Pricing for Demand Response (DR) from Residential & Small Commercial Customers

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Introduction

Many in our business are of the opinion that efficient pricing requires expensive advanced interval metering, a two-way, always-on communications network connecting the utility with the customer, and near real-time measurement and validation of demand response. There are some who believe all one has to do is send real-time prices or critical peak prices and meter the energy. People will respond appropriately to the prices and economic efficiency will correspondingly prevail. Others think that people receiving these highly variable prices will require some programmable control technology in order to respond and take advantage of the highly variable prices.

Let's consider pricing electricity to members of the mass market in order to induce greater economic efficiency in its consumption. Let's consider it using mostly common sense colored by the disciplinary bias of economics.

We'll find that when more efficient price signals can be sent to residential and smaller commercial electricity customers, significant demand response can be thereby motivated, that demand response can be measured and validated to highly significant degrees of accuracy, the price-responsive load management (PRLM) program can be designed so that customers easily understand it, and all of this will still cost utilities, their customers, and society less than what it would have otherwise cost in the absence of the PRLM program.

Even so, PRLM will be more expensive than utility-controlled load management, but so what? DR programs can come in different models and flavors and the market may well be served by having some of both!

Today's fascination with price-responsive load management derives, in my opinion, from certain facts about efficient pricing and the nature of costs within the electric utility industry.

Supply Costs and Proper Pricing

The idea here is a pretty simple and pretty old idea. As it is with most notions, this one emerges from a historical narrative or story. This story begins with the well known fact that the cost of making, transmitting, and distributing electric energy to customers varies continuously with time and, as we have learned from the work on locational marginal pricing, with space or geography.

A second fact upon which the story and, ultimately, the idea depend is that the right purpose for prices is to motivate the economically efficient use of things, including things like electric service.

For prices to do that job well, they need to reflect the cost of supplying the things to which the prices apply. For electricity, this means that prices would need to vary with time and space in the same way that supply costs do.

This is not even close to a new idea. The principle has been known for over two centuries. People in the electricity business have understood it from the days of Sam Insull and they have understood the principle better than many people in other industries. Our trade magazine, Public Utilities Fortnightly has been around since the very early twentieth century. A perusal of early issues of that magazine will establish the point.

Electricity is still one of the very few products or services supplied (dispatched, if you prefer) almost exclusively on the basis of real-time marginal cost but it is rarely priced on that basis.

If electricity is to be priced the same way it is "cost-ed", you have to be able to meter/measure consumption –where it occurs - more or less continuously and store or remember those readings. You also must have the systems available to manage the data collected so that it can be used — primarily for billing purposes. You, therefore, must also have robust billing systems. Most importantly, you must have customers or billing intermediaries who are willing to accept and tolerate a continuously variable pricing scheme for electricity service. Such was not the case in Sam Insull's time nor was it the case throughout most of the 20th century.

Metering that could measure and remember continuously variable mass-market consumption was not initially available at all and, when it became available, it was expensive. It has been becoming cheaper. Billing systems capable of handling this enormity of data have also evolved, albeit more slowly than many of us would like.

Pricing Compromises

It has long been economically feasible to measure monthly maximum kW demand for larger commercial and industrial customers. It has also long been economically feasible to meter monthly energy consumption.

Given this initial state of economic metering technology and given the known knowledge of the continuously variable nature of electricity supply costs, what pricing or rate designs could be employed to roughly approximate the time-varying nature of those supply costs and could still be billed on the basis of what was capable of being measured?

The answers are still around. Customer – energy – demand (CED) rates with seasonal differentials, demand ratchets, increasing or decreasing block energy prices, hours-use of demand rates, and combination rate designs incorporating all of these features are all possible

with very old, very simple, and very reliable mechanical metering technologies. These rate designs were meant to crudely reflect the continuously variable nature of electricity supply costs. Costs are higher in some seasons, so prices can reflect that. It costs more to supply electricity in small amounts than in large, so rates can reflect that too. Because of metering technology constraints, the process was analogous to approximating a French curve using several rectangles.

Metering technology improved. Before too long it became economically feasible to record the usage of large commercial and industrial customers on a more or less continuous basis. Billing systems were not yet capable of managing individual customer data with this high degree of granularity. Translation programs and systems were built to produce billing determinants by rating period since billing systems usually could capture measurements by rating periods (e.g., peak periods, off-peak periods, and shoulder periods) by season. Large commercial and industrial time-of-use rates and riders with energy prices and demand prices delineated by rating period and by season therefore came into being. Soon specialized meters that would only measure these time-sensitive billing determinants were developed. They were still too expensive for mass-market use but they did permit more robust pricing schemes for somewhat smaller commercial customers.

These pricing compromises were made to the state of economic metering technology all the while knowing that continuously variable pricing that mirrored the continuously variable electricity supply costs would be more economically efficient, if and when it was to become practical.

Pricing Possibilities Expand

Today, advances in information, communications, and metering technology have created opportunities for electric utilities to provide price signals that reflect real-time variations in cost better than was ever before possible. At the same time other technologies have emerged that allow energy management systems to automatically respond to these signals in ways that customers have predetermined and preprogrammed.

One popular pricing scheme of this nature that has found wide applicability and acceptance by large commercial and industrial customers is real-time pricing.

A real-time pricing scheme is one that uses changes in some real-time event to trigger changes in the price of electricity. When defined in this way, many existing rates are, in fact, simple real-time rates. For example, a utility with a summer/winter price differential would use a real-time occurrence (e.g., the day when the season changes) to trigger a change in price. In time-of-day

pricing, when the hour of the peak arrives, the peak period price is triggered. Again, a real-time event has triggered a price change. All interruptible rates are real-time rates since some real-time occurrence triggers the order to interrupt. The difference between conventional rates and what are commonly called real-time rates is in the frequency of the price changes and in the nature of the real-time events that trigger those changes. For the most common ilk of real-time rates for large commercial and industrial customers, it is the expected hourly marginal cost that triggers the hourly price to be charged. Other continuously variable phenomena could also be used as an RTP trigger (e.g., the expected hourly temperature since system demand and temperature are so highly correlated).

Large commercial and industrial customers have come to accept RTP pricing although I do not believe that is what they were originally after. As electricity markets began to open up at the wholesale level, many of these customers wanted the same benefits they perceived would be reaped by many of the smaller participants in the competitive wholesale power markets (e.g. municipals and cooperatives). They began pressuring utilities to lower their prices. Utilities, looking for a quid pro quo to accommodate these requests, “invented” RTP pricing schemes, some innovative interruptible, and some new time-of-use related discounts.

RTP pricing produces lower average rates and, perhaps, lower electric bills provided the consumption pattern changes to use relatively more energy when it is relatively less expensive and vice versa. That’s the quid pro quo. Even though these larger customers may not have initially chosen or preferred the RTP rate design, they have accepted it.

Customer tolerance for highly variable prices is however still low among ordinary members of the mass-market. Time-of-use pricing schemes, off-peak pricing discounts, seasonally adjusted rates, and combinations of these have been around forever. In the mid 1960s through the mid-1970s many dozens of TOU pricing experiments were conducted and in many places optional and, in a few places, mandatory residential TOU rates were implemented and their impacts measured. The results of this research was remarkably consistent and is well-summarized by a statement made in a Christensen & Associates study done for the Illinois Commerce Commission in the mid-1970s – The benefits of TOU pricing do not cover the cost of the required metering.

Why would that have been the case? Electricity costs, however annoying they may be, are still a pretty small part of a household’s total budget. Reducing an electric bill by even 15 to 20% for most households was not a sufficient incentive for them to take the trouble to remember the TOU schedule, or, perhaps more importantly, to take the time and effort required to either manually adjust the thermostat at the scheduled times or buy a programmable thermostat that, once programmed, would remember for them and automatically do the adjusting.

For residential customers, the “full” cost (not just the monetary cost) of responding to TOU rates was simply too high in relation to the financial penalties imposed by TOU rates.

For TOU pricing to work effectively with mass-market consumers of electricity, it is imperative for the “full” cost of responding to highly variable pricing schemes be significantly reduced.

It has to be easy and mindless for people to effectuate their responses to electricity price changes by predetermining and preprogramming those responses.

Notification Requirements for “Proper” Pricing

There is a notion and it’s spreading that if only we could measure everybody’s hourly consumption of electricity, we could put them all on an hourly pricing scheme whereby the hourly prices reflect well the hourly marginal cost of making and delivering electricity to them.

If we did that, the argument seems to go, we could leave demand response entirely up to the consuming public because when facing marginal cost prices, they’ll adjust their hourly consumption of electricity up to the point where the marginal benefits from their consumption just equal the prices they must pay each hour. Efficiency rules the day, welfare is maximized, and all’s well with the world.

For many products, this model works just fine. One goes to the grocery store and looks at the posted price for oranges that day, spends a nanosecond or two cogitating, and, finally, decides how many oranges to buy given the posted price. Economists smile and again know that all’s right with the world.

Does this thinking work well for electricity? Is the model in any way altered by the technological fact that consumption and production of electricity occur simultaneously? The answer is a resounding maybe!

For many of the largest consumers of electricity:

- The investment in the communications and metering instrumentation,
- The added cost of an operational method for predicting the next hour’s “real time price,” and
- The investment needed in hardware and software control technologies that will modify their electrical usages in response to these predicted prices,

are costly but not in relation to the potential benefits or these customers’ other costs for doing business. What about residential and small commercial customers?

The spreading notion recognizes the need for interval or “advanced” metering beyond the typical mechanical meters in wide use for residential and smaller commercial customers; after all, the critical peak pricing rate will need to be billable.

The spreading notion doesn't always recognize the need for the rest of the required RTP infrastructure. Instead, the prescription for mass market customers is advanced metering and critical peak pricing. If we do that, mass market consumers will, just like the big guys, adjust their electricity usage in each hour until the marginal benefit from that hour's electricity consumption is just equal to its price. There are a number of problems with this spreading notion.

A critical peak pricing rate, at its most complicated, is a seasonally differentiated time-of-use rate with a real-time kicker. The real-time kicker is a very high price per kWh that displaces the otherwise scheduled price whenever a critical peak period is called. Consider first the seasonally differentiated time-of-use part of the rate.

For the reasons stated earlier, without automation, people simply haven't been able or willing to do very much in the way of responding and I suspect they still aren't.

Consider the real-time kicker part of the critical peak pricing scheme. In this case people may not even know when it's coming. The other prices within the pricing scheme are scheduled but the real-time kicker can't be scheduled because the utility can't know for sure exactly when the conditions for calling a critical peak period will occur.

This fact alone makes it even less likely that mass market consumers will be in a position to effect changes in electricity use. Why is that? The reason lies in that one or two nanoseconds of cogitation over the orange purchase mentioned above.

If I were to be told that tomorrow between the hours of 3:00 and 4:00 p.m. all electricity use by my residence will be charged at $1.50/kWh, I would have time to either do something or choose not to.

Being able to warn consumers of the consequences of their purchase decisions is important if efficiency is desired. William Shatner, in a Priceline.com commercial, marvels at a consumer's response to him when he asks her what she's doing and she responds, "I'm shopping and comparing before I buy."

Being able to cogitate for a time prior to making a purchase decision is important. If people weren't told how much their consumption of oranges would cost them until after they had eaten the oranges, I don't think many economists would be smiling.

Still, this is what is often implied by the spreading notion. Place a meter on the house, measure hourly consumption, and tell them what they spent at the end of the month. As it stands, this is not a good idea.

An analog to the "real-time pricing" infrastructure described earlier as needed for the largest consumers of electricity on real-time pricing is also needed for mass market consumers on critical peak pricing, if CPP is to be successful. Namely, there are four CPP infrastructure requirements:

- A way to rapidly communicate rate changes and critical peak conditions to program participants
- A means of recording and retrieving the requisite billing determinants
- A way for CPP customers to predetermine and program their demand responses in advance of the pricing event (e.g., "If the price exceeds 15¢ per kWh then reset my thermostat's set point to 80° and make sure my electric water heater and pool pump do not operate.")
- A way to effect those predetermined demand responses automatically upon notification of the impending price changes

All of these elements are needed if CPP pricing is to bring significant demand response from mass market consumers of electricity.

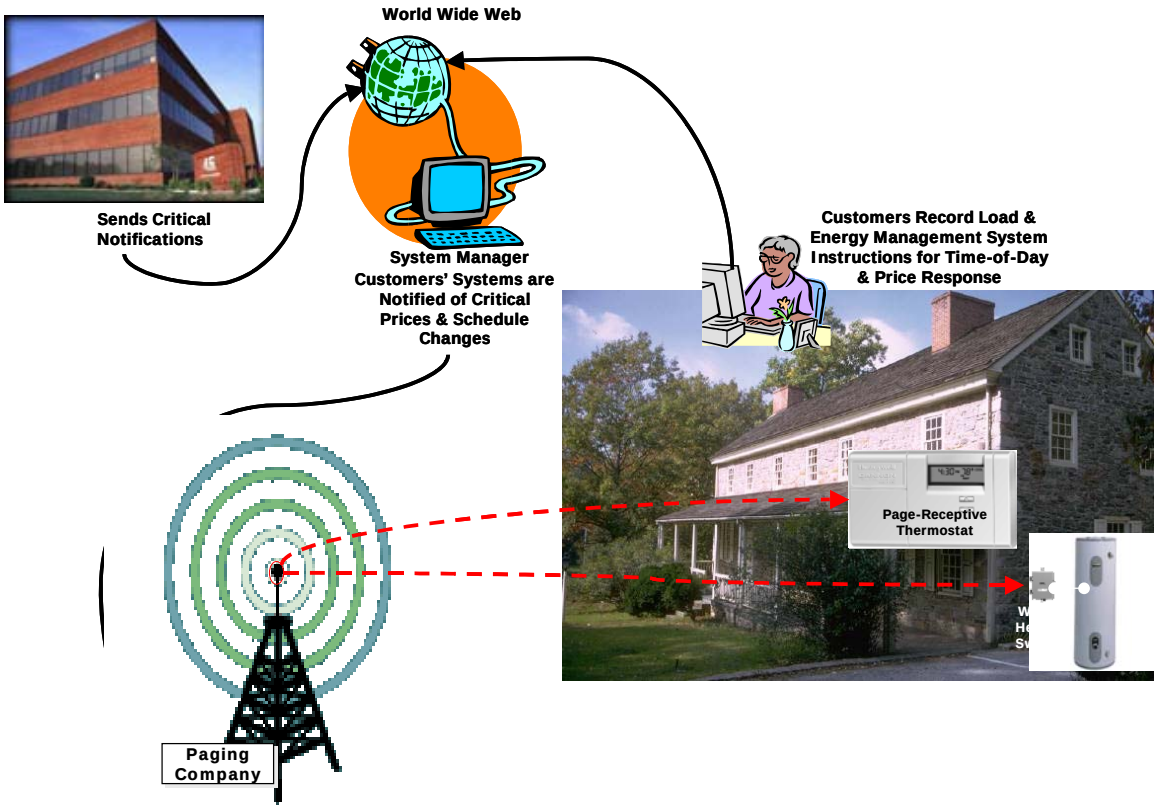
All of these infrastructure elements must exist before mass market critical peak pricing can approximate efficient pricing. All of these infrastructure elements will cost money and for some systems of CPP-facilitating equipment, quite a lot of money.

But, not all members of the mass market need to participate in CPP pricing for it to provide a significant source of demand response. Even if only 3-5% of the residential market participates by programming HVAC, water heating, and significant auxiliary loads (e.g., pool pumps), substantial DR potential exists - 20 MW for every 10,000 participants in a CPP program.

Today, electric utilities can practically send proper price signals to more customers than was ever before possible. Rate designs that reflect well the continuously variable nature of electricity supply costs are proliferating. Locational marginal pricing at the wholesale level is standard operating procedure within the NYISO, PJM, and other control areas. Innovative ways to economically bring proper pricing to the mass market is just a block or two away, and for some market segments it may be here already.

Designing for Critical Peak Pricing

A schematic of a simple "low-tech" approach to critical peak pricing (CPP) follows. This schematic displays what I consider the minimum necessary infrastructure needed to create and implement CPP in a manner that promises to bring value to participants and DR to the sponsoring utility – an approach that is unfortunately at odds with many CPP proponents.



Notice there is no metering path shown. As was indicated earlier, an interval data recorder must, of course be installed at the participant's residence and its readings gathered monthly. Software will then "bucket" these data into the appropriate rating periods defined by the CPP rate. The meter reading can be gathered in any economical way – remotely or by the meter reader. The Internet provides the common interface for both the utility and the participating customers.

There are in my view some commonly held but erroneous assumptions that follow the idea of making CPP available to mass market participants. Some of the more important ones follow.

- Automated Meter Reading (AMR) is a prerequisite
- Two-way, real-time communication is necessary for CPP and for M&V
- CPP is universally preferred to DLC

Some people may want AMR and they may be able to make a business case for it, but AMR is not needed for critical peak pricing programs for residential and smaller commercial customers – the requirement for an interval meter does not imply AMR.

Two-way, always-on, real-time communications between the utility and each CPP customer is not necessary for either the program or for reasonable M&V. For the program, the above schematic of an economical CPP program shows a simple and potentially cost-effective architecture for CPP that does not employ two-way, always-on, real time communications between the utility and each CPP customer. Statistical sampling of CPP program participants will provide M&V to any desired and reasonable degree of accuracy for a fraction of the cost of universal measurement.

Customer-controlled programs will appeal to some and utility-controlled programs will appeal to others. This fact should present no worries to program designers. Kenmore makes different models of refrigerators to appeal to different segments of the refrigerator-buying public. Having different types of demand response programs should be no different. I know of some customer research that shows that residential customers when given the choice between a page-receptive programmable thermostat and an old fashioned DLC switch to allow the utility to cycle their central air conditioners, about 2/3 said they would prefer the thermostat. Two-thirds is not all – one-third of residential customers is still a very large segment and should probably not be ignored.

Designing a 4-Tier CPP Rate - Details

When designing a critical peak pricing rate for mass market customers, program designers should remember these two goals.

- Prices should reflect the time-varying character of electricity supply cost.
  - Implication: Some form of time-of-use rate – probably seasonally differentiated
- Critical real-time supply considerations should promptly be communicated to consumers and reflected in the price they pay.
  - Demand will not otherwise be sufficiently attenuated

For customers, a CPP rate design needs to be easy to understand. The “standard” four-tier CPP rate design is easy for customers to understand. They know and accept the idea that if the costs of production are low, it makes sense for prices to be low also. They also know that for the medium, high, and critical times and prices.

The low price tier of the CPP rate should offer attractive sales prices for off-peak use, and it will probably cover about 40-50% of the hours in the year. A reasonable rule-of-thumb for the initial rate design is to set the low price equal to about half the standard residential or small commercial rate.

Medium price = medium cost = average price = standard rate. Use this reasoning to create a medium price tier and make it effective for about 30-40% of the time.

High price = high cost – goal is to reflect those high costs and thereby induce a demand or conservation response. Rule-of-thumb – set high price about equal to twice the standard rate and make it applicable for 10-20% of the hours (most likely the summertime weekdays between the hours of 10 a.m. and 7 p.m. and maybe some early morning hours in the wintertime).

Critical prices displace otherwise scheduled prices – limited use – get people's attention by setting this price equal to 4 to 5 times the standard rate or more.

You will need a load shape to apply a trial CPP rate design to – so develop one. You will want a load shape for a "typical" CPP subscriber. Our experience is that this subscriber will be a relatively large user of electricity having central air conditioning. In fact, we would recommend that having central air conditioning should be a requirement of the rate. This larger user of electricity may also have electric water heating and one or more large auxiliary electric loads like pool, irrigation, or fountain pumps. These end-uses should not however be required to subscribe for the rate. Once the "typical" adopter has been described, an hourly load shape for that adopter will need to be developed. This is usually accomplished by modeling (using DOE 2 or RBEP or some other load shape builder) or by filtering an existing database of actual hourly load shapes for those that meet the criteria for a typical CPP rate adopter. There is more art than science in this exercise.

Developing a trial CPP rate design requires an examination of your utility's hourly supply costs - I would use expected/forecasted hourly system lambda and/or expected hourly average costs where fixed costs have been "spread" according to your utility's preferred cost allocation methodology. Forecasts for hourly wholesale market prices will also work nicely and perhaps more appropriately for some jurisdictions.

Segment these hourly costs/prices into low, medium, high and critical categories as shown below and examine the prevailing times when these costs are experienced in each category. Use this information to determine the trial rating periods for the low, medium, and high pricing tiers.

- Lowest 40-50% = Low
- Next 30-40% = Medium
- Highest 100 = Critical
- Remainder are High

Regulators typically want optional rates to be revenue neutral, assuming customers do not respond at all to the new rate design. This typical stance can be logically, if not politically, challenged.

It is arguably desirable to offer a CPP rate that should customers not respond to the rate they will, in fact, pay more than they would have under the standard rate. The goal is to motivate

them to provide demand response. If they respond, the rate design could offer them bill savings and if they didn't respond they would pay more. Such a rate would attract more customers who are certainly willing to respond. The problem is, it might detract those who will respond but don't think they will respond enough to insure a bill reduction.

Everyone knows revenue neutrality is a design goal but not an outcome that's preferred. You will offer a CPP because you want people to change their load shape – specifically reduce peak demand and, perhaps, increase off-peak usage during those "sale" times.

When designing a CPP rate, create a candidate set of prices. The price levels and differentials should accord with design goals. The price levels should cover average expected marginal costs across each rating period. Apply the trial CPP prices to the "typical" participant's load shape and compare it to what that "typical" participant would have paid on the standard rate. The two bills won't be the same but you now have a place to start "tweaking."

This "tweaking" involves adjusting the CPP prices and rating periods by raising and lowering prices, adding and subtracting hours from rating periods, and recalculating the bill. The CPP rate designer will iterate until:

- Revenue neutrality is approximately achieved
- Rate design goals are approximately achieved
    - Simple to explain
    - Significant opportunities to save
    - Significant rate differentials – strong signals to respond
- Marginal costs are covered in each rating period

CPP Rate - Consequences

CPP rate designs will almost certainly result in revenue losses to the offering utility. Customers won't choose to participate unless they believe their bills will at worst stay the same. It is possible for some participants to experience increases in their electric bills but decreases in their total energy bills because of fuel switching behavior during the low-price periods of the CPP rate, but this won't be their expectation at the time of their enrollment.

It is, therefore, important for utility's having CPP rate options to experience cost savings sufficient to offset these expected revenue losses.

This may be possible provided that the total cost of the CPP program (marketing, recruitment, enrollment, equipment, installation, hardware and software, program administration, customer service and program maintenance) is less than the cost savings and base revenue losses combined.

Our experience has been that often the program cost calculations performed leave out significant categories of cost and the program savings calculations often undervalue the worth of the demand response. It's not clear that these two mistakes equally offset one another. The most powerful tool of economic or business analysis is a thorough listing of all those things that might impact the question being analyzed – it makes sure you count everything and it minimizes the chance that you will count some things twice. It also makes you acknowledge those costs and benefits for which there are no convenient measures and it makes you creatively seek proxies for those things – proxies you can measure.

In my experience with CPP rates, I have come to expect a non-critical price elasticity of about -.22. This estimate is comfortingly the same for lower to higher price changes and for higher to lower price changes and it enables one to calculate the expected revenue loss. We have also found the critical price elasticity to be about -.13. It is less elastic because electricity use is more important to people at critical times and they have already partially responded when prices rose from medium to high. Still, if the critical price is three times the high price, demand at critical will be reduced by 40% for CPP subscribers or about 2 kW per subscriber.

This demand response, of course, generates avoided cost savings. Critical peak reductions will save between $550-$750 per kW or more depending on the jurisdiction. If total energy use declines, there is also a savings from not having to make it (basically a fuel savings).

CPP Rate – Other Issues

CPP Subscriber Fee

CPP programs for mass market customers, when properly designed, may bring added value to the participants in these programs. Is an in-home automated customer-controlled energy and load management system worth something more to the target population of potential subscribers? Why? Is it possible to persuade them to pay something for these things? It depends.

In order to charge somebody extra for something, you have to provide them with something extra that they will value more highly than the money you are charging them. It has to be worth more to them than you are asking them to pay. How much are people willing to pay for "savings opportunities" and "a greater sense of control and choice"? Nobody knows. The work has not been done and the "market" has not yet revealed it.

We know it is more than $0, but how much more? Flexible program design and a willingness to experiment with various subscriber fees would, with time and analysis, reveal an "optimal

subscriber fee." Knowing what that number is would be very useful and by charging it the CPP program's economics would significantly improve.

How one uses that number in order to persuade people to enroll is a marketing question that also deserves some thought and planning. If there is a willingness to pay, when is the best time to exploit that through a subscriber fee? At the beginning? $5 - $10 per month or encourage sign-up by offering people the first 6 months free and then $5 - $10 per month?

CPP Rate Design – Avoidable Errors

The following represents the most common errors in CPP rate design I have seen.

- Designing prices based on cost vs. desired results
  - You want DR – get their attention
- Making high-priced periods too long
  - Discouraging participation
- Choosing complicated and expensive technology
  - Keep it simple – remember, it's for the customer
  - It may also make the program uneconomic

I know of a recent TOU experiment involving a utility's entire residential customer base. The TOU rate design allowed for an 8 mill differential between the rate's lowest price and its highest price. That's not sufficient. Some people responded because they were asked to, but not to the prices.

The sell to the regulators has to be "motivating DR." Prices during those times you want the DR have to be high enough to get it and it has to be easy and mindless for participants to give it to you. Electricity or any other public utility service is not a top-of-mind act of consumption for people and our industry should strive to keep it from becoming one.

Motivating Mass-Market Demand Response

Motivating mass-market demand response through pricing options and other DR programs will succeed when these things are kept in mind.

- Keep the customer first
- Question incentives
- Be creative
- Keep the program simple
- The "best" load management strategy is a "portfolio" of DR programs

We know from experience that some customers are willing to participate in direct load control (AC cycling) programs.

We know other customers prefer participating in setback thermostat programs because they perceive less potential discomfort as the thermostat is only set back a certain number of degrees. Many utilities like thermostat programs because they're convinced an annual incentive payment may not be necessary to keep these customers on the program.

Still, other customers want to be more in control. They like the idea that they can save money by modifying their behavior. By pre-cooling or pre-heating their homes and reducing energy use during peak periods, they can save substantial energy dollars. Of course, this type of behavior modification is only beneficial to them if the utility offers a time-of-use rate or, possibly, a critical peak pricing rate.

Utilities typically offer one or another of these programs but rarely do they combine programs in one offering or offer multiple DR programs. Why not? Customers aren't a homogeneous group, so why would treat them as if they all think alike? Or, why exclude some of your customers from participating in a, from their perspective, desirable DR program?

Today's technology manufacturers have developed head-end control systems that allow utilities to offer any combination of devices within one program or through multiple programs. Make use of this capability.