Residential Rate Design and Energy Efficiency

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I will first talk about basics of residential rate design and then raise some issues regarding time-of-use (TOU) and dynamic pricing for residential customers. My principal message is that regulators can't spend all their time just doing "fun stuff" with "new 'smart' technology;" they also need to pay attention to the basics. And some of the "fun stuff" actually must be approached very carefully.

In a carbon-constrained world where efficiency is important, regulators should harmonize basic rate design with garden variety energy efficiency.

If a regulator is worried mainly about the cost of new powerplants and market power in deregulated markets, what happens in the highest 100 hours of load is important. If one believes that if people just stay out of the peak, the utility should be happy to generate more power for them, then critical peak pricing by itself is your rate design.

<u>But</u> if the regulatory and societal goal is for people to build better houses, weatherize, make a better choice of heating fuel, buy efficient appliances, some simpler things are even more critical. It is not reasonable to pursue energy efficiency with one foot on the accelerator (ratepayer-funded programs) and the other foot on the brake (rate design that makes those programs less cost-effective). The result will be either less efficiency delivered to customers or higher costs (required to overcome rate design) or both.

The first key step is to stop promoting electric heat. Total energy use efficiency starts with burning gas directly in homes, rather than installing electric space heating, water heaters, dryers, and stoves. As Table 1 shows, even with heat pumps, the all-electric home is a fuel guzzler.

Table 1: Total Energy Use for Residential End Uses Supplied by Electricity versus Gas

	gas	electric combined cycle	coal steam
gas vs. electric resistance heat			
end-use efficiency	90%	100%	100%
conversion and delivery efficiency *	98%	45%	31%
implicit heat rate Btu/kWh	3,870	7,630	10,900
efficiency	88%	45%	31%
energy required for end-use electricity relative to gas		197%	282%
CO2 per MMBtu of heat input (pounds)	115	115	210
CO2 for same useful output as 1 MMBtu of gas heat input	115	227	592
additional CO2 for electric option		97%	414%
gas vs.air-source heat pump (Heating Seasonal Performance Factor = 8.2)			
end-use efficiency	90%	240%	240%
conversion and delivery efficiency	98%	45%	31%
implicit heat rate Btu/kWh	3,870	3,176	4,537
efficiency	88%	107%	75%
energy required for end-use electricity relative to gas		82%	117%
CO2 per MMBtu of heat input (pounds)	115	115	210
CO2 for same useful output as 1 MMBtu of gas heat input	115	94	246
additional CO2 for electric option		-18%	114%
water heater			
end-use efficiency	63%	93%	93%
conversion and delivery efficiency	98%	45%	31%
implicit heat rate Btu/kWh	5,528	8,204	11,720
efficiency	62%	42%	29%
energy required for end-use electricity relative to gas		148%	212%
CO2 per MMBtu of heat input (pounds)	115	115	210
CO2 for same useful output as 1 MMBtu of gas heat input	115	171	445
additional CO2 for electric option		48%	287%
clothes dryer			
end-use efficiency (relative to electricity to dry same amount of clothes)	89%	100%	100%
conversion and delivery efficiency	98%	45%	31%
implicit heat rate Btu/kWh (adjusted for slightly lower gas end-use drying efficiency)	3,926	7,630	10,900
efficiency	87%	45%	31%
energy required for end-use electricity relative to gas		194%	278%
CO2 per MMBtu of heat input (pounds)	115	115	210
CO2 for same useful output as 1 MMBtu of gas heat input	115	223	583
additional CO2 for electric option		94%	407%

* Gas delivery losses between the site of a powerplant and a residence. Electric efficiency based on combined cycle heat rate of 7000 Btu/kWh, coal heat rate of 10000 Btu/kWh, 9% line loss.

Source: Marcus, 2009.

While a heat pump using a gas combined cycle is approximately as energy efficient as direct combustion of gas in a furnace, when the other electric appliances are brought into the all-electric home, and when the use of resistance heat strips in cold or damp weather (not included in the table) is considered, the choice of electricity is markedly less efficient. Moreover, when coal-fired electric generation is at the margin, the amount of both energy use and greenhouse gas emissions burgeons when electricity is used instead of gas.

To stop promoting electric heat, it is necessary to remove explicit subsidies (such as Entergy Arkansas' $144 per year subsidy of electric water heating)[1] and closing declining block rates that make all-electric homes attractive. Declining block rates also reduce cost effectiveness of efficient baseload appliances - refrigerators and freezers.

Some may argue that electric space and water heating are largely off peak loads. Maybe, or maybe not. Large portions of the South are now winter peaking in cold years – it happened in Virginia in the past, several Arkansas co-ops are winter peaking (Marcus, 2004), and Florida not only peaked but almost ran out of power in this winter's cold snap.[2] (Reuters, 2010) In addition, gas is the marginal fuel in many hours in most of the country – even in the winter, so the cost of off-peak electricity is rising.

One caution is that regulators must act gradually. The critical first step is to close promotional rates to new premises so less electric heat goes into new construction to increase total energy use for decades. [3] Then, slowly reduce declining blocks and subsidies to existing customers. Existing customers made decisions in good faith relying on what we now know is poor rate design; they should be moved gradually rather than hit with rate shock. In recent Arkansas cases, explicit subsidies for electric heat have been closed to new premises (APSC, 2007, 2009) and in both Arkansas and Texas,[4] the

[1] This subsidy was closed to new premises in the 2007 rate case decision; Entergy has proposed eliminating it completely in its currently filed rate case. (APSC, 2007, Meyer, 2009)

[2] Florida Progress has even been winter peaking for two years in a row. (Reuters 2010)

[3] The analogy of the installation of electric heat in new construction is to a "lost opportunity" in energy efficiency – an efficiency option that must be done at a specific time or it will not be cost-effective either ever or until the appliance is replaced. The extra electric load from poor choices in new construction will be present for decades.

[4] The Texas case, involving Southwest Public Service, was a settlement.

amount of discount from declining block rates to existing premises has been closed at least somewhat.

A second, even easier step is to leave customer charges at current levels or reduce them. Customer charges blunt price signals that support efficiency. Fixed costs should be limited at most to direct costs of meters, services, and billing; they should not include common distribution or administrative costs, even if those costs are “fixed.” (Washington Utilities and Transportation Commission, 2004) Utilities like to raise customer charges. They love revenue stability – even while wanting special decoupling programs for conservation lost revenues only. Don’t go along with them. Residential rate increases should be applied to energy charges.

Third, regulators need to look at inverted tier rates – especially in peak months. Inverted tier rates, designed properly (and I’m not talking about the five-tier rates we got after the energy crisis in California) promote efficiency. (See Faruqui and Pfannensteil, 2008; BC Hydro, 2008). They also reflect cost causation for four reasons:

a. Customers’ lower tier rates are for baseload and non-space heating uses – refrigerators, lights, computers, and TVs that generally are not heavily used at peak. Higher usage in peak months is driven by space conditioning. (Lazar and Raphals, 2007)

b. Customers who live in apartments cost less to serve than customers who live in separate dwellings. They are more densely packed so that distribution equipment costs less per customer. They have higher aggregate load factors than single-family customers because dwelling units are smaller and attached walls reduce space conditioning needs. (Marcus, 1995)

c. Beyond apartments, data from some – but not all – locations suggests that smaller residential customers often have better load factors than larger ones. This is certainly true in California.[5]

[5] Marcus and Ruszovan, 2007 is the latest of a number of California references on this topic going back for almost 15 years.

d. Finally, for utilities with cheap legacy resources (like hydro), an inverted tier rate assigns cheap resources to low use while allowing better price signals for most customers' marginal usage. (Lazar and Raphals, 2007)

Thus, inverted tier rates are clearly an arrow in the quiver to encourage efficiency.[6]

But let's now think about more technologically oriented rate design.

First, Automatic Metering Infrastructure must be justified largely on real – not phantom – operational benefits. Demand response and dynamic pricing are uncertain. We are concerned that the amounts of these benefits from AMI have been overestimated for a number of utilities. (Schilberg 2006, Schilberg 2008)

When deciding whether to adopt of time of use or critical peak rates on either a voluntary or mandatory basis, we run into what I call the paradox of metering.

If these rates are mandatory or opt-out, even if small customers have some natural benefits from lower peak consumption, it is almost impossible to save the cost of the meter if charged to them on a per customer basis through a customer charge and their rates will rise. They simply do not use enough peak kilowatt-hours to be able to shift or conserve enough to pay for the meter's fixed charge. If TOU rates are voluntary, small customers therefore won't sign up. If the rates are mandatory, small customers are likely to be losers.

If these rates are voluntary, then customers with the most energy available to save or shift at peak are those who use the most during those hours. They have the air conditioners that can be turned off, cycled, etc. But many of them – except all-electrics – start out with lower load factors than the average. So they won't want to sign up for the rate, because they start out in the hole.

[6] California's inverted tier rates do provide an extra baseline (lower tier) allowance for all-electric customers, which makes some sense by providing a limited quantity of low cost power equivalent to baseline gas allowances, but electric heat is prohibited in all but name by California's building energy standards.

The net result is that a voluntary TOU rate will end up with the folks who can naturally benefit signing up for it. Small customers (who can't save enough to pay for the meters) and peak-intensive large customers will be left on plain vanilla rates. And small customers will probably be subsidizing the peaking customers.

The answer to this paradox – before widespread AMI development, could be (after careful analysis of local conditions) a policy requiring TOU rates where incremental costs are low because a new meter must be set anyway, in new single-family construction. PEPCO in Maryland has done this for over a decade. A next step might be to introduce TOU on a mandatory basis among the larger peak season users.

A more modern answer to the paradox taking AMI into account adds two more considerations:

1. Excess costs of AMI and Smart Meters above operational benefits should be charged volumetrically to residential customers, or a large number of small customers will pay more, regardless of their usage patterns.[7]

2. Peak time rebates (PTR) are a way to get some load shifting (though almost certainly not as much as would be achieved if a regulator hits customers over the head with a more coercive critical peak pricing rate)[8] with less customer impact than a mandatory rate.

The next question is whether residential demand response programs might work better than rates. Air conditioner cycling allows a customer to choose once, to install a cycler to turn a machine off for 20 minutes per hour on a dozen hot days in exchange for a periodic rebate. This is a lot easier for many people than trying to learn when a critical peak day is happening and how much costs will rise on a critical peak day so they can make a number of additional choices whether or not to make a lot of behavioral adjustments on that day.

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[7] A strong argument can also be made that these excess costs should be allocated between classes on a generation-related basis because they are providing technology that can reduce generation costs. (California Public Utilities Commission Division of Ratepayer Advocates, 2009)

[8] Schilberg 2008 contains a detailed discussion of this point.

Residential customers are not rate economists. Most residential customers don't care about minute-to-minute choices. Behavioral economics suggests that there is such a thing as too many choices.[9] Until most appliances can be automated so the customer doesn't have to think, there can be too much rate design.[10]

Another key point is that Demand Response and Pricing and Energy Efficiency are at least partly substitutes. When a customer installs a more efficient air conditioner, the customer has less demand that could be reduced at peak. So if a utility is counting on a kilowatt per average residential customer of demand response on air conditioning loads, it will get only get half or three-quarters as much from someone with an EER 16 model air conditioner. In essence, any estimates of demand response from air conditioning must decline over time to reflect that the air conditioner fleet is becoming more efficient. Any justification of AMI that does not consider this factor is flawed. (Schilberg, 2008)

More importantly, demand response works best with oversized equipment. On very hot days, a properly sized air conditioner will barely keep up. If cycled off or particularly turned off for critical peak, the temperature could rise considerably for the rest of the day creating discomfort and customer resistance. Customers with properly sized equipment are more likely to drop from a voluntary program and to feel squeezed and penalized if it's mandatory, and to oversize when they buy a new air conditioner. By contrast, oversized equipment – which wastes energy year round – is better able to cool the dwelling when the demand response event is over.

Finally, one must state the obvious; an efficient air conditioner that will save a kilowatt every time it is turned on (perhaps 1000 hours per year) without increasing customer discomfort is more valuable than a pricing programs that might save a kilowatt on 12 hot days a year at the cost of customer discomfort.

Next, it is important to consider customer bill impacts from seasonal, time-of-use, and critical peak pricing. Rate design that concentrates costs in peak months and particularly

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[9] The impact of too many choices on the rate of retirement savings is explored in Armour and Daly, 2008. A more general introduction to behavioral economics issues is found in Lambert, 2006.

[10] Regulators may also determine that some choices are simply inappropriate because the value of the choice cannot outweigh the societal harm. For example, swimming pool pumps could be required to be interruptible with utility load control rather than providing a choice to pay money to run them at peak.

does so unpredictably, like dynamic pricing, can have big impacts on low income, fixed income, and elderly consumers. If it is already hard for someone to pay an electric bill because they're using more in the summer, it will be much harder if their bill is 20% higher because of a seasonal or time of use rate – even if rates are reduced elsewhere in the year. And critical peak pricing with its unpredictability could be even more problematic – a hot July with several critical peak events may cause an even bigger bill increase.

Customer understanding of critical peak pricing is also of key importance. My 76-year old neighbor made the mistake of signing up for PG&E's voluntary program this summer to save money. She was absolutely miserable – in part because she thought she had to turn off everything in her house but a couple of lights and her computer or TV in order to save anything. This is bad, but mandatory or opt-out programs could lead to worse - including illness and deaths from heat exposure among the elderly. Perhaps, utilities need to take over the function of providing cooling shelters from municipalities (see, e.g., City of Chicago, Department of Family and Support Services 2010) if they want mandatory residential programs.

So before going in the direction of AMI, dynamic pricing, and similar programs, utilities need to learn about their customers. Most utilities have never studied economics, demographics and appliance saturations of their customers. Many of them speculate that poor people use more energy than rich people based on little or no analysis.[11] We have done some of that work in California, (Marcus and Ruszovan, 2007; Marcus, Ruszovan, and Nahigian, 2002) and we have encouraged several utilities to do the analysis. (NERA, 2007) In particular, regulators and utilities need to think about the poor, the elderly and folks who are not as computer literate as those on this webinar. Most low income people use less energy than those with higher incomes, but a group of customers with highly inefficient appliances, in inefficient dwellings, often with larger households, use more

[11] Colton 2002 disproves this point for a Maryland gas utility using national and regional data from the Energy Information Administration and the Bureau of Labor Statistics. JBS has subsequently used these data sources to analyze the issues for other electric and gas utilities. For examples of utilities that have previously denied the link between income and energy use, see Marcus, Ruszovan, and Nahigian, 2007, footnote 2, page 2.

than average. Efficiency programs should be targeted to them, and mandatory or opt-out rates should not be imposed without considering effects on this group.[12]

Summarizing, my key message is to encourage efficiency with the basics. Close declining block rates and all-electric subsidies to new premises, don't raise customer charges, and support inverted tier rates to make investments in efficiency more cost-effective. And be careful with residential time of use and dynamic rates. Thank you.

References

Arkansas Public Service Commission 2007. Order No. 11 in Docket No. 06-101-U (Entergy Arkansas, Inc.) June 16, 2007. http://www.apscservices.info/EFilings/Docket_Search_Documents.asp?Docket=06-101-U&DocNumVal=304

Arkansas Public Service Commission 2009. Order No. 12 in Docket No. 09-008-U (Southwestern Electric Power Company), November 24, 2009. http://www.apscservices.info/EFilings/Docket_Search_Documents.asp?Docket=09-008-U&DocNumVal=183

Armour, Phil and Daly, Mary 2008. "Retirement Savings and Decision Errors: Lessons from Behavioral Economics," Federal Reserve Bank of San Francisco Economic Letter, 2008-16, June 6, 2008.

BC Hydro 2008.Residential Inclining Block Rate Application to BC Utilities Commission. February 2008.

California Public Utilities Commission, Division of Ratepayer Advocates, 2008. Prepared Testimony in Application 08-03-002 (Southern California Edison Company Phase II), September, 2008. Chapter 3.

City of Chicago, Department of Family and Support Services 2010, Weather Relief. http://egov.cityofchicago.org/city/webportal/portalContentItemAction.do?contentOID=537023995&contenTypeName=COC_EDITORIAL&topChannelName=Dept&blockName=Family+Support+Services%2FI+Want+To&context=dept&channelId=0&programId=0&entityName=Family+Support+Services&deptMainCategoryOID=

Colton, Roger D. 2002. Direct Testimony for Maryland Office of People's Counsel. Maryland PSC Docket 8920 (Washington Gas Light 2002 Rate Case). June 2002.

Faruqui, Ahmad and Pfannensteil, Jackalyne 2009. "Inclining Toward Efficiency." Public Utilities Fortnightly. August, 2009, 22-27.

Lambert, Craig 2008. "The Marketplace of Perceptions, Harvard Magazine, March-April 2006, 50ff. can be found at http://www.altruists.org/f832

[12] California's Family Energy Rate Assistance (FERA) rate, which applies to households of 3 or more at or above the limit for low-income rate assistance under California Alternative Rates for Energy (CARE), provides relief from the third inverted tier, while still maintaining the highest tier rates, based on data showing that larger low and moderate income households often use enough energy to reach steeply inverted tiers. (Marcus, Ruszovan, and Nahigian 2002)

Lazar, Jim and Raphals, Philip 2007. Reforming the rate structure to better reflect marginal costs: Comments on Hydro-Quebec Distribution's 2008 Rate Proposal, for the RNCREQ, R-3644-07, Régie de l'énergie de Quebec.

Marcus, William B. 1995, Prepared Testimony on Marginal Cost, Revenue Allocation and Rate Design of Southern California Edison Company on behalf of Toward Utility Rate Normalization (TURN). June, 1995.

Marcus, William B. 2005. Prepared Testimony on behalf of the Arkansas Attorney General. APSC Docket No. 04-141-U (Arkansas Electric Cooperative Corp.). March, 2005. http://www.apscservices.info/EFilings/Docket_Search_Documents.asp?Docket=04-141-U&DocNumVal=48

Marcus, William B. 2009. Prepared Testimony on behalf of the Arkansas Attorney General. APSC Docket No. 08-103-U (Oklahoma Gas and Electric) January, 2009. http://www.apscservices.info/pdf/08/08-103-u_63_1.pdf

Marcus, William B. and Ruszovan, Greg 2007. , ***Know Your Customers: A Review of Load Research Data and Economic, Demographic, and Appliance Saturation Characteristics of California Utility Residential Customers***. Attachment to Formal Comment Filed in CPUC App. 06-03-005 Dynamic Pricing Phase for The Utility Reform Network. December 2007. available from http://www.jbsenergy.com/Energy/Papers/papers.htm

Marcus, William B., Ruszovan, Greg, and Nahigian, Jeffery, 2002. ***Economic and Demographic Factors Influencing California Residential Electricity and Gas Use***. September 2002. available from http://www.jbsenergy.com/Energy/Papers/papers.htm

Meyer, Gordon D. 2009. Direct Testimony on behalf of Entergy Arkansas, Inc. September 4, 2009.

NERA Economic Consulting 2007. ***Economic and Demographic Factors Affecting Arkansas Residential Energy Use***, Report prepared for CenterPoint Energy, April 5, 2007. Included as Exhibit ADH-4 to Alan Henry, Supplemental Testimony on behalf of CenterPoint Arkla in APSC Docket No. 06-161-U.

Reuters, 2010. "Florida Utilities See record Power Use amid Cold:" January 11, 2009. http://www.reuters.com/article/idAFN1116299520100111?rpc=44

Schilberg, Gayatri M. 2006. Analysis of San Diego Gas and Electric's Advanced Metering Infrastructure Application, California PUC Application 05-03-015. August 2006, Chapter 3.

Schilberg, Gayatri M. 2008. Testimony on Pacific Gas and Electric's Demand Response Benefit Estimates. California PUC Application 07-12-009. June, 2008.

Washington Utilities and Transportation Commission, 2004. Rate Spread and Rate Design Elements, Prepared for the Kyrgyz Republic SEA; found at http://www.narucpartnerships.org/Documents/RateSpreadRateDesign.pdf