Advanced Metering Infrastructure: A Snapshot of Smart Metering in North America, Mid-2010

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INTRODUCTION

The concepts of the advanced metering infrastructure, smart meters and dynamic pricing, have evolved quickly. The future of this new technology and new pricing as yet remains uncertain.

It was only in 2002 that the California Public Utilities Commission initiated the process leading to the Special Pricing Pilot or SPP, the first major study of customer responses to various dynamic pricing options enabled by smart metering technology. By early 2008, when NRRI published *Advanced Metering Infrastructure: What Regulators Need to Know About its Value to Residential Consumers,*[1] utilities and regulators in several states and provinces had moved forward with dynamic pricing pilots. Some, including utilities in California, Illinois, Alberta, Ontario, had begun the widespread deployment of advanced metering infrastructure (AMI, or smart metering).[2] In early 2009, promotion of smart grid technologies had become a goal of the Obama Administration in the United States, and the US Department of Energy announced an opportunity to draw on $3.4 billion of so-called "stimulus money" to develop the smart grid in various ways.

Utilities in the United States have announced plans to install over 30 million smart meters in the next few years. Millions of these communicating interval meters have already been deployed, mainly in California and Texas. Utilities in Canada are on track to have installed 5.8 million smart meters by 2017.

Technology development tends to follow some recognizable patterns. There is the so-called Schneider Classic Change Curve (sometimes called the "Hype" curve). As described in a recent e-article,[3] proponents of a new technology (including new methods and processes) have high expectations for the technology when it is first developed. Naysayers are dismissed as pessimists without vision, if not dinosaurs clinging to the old ways (and profits).

As the industry tries to develop and deploy the technology, the high expectations often turn out to have been rosier than warranted by the actual potential of the technology. With this realization of effort and complexity can come despair that the technology will ever prove itself and become widely adopted. If the underlying technology is viable, however, eventually the bugs and glitches will be worked out, and the technology will be adopted, and often provides benefits often not imagined when the technology was first developed. This sequence is shown in the representation[4] of the Classic Change Curve reproduced below as Figure I.

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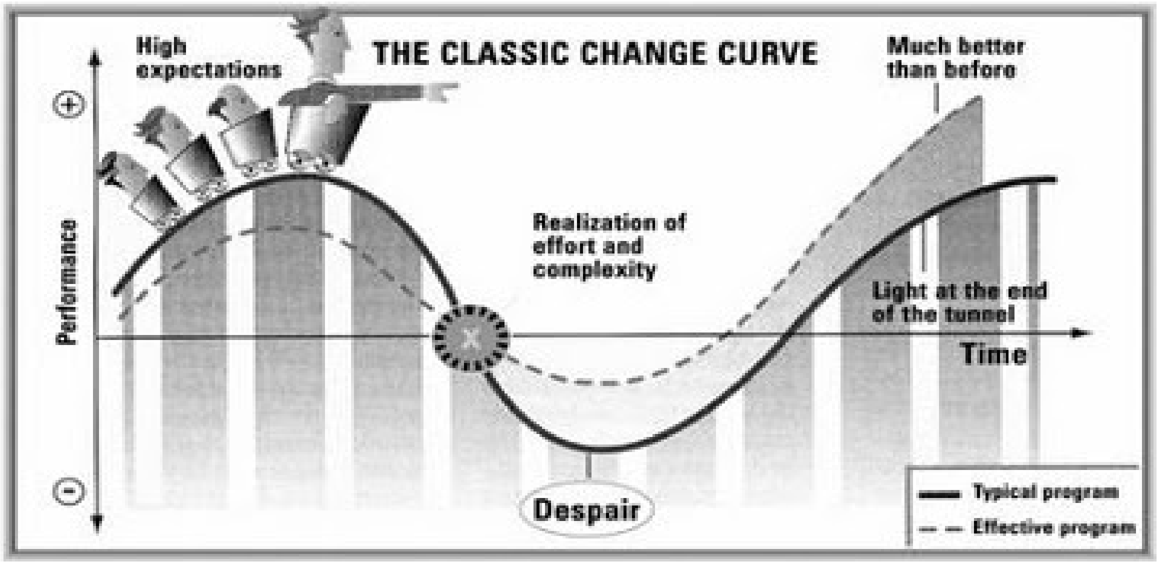
[1] NRRI Report 08-03, February, 2008, written by Nancy Brockway, available at www.nbrockway.com/publications..

[2] This paper will use the term "smart metering" to encompass the use of two-way communicating interval meters, particularly for residential consumers, often to support time-varying rates such as critical peak pricing. For a glossary of smart grid terms, see, e.g. *2007 Assessment of Demand Response and Advanced Metering*, Appendix A, a report of the staff of the Federal Energy Regulatory Commission.

[3] Danahy and Bochman, "Blogging the Grid: Smart Grid Expectations and Our Changing Relationship with Power," April 2010, http://www.smartgridnews.com/artman/publish/Business_Strategy_News/Smart-Grid-Expectations-and-Our-Changing-Relationship-with-Power-2255.html, last viewed 4-30-10.

[4], *Id.* (Schneider's Curve Image courtesy of iowalibrarian.com).

Figure 1: The Classic Change Curve



We are moving into the despair part of the curve. For a variety of reasons, it has taken longer than proponents hoped to get advanced metering infrastructure in place across North America. The roll-out of universal smart metering in the United States especially has been slowed by initial deployment problems in California and Texas. Some consumer advocates (including this author), regulators and utilities have pointed out the uncertainties still surrounding the benefits of the new technology and pricing options. Major fundamental issues like cyber-security, interoperability, consumer protection, cost and benefit allocation, rate design and protection of privacy, still remain unresolved.

Smart metering proponents are beginning to realize that important players in the development of their dream technology are not on board (at least not yet). A main focus of the 2010 National Town Meeting on Demand Response will be "*the consumer---one of the hottest topics today in the world of demand response and smart grid.*" Presenters will try to help utilities and smart metering proponents answer three very basis questions about the smart grid that remain unanswered:

What do consumers want?

What do they care about?

How do we, the smart metering industry, talk to them?

Others have noted that customers do not seem to be getting the message that smart metering and dynamic pricing are useful for them. The industry is trying to respond. Danahy and Bochman[5] reassure the industry that the public's initial coolness towards smart metering can be overcome with better communications:

> There is still plenty of time to improve the honesty and realism of those communications, and utilities must be diligent in their efforts to present the reality of the solutions, the risks, and the benefits, and to dedicate themselves to educating their customers, and not simply to convincing them.

This report aims to assist in the process of improving the honesty and realism of communications about the potential for smart metering and dynamic pricing. It will attempt to present the present reality of the risks and benefits that smart metering brings, based on our experience and knowledge to date. As more experience is gained, risks and benefits will be better defined. The jury is still out on the direction smart metering technology will take us, and how fast we will go there.

I. WHAT IS SMART METERING: A BRIEF REFRESHER

Advanced metering infrastructure is defined by the Staff of the Federal Energy Regulatory Commission (FERC) as:

> ...a metering system that records customer consumption (and possibly other parameters) hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communication network to a central collection point. AMI includes the communications hardware and software and associated system and data management software that creates a network between advanced meters and utility business systems and which allows collection and distribution of information to customers and other parties such as competitive retail providers, in addition to providing it to the utility itself.[6]

The term "smart metering" is used in this report instead of the term AMI. As used here, smart metering is not limited to advanced meters, but refers to an entire infrastructure that ties advanced meters to a data management system and from there to other utility business systems. It also encompasses "smart pricing" - time of use pricing and other pricing made possible by interval metering.[7]

II. ELEMENTS OF THE SMART METERING BUSINESS CASE

When utilities seek approval of cost recovery for smart metering investments, regulators typically require the utility to show that the benefits of the investment will be greater than the

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[5] *Blogging the Grid, supra.* Emphasis removed.
[6] 2007 FERC Staff Report, Appendix A (Glossary).
[7] The specific elements under discussion are highlighted where necessary.

costs.[8] In the first instance, the calculation is performed at the utility level. Benefits to the utility and its customers are counted, and costs to the utility and its consumers are counted. The two are compared.

Benefits of smart metering are typically divided into operational benefits and resource benefits. Operational benefits are those that reduce the operating costs of the utility. Resource benefits reduce the cost of energy and capacity.

Sometimes non-energy benefits (or costs) are included when weighing the pros and cons of smart metering investments. For example, sometimes smart metering proponents claim environmental benefits from demand response and consumption reduction they argue will be made possible by smart metering. Others dispute this assertion. Similarly, advocates for labor may note that meter reading jobs will be lost if the smart metering is used to introduce automated meter reading. What non-energy benefits or costs are identified varies from jurisdiction to jurisdiction.

A. Operating Benefits

The primary operational benefit of smart metering is the elimination of labor and truck roll costs from "manual" meter reading. Typically, utilities estimate that meter reading cost savings will be about half the total claimed savings.[9]

Operational savings claimed for smart metering investments include the following:[10]

1. Remote meter reading
    a. Eliminates need for meter-reader to read meters
    b. Allows more frequent meter-reading
    c. Eliminates problems associated with estimated bills
    d. Improves meter reading accuracy, thus reducing meter disputes
2. Remote disconnection/reconnection (electric only)
3. Identification of outage locations
    a. Supports more rapid customer restoration time
    b. Eliminates need for customer outage reporting
    c. Allows more accurate dispatching of repair crews, with associated cost reductions
4. Improved tamper detection

Pacific Gas & Electric presented a cost-benefit analysis to the California Public Utilities Commission in which it claimed that 90% of the benefits would come from operational savings,

[8] In a jurisdiction like Pennsylvania, where statute obligates all major electric utilities to deploy advanced metering, Act 129 of 2008, 66 Pa.C.S. § 2807(f), the utility should still carry the burden of showing that its particular plan is the least cost among the alternatives allowed within the statutory parameter.
[9] *AMI: What Regulators Need to Know, supra,* p.18. Available at http://www.nbrockway.com/testimony.html.
[10] Some other distribution savings claimed for smart metering include improved capacity utilization, grid voltage and phase monitoring , and better load data for planning purposes. These benefits are not tied to dynamic pricing or other customer-focused practices, and are not addressed in this report.

primarily meter reading.[11] This ratio of operational to non-operational benefits is not typical.

Recently, Nevada Power provided a breakdown of the operational savings it expects from its smart metering project. As shown below, the vast majority of the claimed ongoing benefits will come from reducing labor costs for truck rolls, whether for meter reading or otherwise:

Operational Efficiencies	***% total $***	***Ongoing Operational Savings ($)***
Total Meter Reading	**31%**	**7,483,611**
Total Load Research	**1%**	**206,617**
Total T&D Planning	**6%**	**1,532,391**
Total Credit, Collections	**2%**	**597,492**
Total Billing	**13%**	**3,050,253**
Total Meter Operations	**31%**	**7,605,345**
Total Benefits	**100%**	**24,378,307**

Billing comes in 3rd with just under 15% of the claimed savings. Transmission and Distribution Planning is estimated at a distant 4th, about 5%. Note that utilities often list claimed sources of operational savings in their business case, but do not attempt to quantify the dollar savings associated with each such change in operations. A failure to quantify savings associated with such operational benefits of smart metering suggests that the estimates should be ignored.

Where a utility has already installed automated meter reading (AMR), there remain few concrete operational benefits from a move to smart metering. Beginning in the 1990s, many electric utilities installed technology that permitted AMR. Typically, a wireless module was installed at the existing meter, and a meter reader could walk or drive by, using a device that would pick up a signal from the meter giving the usage data required. These systems were used to reduce meter reading costs: the time it took to go house to house, the cost of the more frequent and longer truck rolls, and other meter reading costs.

As noted above, automation of meter reading is the single largest operational benefit of smart metering. Further, it is the best-defined and most easily quantified operational benefit. As discussed below, some operational changes that produce cost savings come at the expense of erosion of consumer protections. This is true in the case of remote disconnection of customers

[11] *Application of Pacific Gas and Electric Company for Authority to Increase Revenue Requirements to Recover the Costs to Deploy an Advanced Metering Infrastructure*. Application 05-06-028, Final Opinion Authorizing Pacific Gas and Electric Company to Deploy Advanced Metering Infrastructure, July 24, 2006, at p. 10.

who are subject to disconnection for non-payment.

The typical utility will have to show that non-operational benefits of smart grid are large and real. Easier-to-quantify and more assured operational savings do not make up the bulk of the claimed benefits of smart metering, in most cases. For example, operational savings represented only about a third of the benefits claimed by Baltimore Gas & Electric in its smart metering proposal, recently rejected without prejudice by the Maryland Public Service Commission.[12] Given the modest contribution of operational benefits to defraying the cost of the project, the non-operational benefits (and their uncertainties) became much more important in that case.

B. Resource Cost Savings

The primary resource cost saving claimed for smart metering is reduction in system demand, and associated system costs, brought about by customer demand reductions in response to time-varying pricing. Other claimed resource cost savings include avoided consumption costs, and the impacts on the wholesale price of electricity of the capacity and demand savings.

The key resource benefit claimed for smart metering applications is reduction in critical peak demand. The highest responses are claimed for so-called critical peak pricing (CPP), or its variant, Peak Time Rebate (PTR). Under either CPP or PTR, usage during the 60 to 100 hours of the year when system costs are highest are valued much more highly than usage in other hours. As described by Brattle Group researchers,[13] these hours represent a small percentage of hours in the year:

> The demand for electricity is highly concentrated in the top one percent of hours. In most parts of the United States, these 80-100 hours account for roughly 8 to 12 percent of the maximum or peak demand. In California, they account for some 11 percent. In the 12 Midwestern and Northeastern states that form the PJM Interconnection, they account for 16 percent. In the Canadian province of Ontario, the top 32 hours account for 2,000 MW of demand out of a peak demand of 27,000 MW.

Under Critical Peak Pricing, customers are charged multiples of the ordinary rate during those high-value hours.[14] The higher rate is intended to reflect the avoided costs of the high, critical peak generation for the system. Non-critical peak hours are charged at a lower rate than previously, to make the rate revenue neutral for customers who have the average class load profile and do not alter their usage or usage patterns in response to the new price signals.

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[12] *In the Matter of the Application of Baltimore Gas & Electric for Authorization to Deploy a Smart Metering Initiative and to Establish a Surcharge for the Recovery of the Cost*, Maryland P.S.C. Docket No. 9208, Order 83410, June 21, 2010.

[13] Faruqui, et al, *The Power of 5 Percent: How Dynamic Pricing Can Save $35 Billion in Electricity Costs (Power of 5 Percent),* Brattle Group discussion paper, May 2007, at p. 2. Such hours as a percentage of maximum demand may have varied since 2007, but the 2007 percentages are still representative.

[14] To maintain revenue neutrality, non-critical-peak hours are charged less than under pre-existing ratesetting.

Under Peak Time Rebates, pre-existing rates remain the same. Customers who back off usage during the critical peak hours receive a credit that corresponds in value to the costs imposed on CPP customers during such hours.

Both CPP and PTR can be used in the context of inclining block rates, and also can be superimposed on a broader time-of-use rate design.

III. UNCERTAINTIES IN RESOURCE SAVINGS PROJECTIONS

The projections used to develop benefit/cost estimates for smart metering investments are subject to great uncertainties, which go beyond the usual difficulties of predicting market-clearing capacity and energy prices. The type of demand-responsive pricing offered, the extent to which participation in a critical peak value rate is voluntary, the difference between pilot reactions and long-term demand responses, the impact of dynamic pricing and feedback on consumption, and the persistence of demand reductions over time, all are difficult to estimate with precision.

Dynamic prices made possible by smart meters have induced pilot participants to reduce critical peak loads by as much as 33%. The average of recent pilots shows a range of 12% to 25%, low to high. The uncertainties about the peak demand reduction value of dynamic prices are the extent to which pilot results can be extrapolated to the entire customer base of a utility, and the question of whether peak reductions in the short term will persist through a number of planning periods.

Even if the extent of peak demand reduction were relatively certain, utilities would still have some difficulty in estimating the value of such demand reduction. The avoided cost of system peak demand depends in vertically integrated systems on forecasts of loads and resources over the period in question, identification of the marginal generation capacity, and estimation of its future cost. These are all forecasts, and subject to the usual uncertainty of forecasts.

In organized electricity markets, the rules of the market come into play as well in estimating peak demand resource values. In the Mid-Atlantic states, New York, and New England, a forward capacity market with a default price undergirds the price of capacity. The load-serving entity that comes to the market without sufficient firm generation to meet its objective requirements will have to buy power out of the market at the administratively-set estimate of the cost of new generation.

In some markets, there is no explicit capacity market. Capacity costs are entirely subsumed in the energy price (per kWh). In such a case, one would have to estimate the extent to which the energy price covered what are essentially capacity costs, and develop an avoided capacity cost in this way.

There is some energy-related value even in a market that has a capacity submarket. The MADRI analysts, for example, in 2007 estimated that a $2.4 billion avoided peak capacity cost would bring with it $300 million in avoided energy costs, or roughly 12.5% of the avoided capacity value. Reducing critical peak loads reduces usage during the critical peak hours. However, as noted, these hours are a small percentage of the total hours of the year. See below for a discussion of the extent to which smart metering has an impact on consumption overall.

Some analysts note that if capacity and energy requirements are reduced, this will have the impact of reducing the market price for electricity in a wholesale market, at least in the short run.[15] These analysts note that the impact can only be counted in the short term, because once the market has adjusted to the new load levels, other factors will determine price.

The capacity obligation of most utilities is based on the few hours in the year when the system demand is highest, and even the most expensive resources must be deployed to meet the demand. If indeed load can be backed off during such critical peaks, system resource costs can be lowered. But by how much?

Proponents of smart metering and dynamic pricing have identified huge potential resource cost savings from even small reductions in critical peak demand. Brattle Group analysts have suggested that reducing peak demand across the United States by 5% would reduce resource costs by $3 billion per year in that country.[16] The single largest component of this estimate was attributable to capacity savings, $2.4 billion annually, valued at the number of reduced mW times $52/kW-year.[17] This value is greatly inflated, as capacity values rise and fall, and varies by capacity market. The same exercise undertaken today, or using capacity values from another market, would produce different results.

For example, in 2009, Synapse Energy Economics published a forecast of capacity costs in the New England region (ISO-NE). The study found that region-wide capacity costs, which had been running at roughly $30/kW-year, would likely be only $18/kW-year going forward, estimated on a long-term levelized basis.[18] In other words, using 2009 forward-looking capacity value estimates for the New England region, and applying them to demand reductions across the United States, the "power of 5%" would be roughly one third of the value estimated by Brattle Group in 2007.[19]

Thus, we have seen that wholesale capacity costs can be quite low, and may not support the level of metering infrastructure investment necessary to support dynamic prices, at least when resource savings are the sole major benefit expected. When Dr. Hornby presented a low-value but reasonable alternative to the benefit-cost estimate presented by PEPCO-Maryland in support of its smart metering initiative, using more conservative estimates of the value of avoided costs,

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[15] See, e.g., 2006 Brattle DR Study for MADRI/PJM: Newell, Sam and Frank Felder, *Quantifying Demand Response Benefits in PJM*, Study Report Prepared for PJM Interconnection, LLC and the Mid-Atlantic Distributed Resources Initiative (MADRI), January 29, 2007, referenced in Faruqui et al, *Power of 5 Percent, supra.*

[16] Ahmad Faruqui, et al, *The Power of 5%,* at p. 5.

[17] Brattle Group used PG&E's estimate of $52/kW-year, which was derived by taking a capital cost of $85/kW-year, and subtracting the present value of the stream of energy sales expected to be made from the unit. *Power of 5%*, at p. 5, note 18. All values were as of 2007 or 2008.

[18] J. Richard Hornby, et al, *Avoided Energy Supply Costs in New England: 2009 Report, Revised: October 23, 2009*, Exhibit 1-6. Available at http://www.synapse-energy.com/cgi-bin/synapsePublications.pl?filter_type=Topic&filter_option=Price+Forecasting&advanced=false.

[19] One third of $2.4 billion is $8 billion.

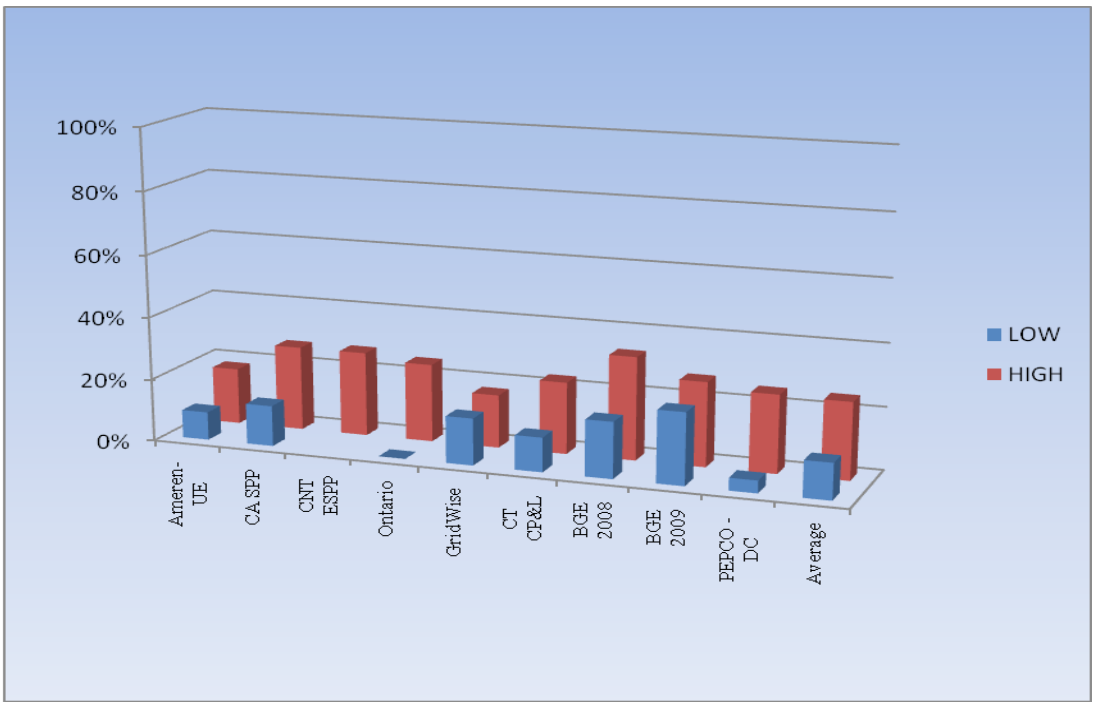
he found that the ratio of benefits to costs dropped from 1.65 to less than 1.[20]

Another factor affecting the value of critical peak load reductions is the load factor of the system in which the critical peak reductions will be experienced. If the load factor is high, the differential between critical peak costs and costs at other hours will be smaller. The value of shaving this critical peak, then, will be less.

A. UNCERTAINTIES IN PROJECTIONS OF DEMAND RESPONSE

It is self-evident that the extent of capacity cost reductions brought about through dynamic pricing will depend on the numbers of customers who take service under the tariff, and their response to the tariff. Recent pilots have consistently shown that pilot participants on average have reduced critical peak demands in response to dynamic pricing. The amount reduced varies with a number of factors, including whether the customer was provided an in-home feedback devices and enabling technologies like an automatic air conditioner thermostat or turn-off switch.

Figure 2: Low/High Demand Reductions - Recent Pilots



As can be seen from the chart above, the percentage by which participants (on average) reduced their demand during critical peak periods varied from a low close to zero, to a high of over 33%. High percentage reductions typically were achieved by customers with air conditioning load who received enabling technologies, such as programmable switches. Averaging the lows and the

[20] *In the Matter of Potomac Electric Power Company and Delmarva Power and Light Company, Request For the Deployment of Advanced Meter Infrastructure,* Direct Testimony of J. Richard Hornby on Behalf of the Maryland Office of People's Counsel, Maryland Public Service Commission Case No. 9207, October 20, 2009, p. 22.

highs for this group of studies, the range of demand reduction observed in recent dynamic pricing pilots has been roughly 12% to 25%, depending on rate design and enabling technology. Averages do not tell the entire story, however, as we will discuss below.

1. Critical Peak Pricing vs. Peak Time Rebates

Both critical peak pricing and peak time rebates constitute versions of time-varying pricing.[21] In the case of CPP, the customer faces very high prices during the critical peak hours of the year. In the case of PTR, the customer has the opportunity to obtain credits (rebates) for the extent to which she reduces demand during those hours. The ability of the utility to adjust the prices for such discrete blocks of hours is made possible by the smart meter, which records usage no less frequently than hourly. With this information, the utility can apply prices that vary over time in response to changes in the overall demand of the system.

The variation of critical peak prices from non-critical peak pricing can follow system costs, in which case the pricing system would be called "real time pricing." Under CPP or CPR, the rates that will be in effect during the especially high critical peak hours are set out in advance.

Consumer advocates tend to prefer PTR, on the grounds that customers are not worse off (aside from smart metering charges) under such rates than under the status quo. CPP has received high satisfaction ratings among pilot participants.[22] Indeed, low-income customers in the PG&E service territory who have smart meters and can sign up for optional SmartRate™ CPP rates have chosen CPP in disproportionate numbers.[23]

The consumer advocate preference for PTR over CPP may be successful in light of the fact that some experts do not observe significant differences in the demand reductions achievable with CPP versus PTR. The evaluation of the 2008 Baltimore Gas & Electric pilot found that the difference between the response to the CPP price signal and to the PTR price signal, while following the general pattern, was not statistically significant.[24]

> It is also important to note that the elasticities for [CPP and PTR] rates were not found to be statistically distinguishable from each other. This result has an important policy implication since it shows that the SEP customers showed the same responsiveness whether the signal came to them through a higher price or through an equivalent rebate.

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[21] So-called hourly pricing and real time pricing are variants that peg the rates more dynamically to changes in the price of power in the wholesale market. The change in the rate can be limited to certain critical periods during the year, reverting to a more static rate for other hours.

[22] See, e.g., Maryland Marketing Source, Inc., *2008 Smart Energy Pricing Pilot: Customer Experience Survey Summary,* December 2008, filed as Appendix 8 to Direct Testimony of Ahmad Faruqui on behalf of Baltimore Gas & Electric, MPSC Docket No. 9208.

[23] While low-income customers made up 35% of the customers who could choose SmartRate™, they were 56% of the customers taking SmartRate™ service. Stephen George, et al. *2008 Ex Post Load Impact Evaluation for Pacific Gas and Electric Company's SmartRate™ Tariff*, Final Report, December 30, 2008, at 4.

[24] Faruqui et al, *BGE's Smart Energy Pricing Pilot: Summer 2008 Impact Evaluation*, Brattle Group, April 29, 2009.

Indeed, in its 2009 pilot, BGE limited the critical peak rate options to PTR, and did not offer any CPP rates. The customer survey analyst for the 2008 pilot reported that, while pilot participants were very satisfied with their critical peak rate, whether the CPP or the PTR, those with the PTR had slightly higher levels of satisfaction.[25]

On the other hand, recent preliminary findings by Dr. Frank A. Wolak concerning the PEPCO District of Columbia pilot suggest that the higher demand response for CPP than PTR is in fact statistically significant.[26] Further, PTR rates have the problem that a baseline must be estimated for the level of demand the customer would have had if the critical peak period had not been called. As in the case of industrial interruptible rates, such estimates are necessarily imprecise.

The eventual acceptance of CPP will have to rest on hard data that persuades the public and consumer advocates that vulnerable customers and low-use customers are not harmed by the extraordinarily high rates during the critical peak.[27]

2. Opt-In vs. Opt-Out

The take-rate for a dynamic rate based on critical peak values will vary greatly depending on whether customers must affirmatively choose to take service under the rate (opt-in), or will take service under the rate as a default if they do not affirmatively choose not to take service on the rate (opt-out). It stands to reason that a greater percentage of customers will remain on a dynamic rate if they are put on the rate as the default, than will choose affirmatively to switch from their present rates (whatever they may be) to the dynamic price offering. Estimates of such take-rates are mostly speculative at this time.[28]

No jurisdiction has yet imposed dynamic pricing as the default rate, thus requiring customers to opt-out to avoid service under the dynamic rate. Baltimore Gas & Electric has proposed that the peak time rebate version of the critical peak tariff be used as the default.[29] Customers who wish

[25] Maryland Marketing Source, Inc., *2008 Smart Energy Pricing Pilot: Customer Experience Survey Summary,* December 2008, filed as Appendix 8 to Direct Testimony of Ahmad Faruqui on behalf of Baltimore Gas & Electric, MPSC Docket No. 9208.

[26] Frank A. Wolak, *An Experimental Comparison of Critical Peak and Hourly Pricing: The PowerCentsDC Program**, preliminary Draft, prepare for the 2010 POWER Conference, March 13, 2010, at 5. Available on Professor Wolak's home page.

[27] Papers reporting the percent of customers in a class who benefit from lower bills, as opposed to those who pay higher bills, are unsatisfactory for a number of reasons. One set of data that needs to be examined is the extent to which critical peak usage reductions are sustainable by low-income and low-use customers, without harming health and safety,.

[28] Only PG&E in California, which has deployed 6 million smart meters, is offering critical peak values to customers on a widespread basis. Ontario's time-of-use pricing goal is to have 1 million customers on time-of-use by the summer of 2010, and by June 2011, to have 3.6 million customers on time-of-use pricing. OEB Monitoring Report: Smart Meter Deployment and TOU Pricing – 2009 Fourth Quarter, February 25, 2010, available online: http://www.oeb.gov.on.ca/OEB/_Documents/SMdeployment/SM_Monitoring_Report_20100225.pdf. It appears from the literature that TOU rates will be mandatory. According to an evaluation of the Newmarket TOU rates, implemented in 2009, non-shopping customers will be required to take service under TOU rates. http://www.nmhydro.ca/pdf/NMH_TOU_FINAL.PDF.

[29] On June 21, 2010, the Maryland Commission rejected BGE's application for approval of its smart metering and

to return to the present flat rate would have to make an explicit choice to opt out of the PTR.[30]

Many pilots have provided a cash incentive to prospective participants, which would not be available when and if the tariff is offered generally. For example, in the Pepco pilot in the District of Columbia, customers who agreed to participate on the rates were promised an "appreciation" payment. In order to ensure that dynamic pricing treatment customers remained on their pricing plan for the duration of the experiment, the utility promised each prospective participant that they would receive $100 for participating in the pilot. The payments were divided, with $50 paid up front and $50 paid at the end of the experiment period.[31]

3. Low-Income and Low-Use Customer Response

One of the continuing areas of concern in the debate over smart metering and dynamic pricing is the effect of smart metering on vulnerable customers, including low-income, low-use, and otherwise vulnerable customers. Many consumer advocates argue that low-income and low-use customers cannot move their demand off the critical peak. It is well-understood that low-income customers have, on average, disproportionately low usage compared to non-low-income customers.[32]

In part because of the perceived inability of low-income to move loads off critical peaks, most consumer advocates object to making CPP the default, and forcing customers to opt out to move back to a flat (or flatter) rate. They argue that low-use customers cannot move their usage off the critical peak, at least without harm to their health and safety, and thus will be harmed by the imposition of critical peak pricing.[33]

Smart metering proponents counter that low-use customers can and do respond to critical peak pricing, and further that even those who do not change their usage behavior can benefit, since they tend to have flatter load shapes and a greater portion of their total usage off the critical peak,

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dynamic pricing proposal, under review in MPSC Docket No. 9208. The primary concern cited by the Commission was the proposal by the utility that consumers take all the risks that the new technology and pricing system would work. *In the Matter of the Application of Baltimore Gas & Electric for Authorization to Deploy a Smart Metering Initiative and to Establish a Surcharge for the Recovery of the Cost*, MD P.S.C. Docket No. 9208, Order 83410, June 21, 2010. BGE sought rehearing, and offered a new plan, now under consideration by the Commission.

[30] Note that PTR is in effect an opt-in form of critical peak pricing, however. That is, under PTR the customer takes service under the existing rate (e.g. a flat rate per kWh), and has the choice of changing behavior during the critical peak periods to receive a rebate, or credit, on the bill.

[31] Wolak p. 14. The utility did not offer a payment to those solicited to participate in the pilot on the critical peak rebate rate, because their bill was protected by the design of the program - under the CPR design, the customer's bill cannot increase as a result of participating in the pilot.

[32] See, e.g., William B. Marcus, Greg Ruszovan, JBS Associates, *"Know Your Customers": A Review of Load Research Data and Economic, Demographic, and Appliance Saturation Characteristics of California Utility Residential Customers ("Review of CA Load Research"),* filing by TURN with California PUC, in App. 06-03-005, Dynamic Pricing Phase, December 11, 2007.

[33] See, e.g., Barbara Alexander, *"Smart Meters, Real Time Pricing, and Demand Response Programs: Implications For Low Income Electric Customers."* Update, May 30, 2007. Available at: http://www.pulp.tc/Smart_Meters__Real_Time.pdf

and enjoy lower rates for their off-peak usage.[34] So far the literature does not permit a firm decision as to which view is correct.

Both are plausible, but impact evaluations of smart metering pilots either do not address this question, or ignore the costs of the smart metering when assessing bill impacts on low-use customers.

Some studies reveal lower percentage demand reductions among low-income customers and low-use customers. Three separate evaluations of the CA SPP pilot revealed that low-income customers participating in the California SPP pilot were less price-responsive than higher-income participants.[35] One analysis of the California pilot showed that low-use customers did not respond to critical peak pricing, or peak time rebates.[36] Another evaluation found some load response on the part of low-use customers, but significantly less than the response of high-use customers.[37]

According to one analysis of the California SPP results, low-income high-use customers by contrast experienced adverse bill impacts (higher bills) under the pilot tariffs, even before counting the cost of the advanced metering infrastructure. For reasons that are not yet well enough understood, they did not reduce loads at the critical peak times. Participants in a small, special low-income outreach portion of the pilot (so-called "Track B") did reduce critical peak loads on average, but later analysis showed that the averages were pulled up by the extreme behavior of a small number of participants.[38]

The experience of Pacific Gas & Electric in 2008 suggests that low-income customers may opt in to critical peak pricing in numbers greater than their presence in the customer base[4] After a pilot that indicated high average responses to critical peak pricing, PG&E introduced critical peak pricing (SmartRateTM) on an opt-in basis to its customers in Bakersfield and Kern counties in California. The Company solicited 100,000 customers to participate. So far, only about 7.5% of residential customers who received the invitation did opt to take service under the SmartRate™.

Load reductions per customer were in line with per customer load reductions forecast on the basis of the California pilot. That is, the low-income customers on the tariff shaved less from the critical peak than the non-low-income customers.

According to the Impact Evaluation, a "disproportionate number of CARE customers enrolled in SmartRate relative to the share of CARE customers in the Bakersfield area."[39] The 2008 impact evaluation observed that, whereas approximately 35 percent of residential electricity customers

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[34] See, e.g., *Quantifying the Benefits of Dynamic Pricing in the Mass Market,* Edison Electric Institute, 2008, Appendix F at p. 8.

[35] See discussion of pilot results by income in Brockway, *Advanced Metering Infrastructure,* at pp. 61 ff.

[36] Karen Herter, "Residential implementation of critical-peak pricing of electricity," *Energy Policy* 35 (2007): 2121-2130 ("Herter"). Available at www.elsevier.com/locate/enpol, at 2122.

[37] Charles River Associates, *Impact Evaluation of the California Statewide Pricing Pilot*, March 16, 2005 ("CRA"). Available at: http://www.energy.ca.gov/demandresponse/documents/index.html#group3.

[38] MCubed, and San Francisco Community Power, *Statewide Pricing Pilot, Track B*, April 26, 2005. According to this evaluation, four Track B participants cut their electricity use in half in response to CPP calls, and one of these reduced demand by two-thirds during the Winter period.

[39] Stephen George, et al. *2008 Ex Post Load Impact Evaluation for Pacific Gas and Electric Company's SmartRate™ Tariff, Final Report*, December 30, 2008, at 4. CARE customers are low-income customers in California who take service under a reduced rate of the same name.

who were sent marketing materials took service under the CARE low-income-rate, 56 percent of the customers who enrolled in SmartRate™ in 2008 were CARE customers.[40] The evaluation also noted that, as had been expected based on the pilot, CARE customers had much lower demand reductions (both in absolute and percentage terms) than non-CARE customers on the critical peak rate.[41] Thus, there is evidence that low-income customers may be more likely to opt into a dynamic pricing tariff, perhaps in the hope of reducing their bills.

There is also some pilot evidence that, contrary to the CA SPP and PG&E experiences, low-income customers will reduce their peak usage more than other customer on a percent-of-prior-peak basis. This suggestion comes from the experiment with dynamic pricing that was carried out during the summer of 2008 in Washington, D.C. by PEPCO, called the PowerCents[DC] program.

PEPCO actively recruited limited income customers in an effort to understand their responsiveness to dynamic pricing. The evaluator found that the average percentage load response of low income customers in the pilot was significantly higher than the percentage load response of by non-low income customers in the pilot.[42]

However, there were too few low-income customers who remained on the tariff for the entire pilot, undermining the ability to make precise estimates of such differences in response.[43] Further, it remains unclear what steps low-income customers in the DC pilot took to achieve the percentage load reduction observed. It may be, as some consumer advocates contend, that the low-income pilot participants stinted themselves in ways that could not be sustained, and that in some cases were harmful to their health or safety.

Low-income customer advocates in Massachusetts (including this author) have pressed the utilities to evaluate the experience of low-income customers in more detail and with more care than has been the case in pilots to date.[44] If smart metering is to be successful, it will have to demonstrate that vulnerable customers are not harmed by the cost of the metering infrastructure, and by the penalties inherent in the rate structure for sharply cutting back load on days of critical

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[40] It is possible that this disproportionate adoption of CPP rates by low-income customers in the first year of PG&E's SmartRate™ availability was driven by the promise of a $50 incentive and a guarantee that bills in the first year would not exceed what they would have been under the regular rates. Stephen George, et al. *2008 Ex Post Load Impact Evaluation*, a tp. 8. Customers were also offered first-year bill protection. *Id.* In the 2009 report, the same pattern of disproportionately high take rates by CARE customers continued. Stephen S. George, Josh Bode, Michael Perry and Zach Mayer, (Freeman, Sullivan & Company), *2009 Load Impact Evaluation,* April 1, 2010.

[41] The average load reduction by PG&E SmartRate™ customers across the critical peak period for the nine critical peak days called that summer was 11.0 percent. By contrast, the average load reduction of non-CARE customers was twice as great, at 22.6 percent. Stephen George, et al. *2008 Ex Post Load Impact Evaluation,* at p. 34. One can thus see that the expected total demand response was larger than the actual demand response, as the participants were more heavily weighted towards those whose demand reductions were low than to the expected proportion of such low-reduction customers. This difference from expectations *ex ante* can skew the benefit-cost evaluation of the proposed smart metering investment.

[42] Frank A. Wolak, *An Experimental Comparison of Critical Peak and Hourly Pricing,* at p. 25.

[43] *Id.*, at 26.

[44] See, E.g. Initial Comments of the Low-Income Energy Network and Massachusetts Energy Directors Association, filed in MDPU Dockets 09-31, 09-32 and 09-33, June 15, 2009, and Direct Testimony of Nancy Brockway in Dockets 09-31 and 09-33 (NGrid and Unitil), 09-32 (NStar) and 09-34 (WMECo).

need for power.[45]

4. Persistence of Reductions

The source of the most troublesome uncertainty in dynamic pricing response estimates is the inability to be sure how many years the observed level of critical peak load reduction will persist. A benefit/cost evaluation premised on the continued response of customers to dynamic prices year after year will be seriously skewed if the take-up of the rate, or the level of response of those on the rate, erodes over time.

The history of time-of-use rates does not support confidence in projections of continued participation and response. If we look back to the efforts of regulators to introduce time-of-use pricing in the 1970's and 1980's, we see a pattern of initial interest in the rates, participation leveling off, and eventual consumer abandonment of the rates. That period in regulatory history was similar to today, in that a number of events came together to focus public attention on the costs (and environmental impacts) of electricity. Many commissions led the electric utilities under their jurisdiction to offer time-of-use rates on a voluntary basis. A number of residential customers signed up for these TOU rates at first. But they did not remain on the rate for the long haul. For example, one major New England utility had 26,500 residential customers on its TOU rate in the mid-80s, but in 2004, only 11 customers remained on the rate.

More recently, customer participation in a TOU rate dropped sharply when a perceived energy crisis had eased, and when the costs of administering the rate became visible to customers. In response to the Western market crisis in 2001, Puget Sound Energy introduced time-of-use rates on a default (opt-out) basis in an effort to curb peak demands. In the first year, almost all residential customers remained on the rate. However, in the next year, when the utility proposed to show the costs of the tariff implementation (e.g. smarter meters) in rates, customers began opting out rapidly, and the public outcry against the rate pushed the Company to withdraw it.

Pilots that last one or two years cannot provide guidance on the long-term likelihood of participation by the average customer. Even the post-pilot satisfaction surveys are not reliable demonstrations of resource saving persistence.[46]

The longest-running pilot to date was the four-year real-time-pricing ESPP pilot fielded in the greater Chicago area by Commonwealth Edison and the Center for Neighborhood Technology. Participants remained on the rate, and continued to respond to price signals. One should use caution in extrapolating from these results, however. A unique feature of the ESPP pilot was that to participate one had to be a member or, or join, CNT. CNT is a cooperative with an express mission to reduce energy costs, among other things. Self-selection may have played a particularly important role in the pilot results.

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[45] Recently, proponents of smart metering and dynamic pricing have issued reports arguing that low-income customers can and will benefit from smart metering on average, and that many will benefit even if they do not shift load. These reports need to be analyzed before being used to support policy choices. For example, none includes the cost of the infrastructure and metering as an offset to benefits obtained by using it.

[46] If survey data were conclusive as to consumer acceptance, there would of course be no need for expensive trials of the different rates.

There are reasons to hope that participation in dynamic tariffs will persist, at least more robustly than participation in voluntary TOU rates did. The key difference is the relatively lower level of commitment and inconvenience required of customers on the CPP or CPR rates. The number of hours during the year when load reduction becomes financially remunerative is limited. The response can also be automated using enabling technologies. On the other hand, customers may tire of stinting themselves during a heat wave or a cold snap, as the case may be. Only time will resolve the open question of persistence of participation and response.

B. Consumption Reduction

1. Smart Meter Purpose: Energy v. Demand Reduction

Another difficult issue in the smart metering debate concerns the question of energy reductions, as opposed to load reductions, in response to information provided on the basis of smart metering. There is no doubt that on average and in the short term, smart metering with critical peak pricing will induce customers to reduce their critical peak usage.[47] But there is not yet agreement that smart metering and related feedback mechanisms will produce energy savings, even in the short term.

The theory that smart metering will lead to consumption reductions extends from the view that if and to the extent customers receive real-time information about their usage and the costs of that usage, they will be spurred to take steps to reduce their bills by reducing usage. That is, some expect that customers will respond to "feedback" by adjusting their behavior to lower their costs.

Proponents of smart metering assert that the more granular feedback available from a meter that records usage in time-intervals-of-demand as small as 10 or 15 minutes can boost customers' ability to adjust not only their critical peak demands, but their overall consumption, as well. For example, an expert witness supporting a Pennsylvania utility's proposal to install smart meters throughout its service territory on an expedited basis testified that smart metering and dynamic pricing do not only induce demand responses from customers:

> Simple customer awareness of energy usage and pricing can result in electricity consumption reductions of 10 percent or more, and participation in price driven demand response programs ... can result in even more consumption reduction. Further, customer participation in the ... dynamic rates programs that rely on Smart Meters will immediately, and over time, reduce the total ... annual consumption.[48]

Similarly, Gary P. Smith, Nevada Power Smart Technologies Project Manager, testified to the Nevada Public Service Commission that the utility's advanced metering initiative (which goes by the acronym ASD for advanced service delivery) will result in energy savings. Mr. Smith described the mechanism for such savings as follows:

[47] There is less agreement that static time-of-use rates will have any appreciable effect on loads.
[48] Rebuttal Testimony of Ethan L. Cohen on behalf of West Penn Power Company. in *Petition of West Penn Power Company d/b/a Allegheny Power for Expedited Approval of its Smart Meter Technology Procurement and Installation Plan,* Pennsylvania Public Utilities Docket No. M-2009-2123951, filed October 27, 2009, at p. 5.

> In the end, ASD should eliminate barriers inhibiting the full potential of load management and energy efficiency programs. *We expect that the project will provide customers with current consumption and pricing information and allow customers to take control of their energy consumption.* Eventually, customer behavior and attitudes should change and they will consume energy more efficiently.[49]

These opinions tying smart metering to energy consumption have one thing in common. All point to the greater amount and precision of information that interval metering gives the customer as to their usage. In other words, smart metering is expected by some to reduce consumption because it provides a form of feedback that customers have not had to date.

Given the increasing interest in the efficacy of feedback, the literature has begun to include more analyses of feedback studies. In 2006, Sarah Darby wrote a literature review of feedback studies to that point, and her work continues to be cited today. In her paper, Darby collected information on 38 studies, including 20 studies of direct feedback, 10 studies of indirect feedback (i.e. enhancements to billing) and 8 studies that included time-of-use rates.

To the extent the information was available, Darby recorded the names of the study's authors, the date of the study, the savings claimed by the study, the length of the study, the sample size, the control (if any), the location, the energy source, the type of feedback, and other changes observed as a result of the feedback. Darby added her own comments to recitation of the study information. In the case of feedback that included time-of-use pricing, Darby included a category showing the relationship of the peak and off-peak rates, where available.

Darby distinguishes what she calls "direct feedback" (immediate, from the meter or an associated display monitor) and "indirect feedback" (feedback that has been processed in some way before reaching the energy user, normally via billing).[50] Whether direct or indirect, Darby says, feedback helps customers reduce their consumption:

> Overall, the literature demonstrates that clear feedback is a necessary element in learning how to control fuel use more effectively over a long period of time and that instantaneous direct feedback in combination with frequent, accurate billing (a form of indirect feedback) is needed as a basis for sustained demand reduction. Thus feedback is useful on its own, as a selfteaching tool. It is also clear that it improves the effectiveness of other information and advice in achieving better understanding and control of energy use ... The norm is for savings from *direct feedback* (immediate, from the meter or an associated display monitor) to range from 5-15%....Savings [from indirect feedback] have ranged from 0-10%, but they vary according to context and the quality of information given.[51]

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[49] Direct Testimony of Gary P. Smith, *Nevada Power Company d/b/a NV Energy, 2010 – 2029 Integrated Resource Plan,* Nevada Public Utilities Commission Docket No. 09 - 07003, at p. 54.
[50] *Darby Study,* at p. 3.
[51] *Id.*

Other recent papers have made similar claims, often drawing upon many of the same feedback studies as Darby reviewed.[52] The Darby study and others do not lay to rest the question of whether and to what extent feedback will affect usage. As noted by Darby, the studies present a wide range of outcomes. Many of the studies followed the implementation of pre-payment metering, which is not the question at issue in smart metering considerations.[53] Many of the studies were conducted without controls, or with such small sample sizes that it is not possible to draw statistically significant inferences from the results. Many of the studies are over a decade old, and thus reflect conditions not in effect today.

Further, a number of the studies provided feedback in the form of in-person interactions with social workers or energy researchers, an expensive way to provide personalized feedback. In Europe, some studies looked at the behavior of customers in ecology affinity groups, where the participants again got personal feedback and a social network to reinforce their actions. Perhaps most telling, several of the Scandinavian studies of what Darby et al call "enhanced billing" involved increasing meter reading from *annually* to six times a year, and billing from one actual and three estimated bills a year to six actuals per year. It is possible to acknowledge that going from one actual to six actual bills per year could produce significantly greater awareness and response to cost and usage feedback, without accepting that adding more granular information to the feedback of a monthly actual bill would produce a similar attention to usage management. Authors of one literature search acknowledged as well that not all the pilots reviewed gathered data on actual usage changes.[54]

The picture is similarly murky with respect to dynamic pricing and overall consumption. It is hard to evaluate the change, if any, in energy consumption brought about by Smart Meter prices and associated initiatives. Not all demand response pilots estimate energy consumption changes associated with the pilot treatments. Where they do, estimates of energy consumption changes in evaluations of Smart Meter pilots in the United States and Canada range from modest usage reductions to actual usage increases.[55]

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[52] See King and Delurey, *Efficiency and Demand Response: Twins, Siblings or Cousins,* Public Utilities Fortnightly, March 2005; and Faruqui, Ahmad, Sanem Sergici, and Ahmed Sharif (2010), "The Impact of Informational Feedback on Energy Consumption - A Survey of The Experimental Evidence," *Energy 35 (2010)*, 1598-1608. See also Karen Ehrhart-Martinez, Kat A. Donnelly and John A. "Skip" Laitner, et al, *Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities,* June 2010, ACEEE Report Number E105.

[53] Prepayment metering apparently has a significant impact on usage. Prepayment requirements threaten important consumer protections, and the studies do not establish that the usage reductions were achievable without unacceptable adverse consequences.

[54] Ahmad Faruqui and Sanem Sergici, presentation to the Colorado Public Utilities Commission, June 7, 2010.

[55] Karen Herter, Patrick McAuliffe and Arthur Rosenfeld, "An exploratory analysis of California residential customer response to critical peak pricing of electricity," Energy, 32 (2007):25-34 (Exploratory Analysis), available at **www.elsevier.com/locate/energy**, at 26. *See also* Pat McAuliffe and Arthur Rosenfeld, "Response of Residential Customers to Critical Peak Pricing and Time of Use Rates During the Summer of 2003," California Energy Commission, September 23, 2004; and Research Reports International, "The Impacts of Dynamic Pricing on Electricity Usage. These studies report that in the California Special Pricing Program, in one mild-temperature period, customers in one treatment group increased load by 8 percent. In a real time pricing pilot fielded by the Pacific Northwest National Laboratory, peak load decreased by 15 to 17 percent, but overall energy consumption increased by approximately 4 percent. Similarly, AmerenUE found that participants in its Residential TOU Pilot who were on the CPP rate with a smart thermostat (the treatment group that consistently shows the highest demand

In one recent pilot, the evaluators observed a statistically significant reduction in consumption during the peak season, in response to feedback from the pricing structure as provided through the Company's web portal.[56] On the basis of these pilot results, however, the Company included the value of a 1% consumption reduction in its smart metering project cost-benefit analysis.[57] The Commission did not accept the utility's claims with respect to energy conservation:

> BGE's proposal does not include any in-home displays that might help customers reduce their energy bills by reducing their energy usage. Rather, the web portal will tell customers how much energy they used on an hourly basis, and even that information is at least a day old. Customers will receive no information as to how they reached these energy usage levels, such as the extent to which certain appliances contributed to the overall energy use, leaving it unclear exactly how they should adjust their behavior in the future. BGE claims that the ZigBee chip will allow BGE to provide appliance-specific information as well as direct communication with a customer's appliances in the future, but concedes that this will only be possible after the customer purchases new appliances with ZigBee-compatible communication technology. Additionally, BGE's web portal will be entirely unavailable to those 30% of BGE customers who lack a computer with Internet access. Because the elderly and financially disadvantaged are disproportionately likely to lack Internet access, BGE's proposal provides no information to those customers most in need of reduced energy bills. To the contrary, both its 2008 and 2009 pilot programs revealed that pilot program participants without enabling technologies only reduced their overall consumption by 0.5% and 0.8%, respectively, during the hottest months of the year. In fact, dynamic pricing might cause some customers to increase their consumption by allowing them to use more energy at the same price by maximizing their energy use during less expensive, non-peak periods.[58]

A fundamental flaw in feedback research to date, whether in the context of smart metering or otherwise, is the short length of most studies. Almost all the studies reviewed in the literature took place over one or two peak seasons. It will be difficult to gauge the persistence of consumption effects of smart metering until dynamic pricing and smart-metering-based feedback has been used for a number of years.

There are a number of hypotheses about what prompts customers to change their usage, up or down. But there is little focused research that can tell us why this pilot showed no consumption change, that pilot showed consumption reductions and this pilot showed consumption increases. The Electric Power Research Institute has reviewed the literature on consumption effects from

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responses to such AMI-supported pricing) increased their usage during the three-hour period after the end of a critical peak period, by 11.6%. Evaluators of the Anaheim (CA) Critical Peak Pricing Experiment found that customers in the treatment group used more energy on the critical peak days than the control group. In Ontario, participants increased load during one critical peak period. Time-of-Day-Only customers in the Idaho Power pilot increased their consumption during on-peak hours in one of the years of the pilot.

[56] Testimony of Ahmad Faruqui on behalf of Baltimore Gas & Electric, I*n the Matter of the Application of Baltimore Gas & Electric for Authorization to Deploy a Smart Metering,* Maryland Public Service Commission Docket No. 9208 (2009), Faruqui Direct at 26; Faruqui Supp. at 17.

[57] BGE Ex. DMV-1 at 12, 14.

[58] I*n the Matter of the Application of Baltimore Gas & Electric for Authorization to Deploy a Smart Metering,* Maryland Public Service Commission Docket No. 9208, Order (June 21, 2010) at 52-53.

customer usage feedback, and concluded that more research is needed before utilities can confidently move forward on the strength of feedback impacts. In a recent report, EPRI reinforced its view that certain areas of research need to be undertaken in order to understand the likely impacts of feedback on usage:

CONSUMER USAGE FEEDBACK ISSUES NEEDING MORE RESEARCH
Source: EPRI Feedback Research Synthesis pp. x-xi

• **Participation.** The studies have employed a large range of sample sizes. The largest have involved enhanced billing and energy display devices. A better understanding of the effects of feedback on specific demographic groups is required, which has sample design selection implications.

• **Feedback delivery mechanism distinction.** The most thorough analyses have involved enhanced billing and direct energy displays. However, more research is required to assess the relative effects between different feedback types, particularly across different demographic groups, as lower levels of feedback might be more cost effective.

• **Persistence.** Some of the studies provide indications that feedback persistence can occur. The best evidence comes from studies involving enhanced billing and energy display devices, although in the case of the former, results may not be generalizable to the North American context. In addition, study durations should be long enough to distinguish between persistence and seasonal effects. Finally, results from ongoing research that indicate that a large percentage of households stop using their display devices over time need to be reconciled against past study results that suggest conservation effect persistence.

• **Price.** Although relatively few in number, some studies support the notion that feedback provided in conjunction with dynamic pricing can have an incremental effect on peak reduction in the 0–2% range. Preliminary results from ongoing research suggest that the percentage could be higher. More work is required to better assess the effects on overall consumption reduction, as at least one study provides evidence that feedback can increase overall consumption while reducing peak consumption. Related to this, a better understanding is required of the relationship between the types of information provided (for example, price signal provision versus energy consumption values) and the resulting effects.

• **Demographics.** Several studies have revealed insightful information about the effects of income, education levels, and household occupant age on the potential effectiveness of feedback. Some tenuous trends have emerged, but these need to be more thoroughly verified.

C. SOME TECHNOLOGY NOT YET READY FOR PRIME TIME

1. The Race for Dominance

One of the key uncertainties in the smart metering space is the exact technology to emerge as the standard, and capture the bulk of the market. As can be seen from looking at the history of the internet and computers, certain industries experience strong pressure to select a single dominant design, or a few dominant designs.[59] Once a technology wins the initial race for dominance, producers focus their efforts on improving their efficiency in manufacturing, delivering, marketing or deploying this dominant design rather than continue to develop and consider alternatives.

Network externalities arise when compatible or complementary goods are important. For example, many people who preferred Corel WordPerfect™ to Microsoft Word™. But at the least, we had to learn Word™ and eventually gave up supporting WordPerfect™ when it became clear that preference was an expensive indulgence. Many people choose to use Microsoft products in order to maximize the number of people their files are compatible with, and the range of software applications they can use.

As a result of these network externalities, consumers gravitate towards the emerging dominant technology in even greater numbers. They focus on obtaining the benefits of a common platform, and generally let go of their preference for certain features of the technology that did not survive the battle for dominance.[60]

Firm strategies to obtain the dominant market share often influence the particular technology adopted for widespread deployment. Microsoft's tying arrangements with desktop manufacturers helped to spread its operating system widely, and made it more expensive for a manufacturer to satisfy some customers' preference for a different OS.

These trends are self-reinforcing. Technologies that take hold earlier are likely to become better developed, making it even harder for competing technologies to catch up. Other market players develop add-ons and other tools tailored to the dominant technology. These effects increase the dominance of the successful technology regardless of its superiority or inferiority to competing technologies.

It may be that, in the case of smart metering, there are large consumer welfare benefits of having a single dominant design. One design could make it easier to standardize and optimize components of the system and the means by which they interoperate. One design could limit the room for error in designing a cyber-secure network.[61] One design could "bake in" privacy protections. If the consumer benefits are large enough, government may want to step in to

[59] The discussion of dominant firms and network technologies draws heavily on Melissa Schilling, slide presentation, Strategic Management of Technological Innovation, Chapter 4, *Standards Battles and Design Dominance,* 2004. Available at www.spsu.edu/mgnt/Yancy/xmgnt4185x/Chap004.ppt.
[60] Of course, producers and sellers of the non-dominant technology can be very successful around the edges of the dominant technology. One only has to look at the Apple computer history to see an example of a non-dominant firm maintaining sometimes fierce customer loyalty, built on differentiation of the product, rather than mass appeal.
[61] Of course, one design makes it easier for a person or group to become familiar with the design and spend time figuring out how to defeat it, rather than having to learn a variety of systems depending on the circumstances.

enforce a standard.[62]

On the other hand, government is properly leery of stepping in to dictate a standard design before the market has had a chance to test the variety of approaches seen at the beginning of a new technology. In the case of smart metering, the government is in effect asked to set the standards when it approves the recovery of a utility's investment in smart metering.

The recent decision of the Maryland Public Service Commission, denying without prejudice the proposal of Baltimore Gas & Electric to install an advanced metering infrastructure,[63] approached this dilemma with wisdom. As the Commission pointed out, there are many uncertainties at this stage of the development of smart metering technologies. The Commission expressed its support for the goals of smart metering and dynamic pricing. The Commission rejected, however, the effort of the utility to place all the risks of the new technology on the consumer, and to evade any financial risks associated with the very large investment at issue:

> As we have noted repeatedly throughout this Order, we believe whole-heartedly in the intentions behind BGE's Proposal. Nothing in this Order should be construed as a vote of "no-confidence" in smart-grid technology's ability ultimately to lower energy bills, improve customer service and relieve peak-time pressure on the transmission and distribution infrastructure. Our desire that BGE share the risks associated with such an investment at this juncture is in no way an indication that we believe an investment in AMI ultimately will prove unwise. We simply think it more equitable that BGE and its ratepayers venture into this relatively unknown territory as partners.[64]

2. Home Area Networks and Smart White Goods

The Federal Energy Regulatory Commission staff[65] has offered the following definition of the Home Area Network (or HAN):

> A home-area network "is a network contained within a user's home that connects a person's digital devices, from multiple computers and their peripheral devices to telephones, VCRs, televisions, video games, home security systems, 'smart' appliances, fax machines and other digital devices that are wired into the network." Integration between home-area networks and advanced metering systems allows an entity to provide information to customers and remotely manage large loads (such as air conditioning and electric heat).

[62] For example, many types of equipment may be connected to the public switched telephone network, but they all must pass FCC interoperability standards. Similarly, in 1998, the European Union adopted a single wireless telephone standard (GSM) to avoid proliferation of incompatible standards, and to facilitate communications within and between EU countries.

[63] I*n the Matter of the Application of Baltimore Gas & Electric for Authorization to Deploy a Smart Metering Initiative and to Establish a Surcharge for the Recovery of the Cost*, Maryland P.S.C. Docket No. 9208, Order 83410, June 21, 2010.

[64] *Id.* at 53-54.

[65] Assessment of Demand Response & Advanced Metering 2008, Staff Report, at 14, available at www.ferc.gov/legal/staff-reports/12-08-demand-response.pdf ; (quoting *What is HAN?* (Aug. 28, 2008), available at http://www.webopedia.com/TERM/H/HAN.html.

The vision for the home area network is wide and creative. For example, one can imagine a smart meter communicating the price in effect (e.g. CPP or off-peak, etc.) to the home's HAN gateway, which is programmed to signal the air conditioning thermostat to allow the temperature to increase a couple of degrees, until the thermostat gets another signal through the HAN.

According to one industry market analyst, HAN capabilities will be included in 49% of all smart meters shipped worldwide by 2013, and the North American HAN-enabled meter penetration rate will be even higher at 81% by the same year.[66] However, this forecast of HAN capabilities in smart meters is perhaps too ambitious, and in any event, will not by itself bring on a HAN-enabled home.

Until the industry settles on one or more dominant communications methods (and associated protocols), mass deployment of HANs will not move forward. In an effort to break through this logjam, a number of metering and appliance firms, and others, have joined together in an alliance to promote a certain form of wireless communications for such meter and home area networks.

The ZigBee™ protocol is becoming the front runner and may emerge as the dominant form of communications. Utilities are obtaining meters with ZigBee™-compliant chips that can be used for communication with a HAN in the future. The ZigBee™ protocol for radio frequency communications has been adopted on a preliminary basis by the NIST process.

The main competing communications method is the power-line-carrier (PLC) approach. This method is well known as a means of creating a computer network in a home or other building, using the existing electric wiring of the house. Under the PLC approach, the HAN gateway can send a message to the smart appliance. In some PLC technologies, the smart appliance can feed information back to the HAN gateway. On June 14, 2010, the HomePlug® Powerline Alliance announced the approval and publication of a specification for smart grid applications, the "HomePlug Green PHY " (HomePlug GP). According to the Alliance press release, "HomePlug GP is a low power, highly reliable, cost-optimized powerline networking specification targeting Smart Grid connectivity for home energy management to devices such as HVAC, smart meters, appliances and plug-in electric hybrid vehicles."[67]

In an effort to make it possible for home area networks to move forward, despite differences in approaches, ZigBee Alliance has partnered with the IPSO Alliance (Internet Protocol for Smart Objects), the DLMS User Association, EPRI, the European Smart Metering Industry Group (ESMIG), and the HomePlug Powerline Alliance to collaborate on wireless home area networks, using the ZigBee IP specification and the ZigBee Smart Energy v2.0 standard. There is thus an effort underway to develop approaches that are compatible with a variety of wireless network technologies.

Perhaps because of the vigorous outreach of the ZigBee™ Alliance on such collaborative efforts, Pike Research reportedly has forecast that ZigBee is expected to lead the HAN technology race

[66] Business Wire, April 23, 2010, citing research reported by Pike Research. Available at http://smart-grid.tmcnet.com/news/2010/04/23/4746345.htm.
[67] http://www.smartgridnews.com/artman/publish/Technologies_Home_Area_Networks_Products/HomePlug-Powerline-Alliance-s-Green-PHY-Specification-for-Smart-Grid-Applications-Published-2518.html.

with approximately 87% market share.[68]

Meanwhile, progress continues towards a market in grid-ready white goods. General Motors has received ZigBee™ certification for the line of grid-enabled appliances it is developing.[69]

Still, the ultimate success of home area network technology is not assured. According to a report prepared for the NARUC Smart Grid Advisory Board, a number of policy issues might potentially constrain customer third-party service, EE, DR,DER, and information service providers; potential conflicts with other customer networks (entertainment, security, IT, health, etc.); privacy implications for retrieval of customer appliance parameters, and settings; and potential liability with customer appliance operations.[70] Home area network technologies will develop, but perhaps not as quickly as some have hoped.

3. Plug-in Hybrid Electric Vehicles

For a number of reasons, researchers and policy makers in the industrialized countries are looking to electricity as a promising replacement for liquid petroleum to power automobiles. One version of an electricity-powered car that has gained a significant following is the plug-in hybrid electric vehicle, or PHEV. Electric vehicles are described as follows in a recent report:[71]

> An electric vehicle is one that uses an electric motor for propulsion at least some of the time. Nearly every electric vehicle carries an on-board battery. If the battery is charged solely from the electrical grid, it is called a plug-in electric vehicle (EV). An EV is distinct from a hybrid electric vehicle (HEV) whose battery is recharged exclusively by energy from the combustion engine and energy recovered through dynamic braking. Typically, an HEV switches frequently back and forth between the electric and internal combustion motors, depending on driving conditions. A plug-in hybrid electric vehicle (PHEV) has the characteristics of both and EV and an HEV: it continually operates as an EV until its battery is sufficiently discharged so that it needs to revert to an internal combustion engine as does an HEV, rather than constantly switching between electric and gasoline operation.

For a number of years, there has been a great deal of interest in the prospect of moving from internal combustion automobiles run on gasoline to electric vehicles, or hybrid internal combustion/electric vehicles. In the United States, the Department of Energy has provided significant support to research and development of electric vehicles.

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[68] http://smart-grid.tmcnet.com/news/2010/04/23/4746345.htm. At the same time, according to Pike, other radio frequency (RF) and power line communications (PLC) technologies will also have a role, particularly in Europe, Africa, and the Middle East.

[69] Smart Grid Today, May 18, 2010.

[70] Chuck Goldman, Roger Levy, and Ron Hofmann,. *Engaging the Customer*, NARUC Webinar #2, Smart Grid Technical Advisory Project, December 16, 2009.

[71] Navigant Consulting, Inc., *PHEV/EV and V2G Impacts and Valuation Study*, presented to Arizona Public Service, March 10, 2010, Section 1.2.

One of the motivating factors spurring promotion of low- and no-emission vehicles is the reduction of greenhouse gases caused by tailpipe carbon dioxide (CO_2) from internal combustion engine vehicles. In addition, the EV industry has become an economic development priority for many states, especially Alabama, California, the Carolinas, Georgia, Indiana, Louisiana, Michigan, and Tennessee.

Electric vehicles are seen as potential storage sumps for generated electricity that is surplus to needs at the time of generation. For example, wind power is stronger at night, but power needs are lower at night. Conceivably extra wind generation could be stored in the batteries of EVs , charging overnight. EPRI and NRDC issued a joint primer on EVs in 2007, in which they explained the possible benefits of using EV batteries for such storage:

> More than 40% of U.S. generating capacity operates at reduced load overnight, and it is during these off-peak hours that most PHEVs would be recharged. Recent studies show that if PHEVs displaced half of all vehicles on the road by year 2050, they would require only an 8% increase in electricity generation (4% increase in capacity).[72]

Two major areas of technology development remain problematic: charging stations and battery cost and capacity. In August, 2009, US President Obama announced $2.4 billion in grants for research and development of electric vehicles and batteries. This funding is additional to government and industry advanced battery technology research activities.

To support the safe and practical application of electric vehicle technology, various industry and government bodies are developing industry protocols and standards. One of the priority action plans of the NIST focuses on electric vehicle. The Federal Energy Regulatory Commission ("FERC") has published a smart grid policy and action plan that includes specific codes, standards, and regulations for smart charging.[73]

Interval meters are important to EV development because they capture usage hour by hour. This ability to record usage at discrete time periods in turn allows for pricing the electricity bought based on the different system costs at different times of the day.

Despite the concerted efforts being made to develop EVs, the need for smart meters to measure and price EV charging based on TOU principles does not yet exist. The EV industry is still at the early stages of development, and mass marketing of EVs may not occur for a decade or more. As one consulting group recently wrote that fully electric vehicles as convenient as ICE-based cars are "unlikely to be available for the mass market before 2020."[74]

A variety of barriers remain to widespread adoption of EVs, and thus widespread use of smart meters in the charging and billing process.[75] An Oregon committee noted that there are perception, product, distribution and infrastructure barriers that continue to slow down EV development. The chief obstacle to mass deployment of EVs is the cost of the batteries. The cost

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[72] EPRI and NRDC, *Technology Primer: The Plug-In Hybrid Electric Vehicle,* 2007.
[73] FERC, *Smart Grid Policy,* March 19, 2009, Docket No. PL09-4-000, Paragraph ZZ.
[74] Boston Consulting Group, *Batteries for Electric Cars*, http://www.bcg.com/documents/file36615.pdf, p. 5 last viewed June 13, 2010.
[75] Report of the [Oregon] Alternative Fuel Vehicle Infrastructure Working Group, January 2010, at 15.

target, $250/mWh, is unlikely to be achieved before 2020.[76]

A study of EVs for Arizona Public Service Company, filed with the Arizona Public Service Commission in April, 2010, found that, given the current trajectory of electric vehicle development, market penetration is likely to be gradual, especially within the next 15 years. The provision of electricity to the grid from electric vehicles is not likely to be viable or effective until 2025 and beyond.

It is conceivable that the government and industry funding of EV research and development will make smart meters for EVs necessary sooner than 2020. But preparation for EV mass marketing should not be a driver of the decision to invest in smart metering, at least not for some years.

IV. UNRESOLVED RISKS

A. STANDARDS AND PROTOCOLS

AMI is essentially a huge and complicated communications and data processing network, or more accurately, a network of networks. Sensitive information will pass over the communications networks set up to administer dynamic pricing and to manage grid functions. New and remotely-programmable controls of various grid components will be installed. Communications systems such as enterprise networks for core business data processing, network access and backhaul, neighborhood or local area networks, and home area networks, will be created and interconnected. The systems will be tied together more than ever. They will be more complex than ever. Interoperability, size, complexity and novelty provide opportunities for unauthorized data and control access.

The National Institute of Standards and Technology (NIST) has been designated by the Energy Independence and Security Act of 2007, EISA Title XIII, Section 1305, to lead a public/private collaborative effort on grid interoperability. While addressing interoperability, NIST must address cyber-security and privacy. The more the systems can talk to each other and send signals back and forth, including control signals such as the remote directive to disconnect power for example, the more opportunities there are for breaches of security and privacy.

George Arnold, NIST National Coordinator for Smart Grid Interoperability, has cautioned that the scope of the standard-setting effort is daunting.[77] He compared the process to the telecommunications industry development of standards for fiber to the home, specifically the development of standards for the Verizon FiOS system. FiOS integrates voice, video and data transmissions. Standards work started in 2003. Initial field trials were held in 2004.
Three principal standards bodies were involved. Release 1 standards were issued year-end 2005, and Release 2 standards were issued in early 2008, five years after the beginning of the process. The FiOS standards consisted of 600 pages of documents, even thought they were mostly "mix and match" and extensions of existing standards. They continue to evolve as the technology evolves.

[76] BCG on *Batteries for Electric Cars*, *supra,* at p. 7.

[77] George W. Arnold, *NIST Smart Grid Standards Roadmap Project Goals: How Many Standards are Needed? How Long?* Presentation April 23, 2009, slide 6.

According to Arnold the FiOS project and the Smart Grid project are about the same magnitude. The key difference between the FiOS standards process and the smart grid process, according to Arnold, is that many more standards bodies are involved. Although NIST is designated to coordinate these efforts, the various interested parties continue to look for ways to push forward standards in the areas of their concern outside the NIST process. The ZigBee[tm] - IP collaboration between five industry alliances and research bodies, noted above, is an example of a subset of the industry trying to move standards for one aspect of the system forward.

1. CYBERSECURITY

The interconnection of systems and the decentralization of data and control to the meter and beyond raise difficult cyber-security problems. Developing "use cases" to form the basis for cyber-safe smart grid engineering is difficult. The sheer complexity of the interconnected IT applications for a smart grid makes it almost impossible for system engineers to anticipate, and thus to provide protections from, all possible problems that might occur - what we refer to as “glitches” or “bugs” when talking about our own personal computers. Smart metering relies on the importation of advanced information and communications technology into the distribution grid. One must anticipate that some bugs will be present, and at some time will cause some form of system failure.

Advanced metering infrastructure is still experiencing rapid technological development. Vendors are promoting their solutions to technical problems, while industry groups are meeting with government facilitation in an attempt to establish common standards, especially in key areas such as cyber-security and interoperability. Security may be compromised by equipment or operational faults, as well as intentional breaches by hackers, and unauthorized access to data and controls.

There are a number of cyber-security vulnerabilities of AMIs that have been identified so far, and as with all complex information technology solutions, there are vulnerabilities that have not yet been, and cannot reasonably be, foreseen. Among the known vulnerabilities are (a) physical tampering with elements of the network, (b) eavesdropping in on or jamming wireless signals that connect Smart Meters to neighborhood data collection points, (c) password compromises, (d) unauthorized data collection [including privacy violations], (e) suboptimal priority for data transfer over public (e.g. cellular) networks, (f) lack of control of internet paths and reliability, and (g) denial-of-service attacks (in which an unauthorized user generates a huge number of messages to go over the system, which overloads the communications system and triggers interruptions of the system).

Even at the present relatively centralized and confined level of data collection and control technology in the utility distribution system, cyber-security breaches have occurred. A cyber security expert from SAIC, a firm offering cyber security services, recently noted to the Kansas Corporation Commission the following examples of cyber security breaches:[78]

[78] Gib Sorebo, *Smart Grid Security*, a presentation to the Kansas Corporation Commission, PHI DP ridertember 18, 2009

1998 Telephone switch hack closes an airport
2000 Gazprom central control is hacked
2000 Disgruntled water-treatment plant employee in Australia rigs controls to release sewage
2001 Hackers protesting US/China conflict enter US electric power systems
2003 Worm shuts systems down at Davis-Besse nuclear plant.
2007 Aurora demonstration shows a remote hacker can cause physical harm to a generator.

Other evidence of grid vulnerability was reported in the Wall Street Journal of April 8, 2009, citing the fact that an electricity grid in the United States had been penetrated by spies, possibly Russian or Chinese. The report, quoting industry and government sources, also noted that hackers had penetrated electrical systems abroad and tried to extort money to avert damage.

In 2007, a disgruntled employee of the California ISO allegedly tried to access the system's emergency power cut-off, and in the process shut down much of the ISO's data center over a weekend. Luckily the only damage, besides the physical damage to equipment, was that CAISO could not get access to the energy trading market. Upon arresting him, the FBI warned that, had the employee carried out this attack during normal business hours, "electric consumers in the Western United States would have experienced disruptions in their electrical supply".

In May, 2008, the General Accountability Office (GAO) released a report, available at http://www.gao.gov/new.items/d08526.pdf ,identifying numerous vulnerabilities at the Tennessee Valley Authority (TVA) that put the nation's biggest public power company at risk of cyber attacks. Among other things, according to the GAO, the TVA used poorly implemented passwords, relied on lax logging practices, failed to install key software patches, and had firewalls that were improperly configured or were bypassed.

A less formal but equally sobering report, published on the on-line journal "Security" (available at http://www.theregister.co.uk/2009/06/12/smart_grid_security_risks/) quotes a "hacker" hired by a utility to explore vulnerabilities in one manufacturer's meters. The vulnerabilities, this security consultant said, are ripe for abuse. The consultant asserted that the new meters needed to make the smart grid work are "built on buggy software that's easily hacked."

At the Black Hat ("benign hackers") convention in Las Vegas this summer, this senior security consultant demonstrated a "worm" that he had created that could infect a particular brand of smart meter, and move back and forth between the meters at homes and businesses in a smart grid network. The consultant said it would be possible to program the worm to infect other manufacturers' smart meters. As the "black hat" security consultant noted, the inclusion in the meter of a module permitting a meter to be turned off remotely through signals sent from a central location creates a risk that a hacker could get into the control system for meters, and remotely disconnect power to hundreds of thousands of customers.

It is not realistic to assume that all cyber-security risks can be engineered out of a smart metering system. It is well known that human error or failure to maintain secure practices is a weak link in cyber security. A frequently cited example of this phenomenon is employees' failure to observe rules for security of passcodes, frequency of passcode changes, and the like.

The electric industry is aware of the importance of cyber security. But while employees of electric utilities may be more aware of the importance of cyber security than those in other industries, they are still human beings, and subject to making errors. This is especially the case here, where the electric industry is faced with information technology security issues that are completely new to it.

A recent allusion to this reality came in an April 7, 2009, letter to industry stakeholders from Michael Asante, the Chief Security Officer of the North American Electric Reliability Corporation (NERC), the organization charged by the Federal Energy Regulatory Commission (FERC) with overseeing industry efforts to maintain reliability (including the prevention of cyber-compromises). In his letter, reporting on the results of a 2008 self-certification compliance survey for NERC Reliability Standards CIP-002-1 – Critical Cyber Asset Identification, Mr. Asante noted that some industry members failed to identify their assets as "Critical" and thus falling under the Standard. Mr. Asante went further and warned the industry of the danger of less than constant vigilance to prevent breaches of cyber security.

Consider also the many reported cases of individually-sensitive data being left on laptop computers that are then stolen or misplaced when employees take them home or on business trips. There are also many reported cases, including a number in the utility business, where a disgruntled employee has used his special access to systems and controls to create problems with the operation of the utility. In one case, a disgruntled water-treatment plant employee in Australia rigged controls to release sewage onto the property of an abutter. In 2003, a worm shut systems down at the Davis-Besse nuclear plant. In 2007, a disgruntled employee of the California ISO allegedly tried to access the system's emergency power cut-off, and in the process shut down much of the ISO's data center over a weekend.

In February, 2010, NIST issued its *Second Draft NISTIR 7628 Smart Grid Cyber Security Strategy and Requirements – Feb 2010.* It took comments on the draft through early June, and as of this writing has not issued a further revision.

2. PRIVACY

In a recent webinar sponsored by Smart Grid Today, "Privacy and the Smart Grid: How to Address Consumer Concerns Without Jeopardizing the Growth of the Grid," conducted on , April 13, 2010, Lillie Coney of the Electronic Privacy Information Center (EPIC) described five kinds of privacy concerns raised by implementation of an ASD system. These include identity theft, personal surveillance, energy use surveillance, physical danger, and misuse of data.
In its most recent draft interagency report on smart grid cyber-security,

NIST calls attention to "potential surveillance possibilities posing physical, financial and reputational risks." Second Draft NISTIR 7628 Smart Grid Cyber Security Strategy and

Requirements – Feb 2010, at 101. NIST goes on to observe that more data, and more detailed data, "may be collected, generated and aggregated through Smart Grid operations than previously collected through monthly meter readings and distribution grid operations. ...

In addition to utilities, new entities may also seek to collect, access, and use smart meter data (e.g., vendors creating applications and services specifically for smart appliances, smart meters and other building-based solutions.)" *Id.* Privacy will be at risk not solely because of the particular data amassed through the smart metering system, but also by combining this data with other publicly-available data to produce specific personally identifiable information (PII) regarding a customer. Smart metering uses AMI-enabled meters to capture, store and communicate electric and gas interval data. Interval data will is communicated via a communications network to the head-end and ultimately to the MDMS. The MDMS posts the interval data to the utilities back-office systems such as billing. In some smart metering applications, the data is also transmitted to a customer portal set up by the utility to provide customer's access to their interval data. Electric usage data may also be communicated to customer's HAN in-home displays and programmable controllable thermostats and white goods.

As end-uses are increasingly identified down to the serial number by manufacturer, and connected to the smart meter and the internet, a person with access to the energy use data from these appliances or other devices (whether legally or illegally) could use their IP addresses to track the activity of a device, and of the individuals who use it. This information in turn could reveal an individual's health condition, daily activities, and other sensitive and private information. Some questions that smart metering data would enable the utility or a third party to answer include the following:[79]

- *Do you have children? Do you leave them at home alone?*
- *What hours do you work?*
- *Do you come home after bars close for the night?*
- *Do you have an alarm system and is it armed?*
- *When do you usually bathe?*
- *Do you cook your meals in the microwave or on the stove?*
- *Are you a restless sleeper?*
- *How frequently do you wash your clothing?*

Utilities have a lot to learn in order to manage the privacy issues of the new types of data and communication they are generating via the Smart Grid. As Jules Polonetsky, Co-Chairman and Director of the Future of Privacy Forum, observed recently, utilities understand the regulated environment and basic security. But they have not been involved with issues such as profiling, tracking and third-party data transfers, because those have not so far been part of their business models.

One of the most annoying results of the proliferation of usage data could be that businesses will use smart metering data to target their marketing, sales pitches, proselytizing or solicitations. The situation is quite different from shopping on line or other voluntary activities that require sharing information on line. When a consumer looks up a product on line, or places an order

[79] Jules Polonetsky, presentation to the Smart Grid Today Privacy Webinar, April 13, 2010, slide 10.

through the internet, we have come to expect that the vendors will capture the fact of our interest in a product, and use it to market other products to us. While this is annoying and intrusive to many, others appreciate the fact that sales pitches over the internet can be narrowly tailored to their interests. For example, customers who buy products on Amazon.com may be glad to have the internet vendor draw their attention to other products that may match their specific interests. In any event, the customer has freely chosen to shop on line. At least presumably the customer receives value (less cost, less hassle, more flexibility) from shopping on line, in exchange for which he accepts some constrained loss of privacy.

Smart metering creates an entirely different situation. The consumer has no choice but to buy electricity, and no choice but to buy it through the utility whose ASD poses the risk of a breach of his privacy. The customer will not be able to opt out of the collection of such data, nor of its communication over the utility's communication networks. It is not clear whether the consumer can prevent her data from being communicated over the internet to the utility's web portal, whether or not she accesses the data.

Standards bodies and policy makers are beginning to address the complexities of privacy protection in a smart metering environment. In the September 2009 release of its Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0, NIST observed that the "major benefit provided by the Smart Grid, the ability to get richer data to and from customer meters and other electric devices, is also its Achilles' heel from a privacy viewpoint." Roadmap Release 1.0, at 84. To address this risk, NIST has set up a task force to coordinate efforts to identify privacy issues and develop ways to address them.

The NIST process has not yet produced specific standards to protect consumer privacy. Some access controls from existing uses of the internet and wireless communications have been identified as likely candidates for application to the Smart Grid. However, the NIST process is not organized to produce mandatory standards on any topic, and has not yet produced formal recommendations on privacy or any other aspect of cyber-security.

NIST has no deadline for publishing recommendations on privacy issues. In addition, the Obama Administration has recently announced an inter-agency a public forum to solicit views on questions and issues pertaining to the consumer interface to the nation's evolving "smart" electric power grid. Jump-started by a federal investment of $10.5 billion under the American Recovery and Reinvestment Act, the Smart Grid will enable two-way flows of electricity and information. OSTP, NIST to Launch Forum for Views on Consumer Interface to the Smart Grid, information available at http://www.nist.gov/smartgrid/ostpnistforum.html, While the purpose of this initiative is to speed up development of necessary elements of the Smart Grid vision, such as cyber-security and privacy standards, the creation of yet another layer of bureaucracy could have the perverse effect of slowing down development of such standards.

States and provinces have taken up the question of privacy and smart metering. Ann Cavoukian, Privacy Minister for Ontario, has stated that utilities without a solid privacy standards plan should stop development of any and all smart grid projects. She recommends that policy makers and utilities adopt the standard of "privacy by design." Under the privacy-by-design protocol, privacy becomes the default, and is built into the Smart Grid from the beginning. Commissioner

Cavoukian is working with Canadian power distributors Hydro One and Toronto Hydro on a paper that is intended to lay out best practices for protection of privacy. According to Commissioner Cavoukian, it is not possible to add meaningful privacy protections after the smart grid has been designed or deployed.

On June 16, 2010, Ontario Privacy Commissioner Cavoukian released a report intended to set out best practices in protecting privacy while implementing the smart grid. The report, prepared with the assistance of utilities in the Province, identified three smart grid applications that must be designed with privacy in mind. This "Trilogy"includes:1) IT systems; 2) accountable business practices; and 3) physical design and networked infrastructure.[80]

The report argues that *Privacy by Design* may be accomplished by practicing 7 originating Foundational Principles, which have been specifically adapted to the Smart Grid context.[81] To create Best Practices for Smart Grid *Privacy by Design*:

> 1. Smart Grid systems should feature privacy principles in their overall project governance framework and proactively embed privacy requirements into their designs, in order to prevent privacy-invasive events from occurring;
>
> 2. Smart Grid systems must ensure that privacy is the default — the "no action required" mode of protecting one's privacy — its presence is ensured;
>
> 3. Smart Grid systems must make privacy a core functionality in the design and architecture of Smart Grid systems and practices — an essential design feature;
>
> 4. Smart Grid systems must avoid any unnecessary trade-offs between privacy and legitimate objectives of Smart Grid projects;
>
> 5. Smart Grid systems must build in privacy end-to-end, throughout the entire life cycle of any personal information collected;
>
> 6. Smart Grid systems must be visible and transparent to consumers — engaging in accountable business practices — to ensure that new Smart Grid systems operate according to stated objectives;
>
> 7. Smart Grid systems must be designed with respect for consumer privacy, as a core foundational requirement.

Privacy by Design recognizes that utilities may be adapting legacy systems to work together with new technology in the smart grid. While acknowledging this reality, the report urges that "whenever there is an opportunity to incorporate *Privacy by Design* into existing systems that involve personal information, these best practices should be used."[82]

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[80] Information and Privacy Commission, Province of Ontario, *Privacy by Design: Achieving the Gold Standard in Privacy for the Smart Grid,* June 2010, at 2. Available at http://www.ipc.on.ca/english/Resources/Discussion-Papers/Discussion-Papers-Summary/?id=967.
[81] *Id.*
[82] *Privacy by Design*, at p. 15.

The Public Utilities Commission of the state of California has opened a proceeding to explore issues of privacy and the Smart Grid.[83] The state has strict privacy statutes, which likely are implicated by the data developed and disseminated by the Smart Grid. In addition, the Commission wants to protect privacy while promoting the deployment of the Smart Grid.

Privacy advocates have recommended steps to protect consumer privacy in a smart metering context. The Electronic Privacy Information Center has set out eight principles for smart metering privacy protection in the paper available on its website. The eight principles are as follows (a) Smart Grid service providers should limit collection of consumers' personal data; any such data should be gathered by lawful means, and with the consent of the customer, where appropriate; (b) data collected by Smart Grid providers should be relevant to a specific purpose, and be accurate, complete and up to date; (c) the purpose for collecting Smart Grid information should be settled at the outset [i.e. before implementation and activation of the smart meters]; (d) the use of Smart Grid information ought to be limited to certain purposes, and data collected for one purpose ought not be used for others; (e) Smart Grid data must be collected and stored in a way reasonably calculated to prevent its loss, theft or modification; (f) there should be a general posture of transparency with respect to the practices of handling Smart Grid data; (g) Smart Grid consumers should have the right to access, confirm and demand correction of their personal data; and (i) those in charge of handling Smart Grid data should be accountable for complying with the principles of the privacy guidelines. EPIC also sets out 11 specific recommendations for implementation of its recommended privacy principles.

In comments made to a Smart Grid Today webinar on privacy, Jules Polonetsky drew on his many years as a privacy advisor to major U.S. corporations to observe that even apparently simple business decisions may have privacy implications. He noted that already vendors offering services such as energy efficiency tips based on data about household usage have created privacy concerns that they have not yet addressed. For example, Polonetsky said, OPower, a web-based provider of efficiency information and services that provides comparative data about a subscriber's usage and that of her neighbors based on publicly-available information, has no privacy policy noted on its web site.

Polonetsky observed that historically, vendors of products and services that use data that alone or in combination can reveal personally identifying information have lagged in recognizing the privacy implications of their activities, and waited until angry customers brought problems to their (and the public's) attention. Smart corporations, he said, have taken a more pro-active approach. They have evolved their approach to privacy beyond the idea that a "privacy notice" is sufficient to alert customers to privacy risks, and that a click through to services is acceptable as a grant of permission to use the customer's data. Such an evolution in outlook is needed in the Smart Grid space, and quickly. Unless the consumer feels that he is getting value in exchange

[83] *Order Instituting Rulemaking to Consider Smart Grid Technologies Pursuant to Federal Legislation and on the Commission's Own Motion to Actively Guide Policy in California's Development of a Smart Grid System*, California PUC Rulemaking 08-12-009.

for parting with data about himself and his household, he will be resistant to implementation of the infrastructure and policies that generate the data.

As does Commissioner Cavoukian, Jules Polonetsky urges the adoption of the "privacy by design" standard. Layering privacy protections on top of an already-constructed system would be costly and ineffective, he notes. He recommends that utilities not wait for the NIST or OSTP processes to address privacy issues. Polonetsky also stresses that end users must be given control of their own data. Policies concerning control of data use and information-gathering by all concerned parties must be transparent. This includes issues of use of data by third parties who likely have not been given explicit permission to use customer data. Utilities and vendors must help develop enforceable rules to give customers control over access to and use of data downstream of the utility and original vendors. Utilities and policy makers should recognize and consider that the more specific the data are to the customer's circumstances, the more useful it might be, but the greater the risk to privacy. Utilities need to "look down the path and think through a philosophy around using the data" that the Smart Grid will generate.

Polonetsky suggests that utilities and vendors do a privacy health examination - they should " learn what the pressure points would be and so carefully examine what vendor's risks would be." Like IT and tech firms, they should develop a position of chief privacy officer, who would be accountable for the firms' privacy policies and practices, and fill the post with dedicated and knowledgeable privacy professionals. Finally, Polonetsky states that consumer research and innovation are needed to learn how to best communicate and inform users about new types of data use that will arise as a result of the Smart Grid. He recommends that utilities stick up for their consumers in the protection of privacy in the Smart Grid.

If a utility wishes to push ahead with smart metering and dynamic pricing today, it will be a pioneer in the privacy area, as well as in many other areas. Early adopters of smart metering technology will have to develop and implement stringent protections for consumer data, and lead the industry in this way. As noted in the *Privacy by Design* report, utilities "have an interest in ensuring that consumer adoption of Smart Grid energy saving programs is not impeded by fears relating to privacy. Electricity providers must embrace a new positive-sum business model — one that is protective of privacy — or risk losing consumer confidence and the public's trust.[84]

3. Too Many Cooks?

The standards setting effort, along with other efforts to push smart grid technology along, suffers from the fact that many entities have a role to play, including the various industry groups noted above, as well as a number of different government entities. At the federal level in the United States, some of the agencies and offices with a responsibility in the smart metering arena include the Federal Energy Regulatory Commission, the Department of Energy, the Federal Communications Commission, the National Institute of Science and Technology, and the White House Office of Science and Technology Policy. There are a number of international efforts under way, as well.[85]

[84] *Privacy by Design*, at p. 3.
[85] The work being done by the North American Electricity Reliability Council includes contributions from Canadian members. Another example, unrelated to any legislative requirements of the United States, is the May 2010

OTSP issued a request for information earlier in 2010,[86] and it appeared at the time that that office was being tapped by the President to lead the effort to engage consumers in accepting smart metering. Later, DOE and the FCC issued companion requests for information about smart grid issues.[87] It must also be remembered that Congress has played a role in smart grid development and will continue to do so.

B. CONSUMER PROTECTION

Smart meters can be used to introduce three practices, each of which pose risks to low-income and handicapped customers of unnecessary or unfair disconnections. First, smart meters can be installed with modules that permit the utility to disconnect the power to a customer's house remotely, by flicking a switch at the utility's offices, without sending a technician to disconnect the meter. Second, smart metering provides a relatively inexpensive foundation for implementing pre-payment metering. Third, smart metering provides a relatively inexpensive foundation for implementing service limiters.

Today, to cut off power to a customer, the utility sends a technician to the premises to "pull the meter". This process provides an opportunity to avert disconnection in the case of a payment-troubled household threatened with disconnection for non-payment. When a technician comes and pulls the meter, the customer gets final notice of the impending shut-off. Also, the customer has an opportunity to pay any delinquencies on the bill, and avert shut-off. This "last knock" notice and opportunity help prevent unnecessary shut-offs by providing an opportunity for the customer to fix the problem that led to the disconnection decision. The in-person disconnection also provides an opportunity to work out problems with the utility. Remote disconnection eliminates this "last knock" notice to the customer, and final opportunity to resolve bill issues.

In the event of voluntary terminations, such as at move-in and move-out of premises, remote disconnection would not threaten consumer rights. Further, if the utility were to send out an employee to make the "last knock" before a remote termination, the customer's rights could be preserved. Such an employee would not need to be an electrician, or bring a service truck to the location when making the last knock visit, but could presumably call in the results of the visit to the control center. The employee would need to be able to take payments on account, and work out payment arrangements or refer the customer in real time to a customer service representative authorized to make such arrangements and avert the disconnection. In this way, savings from avoiding the meter pull could be realized without undermining access to service.

Utilities have already started using the remote disconnection function, and as a result, disconnections for non-payment have increased. In the PG&E service territory, where over 4 million smart meters have been deployed, the utility increased its rate of disconnection for non-payment by 40% from August 2008 to August 2009. This increase cannot be laid entirely at the feet of the worsening economy in that period, as other California electric utilities' disconnection

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creation of a Focus Group on Smart Grid standards by the International Telecommunication Union. http://www.itu.int/net/pressoffice/press_releases/2010/21.aspx#url.

[86] OTSP Request for Comment, February 19, 2020, 73 FR 7527.

[87] DOE Request for Information on Smart Grid Data Access, May 10, 2010, 75 FR 26203; FCC Request for Information about Smart Grid Communications, May 10, 2010, 75 FR 26208.

levels went up only 9%. PG&E reportedly advised the California Commission in a January 2010 filing in its rate case that by 2011 it expects to increase its rate of disconnection of those customers eligible for disconnection from 37 percent in 2008 to 85 percent of all such customers.[88]

In Nevada, the major electric utility has announced that it plans to use its smart meters to pursue more aggressive disconnection for non-payment. Remote disconnection is less expensive than in-person disconnection. As a result, for the same budget the utility can disconnect many more customers with remote disconnection than with in-person disconnection.

Prepayment metering also raises the risk of disconnection of service. Under a prepayment metering approach, power will flow only so long as the customer has paid in advance. The customer puts money in the meter to get power, typically through a smart card, which operates much like a prepaid wireless or long-distance card. If the smart card amount is used up, and the card is not "recharged," the customer's service will be disconnected. In practice, the result is that customers are disconnected without the advance notice and consumer protections afforded by regulation and utility practice.

The French distribution utility, Electricité de France, at one time required delinquent customers to accept prepayment metering as a condition of continuing to receive service. They abandoned that practice after their sociologist's research found that low-income and other vulnerable customers were cutting themselves off, inadvertently, when they were unable to charge up their prepayment smart cards. Because the disconnection was automatic, and "remote" (at least from the awareness of the utility), there was no advance notice, nor an opportunity to work with the customer to arrange for help paying the bill, make payment arrangements, or otherwise manage the customer's payment difficulties in a humane and practical way. As a result of this research, EDF changed its policy, and does not allow such vulnerable customers to take service under a prepayment arrangement.

A recent investigative news report from Texas (where deregulated electricity commodity vendors can offer service on a pre-paid only basis) tells of vulnerable pre-paid electricity customers being cut off without notice.[89] Families with children have had to abandon their homes. A paraplegic who requires air conditioning to maintain a safe body temperature lost his electricity on days when the temperature exceeded 100 degrees. A heart failure patient who needed power for an oxygen machine was cut off twice in one summer.

The Massachusetts Department of Public Utilities recently dismissed the smart grid filing of a major electric distribution utility in the state because it proposed to pilot prepayment metering among low income customers. The Commission found that such metering would violate regulations promulgated to ensure safe and reasonable access to service, including advance notice of pending disconnection and an opportunity to dispute the bill. In Ohio, the request of Duke Energy to use remote disconnection without prior in-person notice in its smart metering pilot was denied by the Commission. The Commission refused to waive the regulation that

[88] http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2010/01/26/BUUG1BNBVD.DTL
[89] Steve McGonigle and Ed Timms, "Cutoffs, complaints abound with Texas' prepaid electric providers," Dallas Morning News, October 4, 2009.

provides that an attempt will be made to contact the customer through an in-person visit before disconnection for non-payment.[90]

Service limiters are just what they sound like: devices that cause a circuit breaker in the meter to trip open if the amount of electricity used exceeds a preset limit. Like a circuit breaker, they can be reset under certain circumstances. In essence they put a customer at risk of the power going off without advance notice if usage happens to exceed the limit. As in the case of prepayment metering, tripping the service limiter causes a disconnection without notice and an opportunity to take care of the bill.

Service limiters can pose dangers to health and even life. This past winter, a 93-year old gentleman from a town in Michigan froze to death because a service limiter was put on his meter. He had fallen behind in his bill, and the (municipal) utility had a policy of putting on service limiters until bills were paid up. The fellow was found dead in his freezing cold house. On the kitchen table was found money sufficient to pay the bill. The fellow never got a chance to pay his bill before disconnection – he may not have been able to get to the meter to reset it, he may not have understood that he could do that, or how. But in any event, he suffered a painful death because the service limiter tripped in the middle of winter.

Policy makers should issue findings to the effect that these three uses of the smart metering installation pose risks of unnecessary and unfair loss of electric service, and that the regulators will not accept them as an element of smart metering deployment. Utilities would retain the right to petition for a change in the policies, practices and regulations, but consideration of such changes should take place only in proceedings that are focused enough on the issue to permit a full exploration of the facts and the ramifications.

V. WHAT IS THE VALUE PROPOSITION?

A. WHO PAYS, WHO GAINS? SMART METERING COST ALLOCATION

Answers to the questions of who pays the costs for smart metering, and who gets the benefits, remain unanswered. The unexplored relationship between smart metering costs and benefits helps explain why utilities have been successful in obtaining authority to recover smart metering costs through flat, per-customer charges. The utility argues that the metering costs are customer-related, and do not vary with the amount of usage. On this basis, some Commissions have explicitly approved smart metering cost recovery on a flat, per customer, basis. Further, all customers must pay for the smart metering deployment, even those who do cannot take advantage of the opportunity for bill savings through reduced load.

The smart metering cost-benefit equation is different from the cost-benefit equation for new generation in a growing service area. For 100 years since the beginning of the electricity

[90] Posting by David Rinebolt, Ohio Partners for Affordable Energy to the energy listserv of the National Consumer Law Center, June 8, 2010. The Commission ruling is available at http://dis.puc.state.oh.us/TiffToPDf/A1001001A10F02B40337A28572.pdf.

industry, as usage grew, all customers enjoyed lower rates. Higher usage spread fixed costs over a larger base of revenues, and also supported the introduction of larger, and more efficient, generation stations and transmission systems. By contrast, enjoyment of the benefits of smart metering depends primarily on participation in the rate, the ability to shift load off critical peaks, and the load factor of the customer.

Some spill-over benefits may accrue to non-participants as a result of the impact on wholesale prices of peak load shaving by participants, but these benefits are modest compared to the direct benefits enjoyed by participants who have the ability to shift load or who have unusually high load factors.

If a CPP or PTR is purely opt-in, a customer would have to choose the rate to get the benefit of critical peak reductions. Once on the rate, there are two key ways to benefit. If the customer is able to shift load off the critical peak, the customer can get the benefit of avoiding the higher cost on the critical peak, or obtain the rebate benefit of reducing load at the critical peak hours. They would not obtain the benefits of real-time or near real-time usage and cost feedback, and thus not be "empowered" to reduce their overall consumption.

Customers not on the rate would benefit from the impact of lower load on the energy and capacity costs of the standard offer service on which they take power. There is another way to benefit, at least hypothetically, from critical peak time-varying pricing. If a customer has a high load factor, she will benefit from the fact that rates during non-critical-peak hours are reduced, to make the critical peak rate revenue-neutral for the utility.

Note, however, that this benefit, as is the case with the market impact benefits, will be offset by the incremental costs of metering, which can be significant. Surcharges proposed in the States for utilities to recovery smart metering costs have run as high as $15 per customer, and typically run between $2 and $5 per month. The off-critical-peak benefit of a better load factor would have to exceed these amounts for the customer to enjoy a net benefit.

Some argue that low-use customers cannot benefit because they cannot move any appreciable level of demand off the critical peak. Proponents counter that low-use customers have better load factors and should benefit from the low off-critical-peak prices. Aside from the question above of the trade-off between smart metering costs and the benefits of lower off-critical-peak prices, low-use customers face an additional problem. Most utilities have proposed a flat monthly customer charge increase as the mode for recovering smart metering costs.

The effect of a flat monthly charge is that lower-usage customers pay a disproportionately high percentage of smart metering costs. The argument is made that metering costs vary per customer, and not per usage.[91] This theory ignores the fact that a primary purpose of smart metering is to encourage load shifting, if not consumption reduction. The resource benefits of the metering vary according to usage and usage patterns, not the number of customers.

There is also a debate about how to allocate smart metering costs among classes. This debate

[91] Petition of West Penn Power Company, d/b/a Allegheny Power for Expedited Approval of its Smart Meter Technology Procurement and Installation Plan, Initial Decision, Pennsylvania PUC Docket No. M-2009-2123951..

takes a similar form as the debate over flat monthly surcharges versus volumetric charges to recover smart metering costs.

The effect of using customer counts to allocate and recover metering costs is to raise the percentage bill impact of the smart metering surcharge on the average residential customer, and on all low users of electricity.

In the case of pilots, other considerations enter in. Some utilities propose to allocate pilot costs to all customer classes, on the theory that a pilot will benefit all classes, not just the class of participants, because of the transferable knowledge gained.

The regulatory theory of smart meter cost allocation is immature at this point. Allocating costs to classes by numbers of customers, and within classes by numbers of customers, is an easy approach, but ignores the subtle questions of cost causation and cost/benefit that apply in the smart metering space.

B. Will customers accept the new technology?

Adverse customer reactions have surfaced towards smart grid deployments in various areas of the United States. Customer reaction has become an issue of active discussion in the smart grid trade press, because of the instances of customer rejection or questioning of smart grid deployments. In addition, in light of concerns raised, regulators in a number of states have made decisions that have the effect of slowing down and scaling down proposed smart grid deployments.

For example, problems with meter accuracy and high bills in the first area in the Pacific Gas & Electric ("PG&E") service territory to get universal smart metering have led to a number of adverse customer reactions to the PG&E smart grid deployment since mid-2009. These have included: (a) consumer complaints, (b) a town meeting against the meters held by the local State Senator, (c) a class action suit, (d) adverse press coverage of the utility's deployment and its impact on customers, (e) filings at the California Public Utilities Commission ("California Commission") by a statewide consumer advocacy group, (f) the intervention of the California Commission to hear customer grievances and investigate the issues, (g) widespread customer distrust of the new meters, and (h) a hold on further meter deployment in one area until the problems were sorted out.

The utility had pushed the first meters out at the same time as it implemented a rate increase, and during a particularly hot summer. The utility claimed that the high bill complaints were a mistaken response to the rate increase and summer usage increase. The utility also claimed that some analog meters that were replaced had been running slowly, and the smart meter merely corrected an underbilling that had been experienced before. Customers argued that their usage had not gone up and that the meters malfunctioned. Whatever the cause of the high bill complaints, it is clear that PG&E damaged its credibility on smart grid issues as a result of the problems with its smart metering roll out.

Eventually, PG&E became proactive in responding to consumer complaints about the smart meter installation. It has released reams of data concerning its testing of meters, added call center representatives to specialize in answering smart meter questions, and conducted town meetings in local communities to respond to customer questions. PG&E still faces organized opposition to its smart metering project.[92]

In Texas, another major distribution utility has also experienced customer complaints about its smart meter deployment. Disgruntled customers of Oncor have complained of high bills after the switch to smart meters. One customer has filed a lawsuit against Oncor claiming fraud. The Texas Public Utility Commission engaged an expert to test the meters Oncor was deploying, to resolve consumer assertions that the meters malfunctioned. So far the tested meters have passed the accuracy standards.

As with PG&E, the utility has blamed a number of factors for giving customers the impression that the smart meters were faulty. Oncor has pointed out that it introduced the smart meters during a particularly cold winter, when space heating requirements were unusually high. In addition, the utility altered its meter reading frequency when it installed the smart meters, so the first bill after the installation covered more than the usual 30 days for some customers.

At the same time, Oncor has implicitly recognized that it has a public relations problem with smart metering. The utility has created a new management position, "Chief Customer Officer," ostensibly to provide a means for the utility better to pay attention to consumer concerns.

In both the PG&E case and the Oncor case, utility stumbles in the introduction of smart metering led to customer mistrust of the new technology. The smart metering and dynamic pricing industry has begun to recognize that consumers generally are not welcoming the new metering system and pricing options. Consumers definitely are not demanding that utilities install the new technology or offer dynamic pricing. Consumer advocates have been almost universally cool to the new meters and pricing options. The industry has begun to realize that it has a customer acceptance problem.

In response to concerns about customer acceptance of smart metering, industry proponents have formed a Smart Grid Consumer Collaborative to conduct focus groups and collect best practices for engaging customers. There is token representation from utility regulators and consumer advocates. One of the first activities of the Collaborative will be to help the National Town Meeting on Demand Response and Smart Grid[93] to address a Smart Grid Action Plan Aimed at Consumers. In the words of the brochure for the 2010 National Town Meeting (emphasis in the original):

> A main focus of the 2010 National Town Meeting will be *the consumer---one of the hottest topics today in the world of demand response and smart grid.* It is commonly acknowledged at this point that a key way in which the grid becomes "smart" is to engage

[92] On June 17, the city attorney of San Francisco asked the California PUC to halt the planned deployment of smart meters in the city pending the completion of the PUC-ordered investigation of the meters and communications systems that have been the subject of high bill complaints. The utility strongly opposes this request. See, Smart Grid Today, June 21, 2010. Available at http://www.smartgridtoday.com/public/1724.cfm.

[93] http://www.demandresponsetownmeeting.com/home/, last viewed June 23, 2010.

> the electricity consumer in demand response and other activities that help optimize electricity system planning and operation. *But questions remain...*
>
> *What do consumers want?*
>
> *What do they care about?*
>
> *How do we talk to them?*

Industry proponents have had to exhort one another to look at the smart meter from the consumer's point of view. Speakers at this year's Connectivity Week in late May 2010 told attendees to "get all warm and fuzzy." Messages taken away from the conference included the following:

> Customers are “people with emotions” and you’d better not forget it. "Industry people need to think of customers not as 'ratepayers' or 'loads' but as single mothers, commuters, people with emotions and motivations…” "What would life be like if consumers actually wanted this stuff like they wanted the iPhone and Star Wars prequels?"[94]

Unfortunately, many in the smart metering industry think the solution is to educate consumers about why the smart meter matters. That approach assumes that if consumers have information about the smart metering opportunities, they will welcome the technology. This approach betrays an inability to see smart metering as anything but an unalloyed positive.

Other utilities are responding to the issue of public acceptance by trying to manage expectations. Earlier this year, the Senior Vice President for asset management of PEPCo cautioned that customers will notice benefits of the smart grid emerging incrementally, given the scope of the project. The PEPCo executive Vice President has said that it is important to manage customer expectations to achieve successful smart metering rollout, since it will take longer than a decade to achieve all the benefits. "Optimization of the grid is about 15 years in the future," he said at IEEE's Innovative Smart Grid Technologies Conference in January.

Most recently, a state commission has rejected a utility proposal to deploy smart metering, despite the fact that the utility in question stands to receive a substantial federal grant to help pay for the costs of the investment. The decision of the Maryland Public Service Commission on June 21, 2010 jolted the smart grid industry, and instantly generated a flurry of opinions on whether it meant a major reversal or a "bump in the road" to the smart grid. The Maryland Commission basically said that the costs were likely understated and the benefits, while plausible, were uncertain. In this situation, it would not lock consumers in to paying for the system:

> The Proposal asks BGE’s ratepayers to take significant financial and technological risks and adapt to categorical changes in rate design, all in exchange for savings that are largely indirect, highly contingent and a long way off. We are not persuaded that this

[94] Anto Budiardjo, Clasma CEO, as quoted in *Smart Grid Today*, May 26, 2010.

> bargain is cost-effective or serves the public interest, at least not in its current form. But we invite BGE to revisit its Proposal in light of this Order and to submit an alternative that addresses the issues we discuss...[95]

The Maryland Commission essentially invited the utility to come back with a proposal in which the shareholders of the Company that stood to gain a profit from the investment took on a fair portion of the risk that the investment would not provide the net benefits claimed for it.[96] The significance of this decision, if followed by other states, will be to force the industry to put its own money behind the idea.[97] Such an approach might slow the development of the smart grid, but would also force the smart grid to be designed and deployed so as to live up to its billings.

VI. Conclusion

There have been sizable investments in residential smart metering in the last few years. United States, state and provincial policies have been enunciated in support of smart metering. Additional dynamic pricing pilots have been completed, with results generally consistent with the results of the first smart metering pilots. Utilities in the United States have announced plans to install over 30 million smart meters in the next few years. Millions of these communicating interval meters have already been deployed. Utilities in Canada are on track to have installed 5.8 million smart meters by 2017. At least twenty types of in-home feedback devices are on the market already. White goods manufacturers have announced plans for HAN-compatible household appliances.

It would seem that a great deal of progress has occurred in these last few years. In some ways that impression is correct. On the other hand, the uncertainties that counseled caution three years ago remain unresolved. We cannot know how many customers of what types will take up (or stay on) which dynamic prices upon full deployment. We cannot be sure what demand response they will make to dynamic prices. We are not sure to what extent, if any, customers will adopt feedback devices, or use them to guide consumption reductions. Perhaps most importantly, we do not and cannot yet know the extent to which demand and usage reductions in the early years of a dynamic pricing offering will persist reliably into the future.

At the same time, we have not established the standards and protocols necessary to build out the smart grid and install smart metering on a wide scale. We continue to learn about cyber-security risks and risks to consumer privacy. Consumer protections must be fashioned to fit the new technology and preserve customer access to affordable and efficient power. Industry players continue to debate details of open standards versus proprietary solutions. No approach has achieved dominance, and there is as yet no sign of path dependence or other factors forcing a convergence around a few marketable technologies.

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[95] Even after applying the federal grant, the BGE project was estimated to cost $700 million. *BGE Order* at 4.
[96] *Id.*, pp. 7-8.
[97] Vendors of meters and related devices have put significant amounts of money into pilots. Query whether they too should take on the risk that smart grid deployments will not provide the net benefits claimed for them. This might be effected by contract terms between the utilities and the vendors, at least those vendors whose products are built into the smart grid system and the costs of which are recovered in utility rates.

Customer acceptance of the new prices and technologies has been set back by botched roll-outs in California and Texas. Smart metering proponents have begun to realize that they do not understand their prospective customers enough to develop the industry in ways that will attract customers. The smart metering market does not yet have the buzz of excitement that a new technology often has, when early adopters are willing to pay premium prices to be the first on their block to have the latest gadget, with the mass market developing from there. Tension continues to exist between the impulse of government and the industry to "build it and they will come" and the drive to answer the question "what does the customer want?"

Technology innovations seem to roll out in fits and starts. As of now, development and deployment of smart metering is taking longer than many thought it would just a few years ago. We have not reached the stage where unforeseen uses for the new technology begin to appear. It is difficult to predict how long it will take to work through the issues that still have not been resolved.

Thus, the development of smart metering in the last few years has not yet significantly narrowed the number and scope of imponderables facing policy makers trying to decide whether and how fast and in what direction to promote smart metering and dynamic pricing. In this context, it is useful to set out some options facing policy makers, and in particular state and provincial regulators, faced with demands by some to push hard for smart metering and calls by others to hang back if not reject smart metering outright.

In principle, a regulator could require utilities to come in with a showing why they are not doing everything in their power to implement smart metering and dynamic pricing. At the other extreme, regulators can announce that smart metering will not move forward in their jurisdiction until all the issues have been fully and finally resolved - in other words, not for many years.

> "The benefits of the smart grid are not immediately obvious to the consumer. There's very much the perception that the smart grid may be for the benefit of the utilities."
>
> Annette Papadopolous, of Ideo, at Connectivity Week.

regulator can indicate interest in the promise of smart metering, but hold off on approving particular plans until other jurisdictions have had more experience with their initiatives. Alternatively, the regulator can approve the plan and the funding, but contingent on a showing that certain levels of progress on key issues has been achieved, and with the caveat that the utility takes the full risk that operational and resource benefits will not arise as forecast. This is particularly important with respect to resource savings projections, which remain subject to great uncertainty. Conversely, the regulator can allow deployment and generous cost recovery terms, essentially putting the risk on the consumer that smart metering will not bring about the benefits promised, and will not pose insurmountable risks.

In any event, some issues should ideally be left for the market to resolve. In-home devices, HANs, and compatible white goods are essentially consumer goods. The numerous competing designs should be allowed to compete for customer acceptance. The winners will be able to ramp up to production levels, and prices will come down. Likely different models will appeal to different customers, and the regulator need not and should not choose winners in this market.

Regulators may be tempted to step around the question of the ultimate wisdom of smart metering investments by approving pilots. There are some questions that further pilots could help to answer, particularly with respect to the behavior of and likely impact of dynamic pricing on vulnerable residential customers. But aside from such discrete issues, the remedy for the remaining uncertainties is either blind faith or the tincture of time. And the determination of the industry not to shift the risks associated with the uncertainties to captive consumers.