131363	1.24E−35

IV. Statistical Results

For the residential rate class sample, the correlation coefficient between kWh and maximum monthly kW is 0.618. To test the strength of this correlation we also regressed maximum kW on monthly kWh. The estimation results for Max kW = $a + b \times$ kWh are provided in Table 2. The relatively low R-squared may be explained by an omitted variables problem in that other factors also influence maximum demand for a household, such as major electrical appliances and home heating efficiency. However, keep in mind that we are not using the regression model to explain behavior or the causes of maximum kW; instead, we are simply interested in the correlation between kWh and maximum kW. The focus here is rate design and that relationship provides evidence on how the energy charge may be used as a substitute for a demand charge when demand metering is not available. The estimated coefficient is $b = 0.0025$ with a very high t-statistic of over 14, suggesting a very strong correlation between kWh usage and maximum kW. The estimated coefficient predicts that an increase of 1,000 kWh per month would increase maximum monthly demand by 2.5 kW. Recall that maximum kW is the standard billing determinant when a demand charge is used.

Theoretically, the intercept in this regression equation should be zero. In other words, if there is no energy use during the

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Table 3: Regression Results: kW = $b \times$ kWh

Regression Statistics	
Multiple R	0.88272846
R square	0.77920953
Adjusted R square	0.77612311
Standard error	3.05691049
Observations	325

ANOVA

	Df	SS	MS	F
Regression	1	10685.24257	10685.24	1143.455
Residual	324	3027.683372	9.344702	
Total	325	13712.92594		

	Coefficients	Standard Error	t Stat	P Value
Intercept	0	#N/A	#N/A	#N/A
X variable 1	0.00553351	0.000163641	33.81501	2.7E−108

month (kWh = 0), then kW demand would be zero for all 15-min intervals throughout the month. Therefore we also estimate the following equation:

$$\text{Max kW} = b \times \text{kWh}$$

The regression results for this zero-intercept equation are provided in Table 3. The estimated parameter is now $b = 0.0055$ and highly statistically significant. This suggests that an increase in monthly energy use by 1,000 kWh would increase maximum monthly demand by 5.5 kW.

The positive and significant correlation by monthly kWh usage and maximum monthly demand strongly suggests that some portion and possibly most of the demand-related costs allocated to the residential class should be recovered through the energy charge.

V. The Winners and Losers in Rate Design Choice

Although the strong correlation between household kWh usage and maximum monthly kW demand suggests that the energy charge may serve as a surrogate for a demand charge, it alone is not sufficient to determine how much of the demand-related costs should be recovered through the energy charge versus the customer charge. We have to also look at household load factors to complete this analysis. When load factors are the same across households, the energy charge is a perfect substitute for a demand charge because it results in the same billed amount for all customer sizes. As is well known, customers with above-average load factors prefer more cost recovery through a demand charge rather than the energy charge and those customers with below-average load factors prefer cost recovery through the energy charge rather than a demand charge. In terms of load factor (LF) and kWh usage, households are categorized as one of four types (percent of total sample observations):

Type 1: Below-average load factor, below-average kWh (54.2%)

Type 2: Below-average load factor, above-average kWh (8.9%)

Type 3: Above-average load factor, below-average kWh (7.4%)

Type 4: Above-average load factor, above-average kWh (29.5%)

Both Type 1 and Type 2 customers benefit from not having a demand charge because their bills will be lower without a demand charge. In other words, moving the recovery of the demand-related costs into the energy charge enhances consumer surplus for these households. Type 3 customers' bills are higher relative to a rate design with a demand charge; however, because they have below-average kWh usage, their bills would be even higher if we move cost recovery into the customer charge. Type 4 customers are the only households that do not benefit from not having a demand charge but would benefit from moving cost recovery to the customer charge away from the energy charge. In our sample, 29.5 percent of the household-months are both above-average LF and above-average kWh and the amount of energy use by these households that is in excess of the average kWh is 26.1 percent of the

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total annual kWh. Therefore, in terms of consumer surplus, shifting cost recovery away from a demand charge to the energy charge and not to the customer charge only negatively impacts 29.5 percent of the household months in our sample.[3] Movement of cost recovery away from the energy charge to the customer charge negatively impacts the consumer surplus (higher bills) for 61.6 percent of the households that have below average kWh usage (Type 1 and Type 3). Because Type 2 customers have already benefited from not using a demand charge, it is arguably not appropriate to give them an additional benefit with a lower energy charge.

VI. Actual Rate Design Alternative Calculations

We now consider some rate design alternatives. We begin by calculating the rate design as if a demand charge could be implemented for residential customers (see Appendix 1). All of the demand-related costs are included in the calculation of the price per kW-month, all of the customer-related costs are included in the calculation of the fixed monthly fee, and only the energy-related costs are included in the price per kWh.[4] The resulting rate design would be as follows:
$11.26 per kW-month (defined as maximum kW)
$0.004 per kWh
$13.25 fixed monthly customer charge

Next we eliminate the demand charge and allocate the demand-related costs between the energy charge and the customer charge, 60 percent and 40 percent, respectively (see Appendix 2). The resulting rate design would be as follows:
$0.061 per kWh
$31.86 fixed monthly customer charge

Finally, we change the allocation of the demand-related costs between the energy charge and the customer charge to 100 percent and 0 percent, respectively (see Appendix 3). The resulting rate design would be as follows:
$0.098 per kWh
$13.25 fixed monthly customer charge

We can now take a look at the impacts on households with below-average kWh consumption, average kWh consumption, and above-average users under each of the above scenarios.

Monthly bills under the first scenario in which the demand-related costs are collected through a demand charge are shown in Table 4.

Monthly bills under the second scenario in which the demand-related costs are collected 60 percent through the energy charge and 40 percent through the customer charge are shown in Table 5.

Note that the average customer bill does not change, the below-average user's bill increases, and the above-average user's bill declines. This seems to contradict cost-causation arguments in that higher kWh usage implies higher kW demand on the system and higher capacity requirements. Furthermore, a reduction in the billing for above-average users relative to the rate design with a hypothetical demand charge seems counter to cost-causation expectations.

Table 4: First Scenario

	Below Avg	Avg	Above Avg
kW	0.84	4.13	12.56
kWh	100	493	1,500
# accts	1.00	1.00	1.00
Tot. bill	$23.08	$61.75	$160.73

Table 5: Second Scenario

	Below Avg	Avg	Above Avg
kW	0.84	4.13	12.56
kWh	100	493	1,500
# accts	1.00	1.00	1.00
Tot. bill	$37.92	$61.75	$122.75

Monthly bills under the third scenario in which 100% of the demand-related costs are collected through the energy charge, as shown in Table 6.

Note that the bills under the third scenario precisely match the bills under the first scenario in which we implemented a demand charge on the customers. This is due to the fact that we have set the load factor to be the same for all three types of customers. When load factors are the same across households, the energy charge is a perfect substitute for a demand charge because it results in the same billed amount for all customer sizes. Therefore, our future research will focus on

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Table 6: Third Scenario

	Below Avg	Avg	Above Avg
kW	0.84	4.13	12.56
kWh	100	493	1,500
# accts	1.00	1.00	1.00
Tot. bill	$23.08	$61.75	$160.73

finding a metric related to load factor variance to determine the amount of demand-related costs that should be collected through the energy charge.

VII. Conclusion and Continuing Research on this Topic

We have demonstrated a strong and significant correlation between monthly kWh consumption and monthly maximum kW demand. This would suggest that it is correct to collect most of the demand-related capacity costs through the kWh energy charge. The exact amount seems to be related to the level of variation in load factor across households. The lower the variation in load factor, the greater the amount of demand-related costs that should be placed in the energy charge. With homogeneous load factors across households, the energy charge is a perfect substitute for a demand charge insofar as total monthly billing amounts are concerned. Our future research will focus on finding a metric related to load factor variance to determine the amount of demand-related costs that should be collected through the energy charge.■

Appendix 1. Calculation of Rate Design as if a Demand Charge Could be used for Residential Class

Forecast Year: 2011	Total	Residential 11
Billing determinants		
Total kVa	1,998,675	
Total demand (kW)	3,582,707	1,750,331
Total energy (kWh)	1,124,882,533	242,754,947
Average monthly customers	30,830	24,302

Functional Cost	Total Cost	Residential 11
Production		
Demand (PD)	$37,918,297	$9,240,824
$/kW		$5.28
Energy (PE)	$4,395,734	$574,151
$/kWh		$0.002
Direct assignment (PDA)	$198,835	
$/kW	$0.06	
$/kWh	$0.000	
Transmission		
Demand (TD)	$2,578,250	$527,796
$/kW		$0.30
Energy (TE)		
$/kWh		
Direct assignment (TDA)		
$/kW		
$/kWh		
Distribution		
Demand (DD)	$28,177,087	$8,100,540
$/kW		$4.63
Energy (DE)		
$/kWh		
Customer (DC)	$6,821,797	$3,863,345
$/Customer/month		$13
Direct assignment (DDA)	$1,890,145	
$/kW		
$/kWh		
Total	$81,980,145	$22,306,656
Total		
$/kW		$10.21
$/kWh		$0.00237
$/Customer/month		$13.25

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Appendix 2. No Demand Charge and 60% of Demand-Related Costs Collected through Energy Charge

Forecast Year: 2011	Total	Residential 11
Billing determinants		
Total kVa	1,998,675	
Total demand (kW)	3,582,707	1,204,811
Total energy (kWh)	1,124,882,533	143,843,977
Average monthly customers	30,830	24,302

Functional Cost	Total Cost	Residential 11
Production		
Demand (PD)	$37,918,297	
$/kW		
Energy (PE)	$4,395,734	$8,715,642
$/kWh		$0.061
Direct assignment (PDA)	$198,835	
$/kW	$0.06	
$/kWh	$0.000	
Transmission		
Demand (TD)	$2,578,250	
$/kW		
Energy (TE)		
$/kWh		
Direct assignment (TDA)		
$/kW		
$/kWh		
Distribution		
Demand (DD)	$28,177,087	
$/kW		
Energy (DE)		
$/kWh		
Customer (DC)	$6,821,797	$9,291,006
$/Customer/month		$32
Direct assignment (DDA)	$1,890,145	
$/kW		
$/kWh		
Total	$81,980,145	$18,006,648
Total		
$/kW		
$/kWh		$0.06059
$/Customer/month		$31.86

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Appendix 3. No Demand Charge and 100% of the Demand-Related Costs Collected through the Energy Charge

Forecast Year: 2011	Total	Residential 11
Billing determinants		
Total kVa	1,998,675	
Total demand (kW)	3,582,707	1,204,811
Total energy (kWh)	1,124,882,533	143,843,977
Average monthly customers	30,830	24,302

Functional Cost	Total Cost	Residential 11
Production		
Demand (PD)	$37,918,297	
$/kW		
Energy (PE)	$4,395,734	$14,143,303
$/kWh		$0.098
Direct assignment (PDA)	$198,835	
$/kW	$0.06	
$/kWh	$0.000	
Transmission		
Demand (TD)	$2,578,250	
$/kW		
Energy (TE)		
$/kWh		
Direct assignment (TDA)		
$/kW		
$/kWh		
Distribution		
Demand (DD)	$28,177,087	
$/kW		
Energy (DE)		
$/kWh		
Customer (DC)	$6,821,797	$3,863,345
$/Customer/month		$13
Direct assignment (DDA)	$1,890,145	
$/kW		
$/kWh		
Total	$81,980,145	$18,006,648
Total		
$/kW		$0.09832
$/kWh		$13.25
$/Customer/month		

Endnotes:

1. ''Efficiency'' in this context is ''allocative efficiency'' wherein consumer surplus is maximized subject to the constraint that the utility generates enough revenue to recover its costs – including a ''fair'' or ''normal'' profit.

2. The raw data had several households with missing data that were removed such that only households with a complete month of data remain in our sample. Also, not all households had data for all months, which is why the actual number of monthly observations (325) is less than $43 \times 12 = 516$.

3. Of course, in terms of money, we know that rate design alternatives are a zero-sum game in that the same amount of revenue will be collected from the customers as a whole.

4. The energy-related costs exclude fuel and purchased power.