# Value of Electricity versus Cost: Resolving the Customer Benefit Dichotomy in Ratemaking

*There is a compelling need for new considerations in the process of ratemaking to allow an explicit linkage between the costs that utilities incur for continuity of service with the value customers derive from the service. Separating the decision rationale for improving the quality of service from investments in enhancing resilience of the system is necessary to ensure the integrity of a critical societal infrastructure.*

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## I. Introduction

Should ‘‘value’’ of electricity rather than cost become the basis for regulation of the sector? If it can be shown that there is indeed a wide gap between the value of electricity service delivered to a customer and the cost of service, then a compelling rationale exists for a deeper examination of this issue. The primary economic justification for regulation of electric utilities arises out of the obeisance to the idea that electric utilities are natural monopolies. According to classical economic theory, a natural monopoly exists when a single firm can provide the lowest-cost means of supplying a product or service in a specific geographic area or region.

It was in 1898, at the dawn of the electricity industry, that Samuel Insull made the decision to acquire and monopolize the electricity sector in order to stop

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the problems with the full competitive market at the time: Insult stated:

> In order to protect the public... exclusive franchises should be coupled with the conditions of public control, requiring all charges for services fixed by public bodies to be based on cost plus a reasonable profit. (Platt, 1991)

This made sense in an era – Chicago, circa 1900s – because:

> Rate wars, distributor duplication, and torn-up streets presented an alternative that was attractive to virtually no one. (Platt, 1991)

This anecdote from the early days of the electric power industry serves as a reminder of the central and still-unresolved issue of regulation in the electric power sector, particularly the ratemaking process and the definition of ''reasonable profit,'' and the dichotomy that pervades discussion of the value of electricity to the customer versus cost of service. Recently in a series of articles published in *The Electricity Journal*, Steven Mitnick has raised the red flag – and for good reason – on this critical issue: there is a need for new considerations in the process of ratemaking and to relate the costs that utilities incur with the value customers derive from the electric service (Mitnick, 2013, 2014).

We present here an analysis of Mitnick's thoughtful perspective on this subject, along with a discussion of the utilities' costs and how the ratemaking process could be improved. We highlight an approach to address the controversy over the justification of costs for grid reinforcements to enhance resiliency – a challenging concept arising from the need to adapt to climate-induced extreme weather events (Linkov et al., 2014). The goal is to separate the issue of enhancing grid resiliency from the classical domain of investments in quality of service (QoS) improvements in the distribution sector. Separating these two issues of funding for resilience and QoS is necessary to ensure the long-term integrity of a critical societal infrastructure subject to failures caused by events leading to long-term interruptions.

*There is little dispute on one fact: the customers' perspective in the ratemaking process is limited to seeking the minimal cost of supply.*

We amplify the dissonance inherent in the concept of the value to customers of continuous electricity service versus the cost of electricity service. We also argue that at the core of the complexity and legal acrimony that often surrounds specific regulatory decisions is our collective unwillingness to accept the cost of investments in new electric infrastructure to enhance the quality of the electric delivery system and how to allocate the costs of resilience across customer classes. There is little dispute on one fact: the customers' perspective in the ratemaking process is limited to seeking the minimal cost of supply, even though, that can work against the customers' own interests if long interruptions persist.

## II. Review of the Evidence

Mitnick's perspective highlights the notion that the ''value'' customers attach to provision of continuous electricity service is very vague. The case is made for quality of service delivered to residential customers of distribution utilities. The articles are mainly concerned with the restoration activities of distribution utilities and the actions they undertake when dramatic events cause multiple failures with widespread consequences for societal wellbeing. The focus on distribution utilities is justified in light of the evidence, as the author notes:

> Federal Energy Regulatory Commission has taken many steps to ensure the reliability of the interstate grid. Yet, virtually all power


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outages are due to problems with local distribution grids. (Ref. 14 in Mitnick, 2014)

Over the last 20 years, restoration for the transmission grid has been an understood problem, widely studied and receiving sufficient regulatory oversight and support for the adoption of new technological solutions. This has not been the case for the distribution sector.

Mitnick focuses solely on residential users. In our view, a broader, comprehensive understanding of the value derived by different customer classes is necessary because it will not only provide additional relevant information but also help to guide decisions for a better allocation of the improvements costs. Since all customers, regardless of the economic sector they belong to, are connected to the same grid, the investment in upgrades should be made with the criterion of net overall benefits to customers.

From a societal perspective, it is imperative that a more detailed basis of evidence be developed to highlight the value of electricity service. In the past, several observers have noted that it is difficult to quantify the value of electricity. One remedy is to bring 20 years of research on this subject into the mainstream processes of regulatory decision-making and develop it further using the data collection and analytical capabilities available to augment the insights from previous research. The essential problem arises from the fact that the regulatory bodies have not provided a clear signal that bridging the gap between ''value'' and ''cost'' is a desirable regulatory objective and would consider acceptable to incorporate such information into ratemaking. Extensive surveys and assessments that link the interruptions in service with the consumers' economic losses have been made by the Lawrence Berkeley National Laboratory (Sullivan et al., 2009) yet the information has been only treated perfunctorily. These data also provide a starting point for the information required to allow formulation of customer damage functions (Munasinghe and Gellerson, 1979), a well-known tool with extensive discussion in the literature but little uptake from the industry. A result from the assessment made in 2004 (LaCommare and Joseph, 2004) shows that the commercial sector usually bears the larger share of the cost of interruptions (**Figure 1**); this kind of ex post analysis is evidence of the value customers get and who may be more willing to pay for enhancements.

One of the most important contributions that Mitnick's papers make is to provide a historical context for the interpretation of regulatory policy in the U.S., and its widespread influence on regulatory practices in many other countries. In the U.S. context, it is important to note that a thorough review the distribution systems regulation developed by Davies Consulting for the Edison Electric Institute, showed that 24 states did not have any performance requirements (in 2005) and only 3 have a combined penalty and incentive based framework (DCI, 2005). The regulatory practices of price caps without quality of service control produced a negative effect on the cost of financing new investments (Jamasb and Pollit, 2007). The examples used in the Mitnick articles are a good sample of the discussion of this issue in regulatory policy: in the short term, incentive-based regulation was effective in reducing costs, but in the long term empirical experience shows deficiencies in

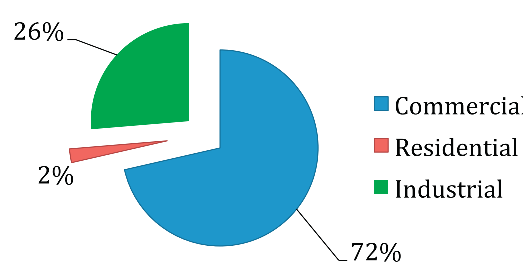


**Figure 1:** Base-Case Estimate of the Cost of Power Interruptions by Customer Class (LaCommare and Joseph, 2004)

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a guarantee of the required investments flow to provide improved services and particularly for adapting to the higher standards required by customers. By broadening the scope of analysis to other regulatory bodies in different countries, as discussed below, the existing deficiencies in regulatory practice can be overcome.

Another important consideration is the multiple levels at which economic exchange can be made for different levels of quality of service. This view is supported by research pointing to the willingness of customers in certain segments to pay for services such as insurance or backup power, and to purchase reliability enhancers to get a better service than the one the utility can provide (LeBlanc et al., 1999; Sullivan et al., 2009). The conclusion is that there are product substitutes for provision of enhanced reliability, thus creating an opportunity to increase rates to improve the system performance. Another example of willingness to pay for extra quality in the electric service is the French experience, where different quality standards are provided according to the level of service and tariff the customers' prefer (Javerzac, 2000).

Mitnick further highlights the role of adequacy of service as an important part of valuation of service interruption:

> Ironically, adequacy, the first of the duties imposed in the public utility at common law, was the third and last to have recognition as a concern of regulation... These and other factors contributed to the tendency of adequacy of services to take a back seat in the regulation field. (Ref. 7 in Mitnick, 2013)

A powerful case can be made for including the costs associated with enhanced resilience of the system (i.e. restoration costs arising from extreme climate events) in the same way: by emphasizing the requirement for continuous service, resilience is brought to the forefront even as regulators struggle with its definition.

*It is important to acknowledge that loss of power can result in more dire consequences to some customers than others, beyond economic losses.*

There is no doubt that general, widespread availability of electric service has increased the value derived from its use, although stating that the increase in the value customers obtain from electricity is primarily related to their expenditures on appliances is difficult to sustain. Given the availability of analytical tools to quantify value through customer damage functions and critical event ex post data, it seems odd to use purchase of appliances as a benchmark. Nevertheless, for cases where the loss of power to a certain device may result in death or serious discomfort, it is important to acknowledge that loss of power can result in more dire consequences to some customers than others beyond economic losses.

## III. Nature of Utilities' Costs to Deliver Electricity

Tariff design and calculation is essential activity that promotes accessible costs to the electric service in the short term and proper incentives for an efficient long-term infrastructural development. For a more transparent analysis, the increase in costs of a distribution utility can be broken into the following categories:

- *Fixed costs*: These costs are related to labor, taxes, and costs of supplies. They will increase proportionally to the PPI indices in the countries, so that the net effect can be neglected if the salaries and income of the customers' are adjusted in the same proportion. Since most regulatory practices recognize that these increases are outside the utilities' control, they don't cause major reductions in the quality of service (e.g. reducing payroll due to the salary increases, lower levels in hiring standards).


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• *New investments*: The major part of the acrimonious debate in ratemaking is in the plans that the utility makes to build new infrastructure or reinforce the existing system. Under ''cost of service'' regulation, utilities can profit by overinvesting and this has often led to inefficient expenditures known as the Averch–Johnson effect.
The investment in new infrastructure can be further broken down in order to make the analysis more clear: (i) Investment to increase capacity of supply and (ii) investments to increase the reliability of the system. The latter is the focus of this discussion since the investments to increase capacity are usually contained in the expansion plans of the utilities subject to approval from the regulatory bodies. Furthermore, in most developed countries including the U.S., demand growth is low and the same pattern repeats for average per customer consumption (Electricity Currents, 2014), hence increasing delivery capacity is not a pressing issue.

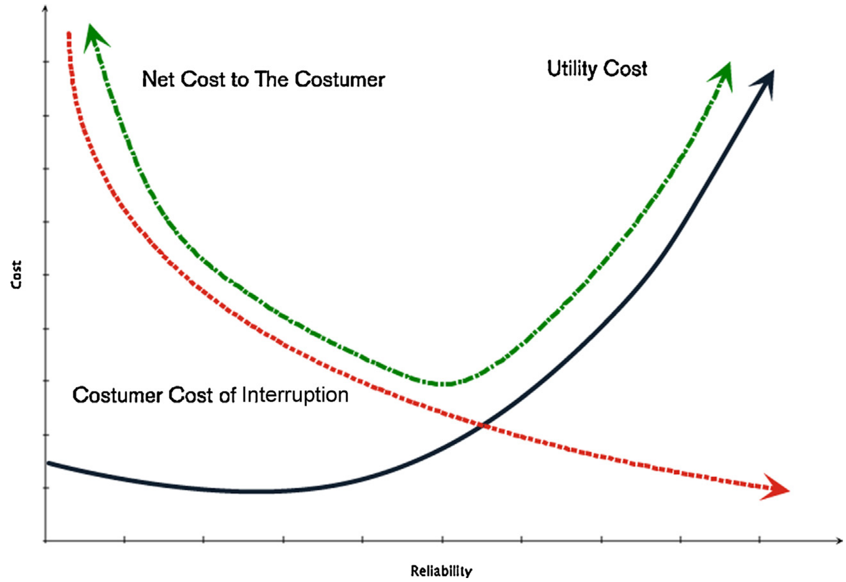

**Figure 2:** Model of Grid with Differential QoS

Distribution system theory points out that there should be an economic optimal point between the cost to the utility to increase reliability and the cost to the customer of not having that reliability as depicted in Figure 2 which is a general economic curve for a differentiated product model applied to system reliability.

This economic foundation laid the ground for predictive reliability theory proposed for a long time in order to assess improvements in system design and architecture that lead to better reliability performance. However, this predictive analysis is designed for interruptions caused from normal operation of the distribution system such as equipment failure rates or by normal events such fuse blown by short circuits. Since these interruptions can be addressed by the technological substitution of certain equipment, increased tree trimming activities and others, all of them well known and understood by regulators.

Regulators have used, for some time now, indices to evaluate the performance of the distribution utility (where evaluated). The seminal work of professor Billinton set the bases for the well-known SAIDI, SAIFI indices later included in the IEEE-std 1366. After the 2003 revision, the standard included a measure to separate interruptions created from the daily operating events (e.g. fuse replacement after a short circuit) and major events (e.g. Toronto ice storm in 2013), though to our knowledge there is no evidence of its adoption in regulatory practices.

Mitnick raises a fundamental issue that needs to be addressed as part of the ratemaking process:

> In many cases, storms don't actually hit a particular area or hit with less force than the weather forecasters predicted. As a consequence, utilities are left with considerable expenses for the crews later found to be unnecessary and regulators are left with the conundrum as to the inclusion of these expenses in customer rates. (Mitnick, 2013)

What is the proper cost of electric service restoration under circumstances that cause long periods of interruption? Should disaster management be reactive or proactive? And what would be

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the allowable cost for improved resilience?

## IV. The Role of the Regulation Model in the Reduction of the Quality of Service

To the question ''How is it possible that electric service has not become more expensive?'' (Mitnick, 2013), a possible answer is that customers are still benefitting from ''historical overinvestments'' (i.e. ''gold plating'' of the asset base) that has already been paid for, and the operational costs have kept pace with nominal increases in the overall economy. Thereby, the customers' perception threshold for increases has not been triggered. Given the changes in regulation, especially the change to price cap regulation limiting the utilities' incentive to reinvest in their networks, it is no surprise that the rates have remained flat.

Regulatory policy has been reactive when new challenges arise in the electric power sector. Evidence of that is the case of service adequacy – the last item to be included in the regulation practices. Thus, it is likely that in light of new requirements from users toward restoration services, the costs of embedding increased resilience into the system may become a separate item for consideration in future ratemaking, though a framework to include it and allocate the costs is still up for debate.

Even though some regulatory bodies have imposed requirements on the QoS, the evidence show that the quality expectations from users are not met (Ajodhia, 2005). From that point of view, as long as regulatory policy focuses only on indices designed for operational interruptions, it is unlikely that we will see any improvements in the reduction of restoration times or investments for enhanced resilience to address major events causing widespread failures. We note some differences across jurisdictions. In the U.S. case, utilities have been risk-averse and have avoided the cost of innovation risks by increasing the customers' risk to interruption. On the other hand, in the U.K., for example, other means to incentivize the development of infrastructure were established. The requirements and control of the quality of service have evolved with each regulatory period, closing the gap between the long-term horizon of investments and short price control periods. The last iteration of the U.K. model, known as the RIIO model, now includes incentives for innovation, carbon-reduction, and increased grid resilience.

*The challenge for the regulator would be to ensure some limit on price discrimination.*

The central object in this discussion is always the customer. Thus the key question is: What is the value that a customer – in particular a residential customer – puts on QoS, and if the distribution grid is to be reinforced, how do we allocate the costs to other classes of customers who may be willing to pay? The challenge for the regulator would be to ensure some limit on price discrimination. As customers' incurred costs are real but the gain in benefits are often intangible or hidden – at least until an extreme event hits the entire population – the regulator has the obligation to avoid scenarios that result in loss of service to all because there is a widespread acceptance for lower standards in QoS or restoration services. This situation arises because the explicit monetary costs of the rate increases do not always translate directly into monetary gains for all. Hence, the regulator must address the asymmetry of information on specific costs, benefits, and risks and foster a discussion focused on investments and costs of preventing long-term interruptions due to extreme events and less about the costs of restoring the system after the event.


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## V. Allocating the Cost of Increasing Reliability among Stakeholders

A detailed plan with quantitative modeling of the risk and risk-abating measures taken by the utility to improve service restoration will also require the same level of expertise and understanding of the distribution sector, perhaps making regulation more expensive – an issue well discussed among regulatory policymakers. This has been the case for existing regulation as experience also showed that incentive based regulation turned out to be very expensive and complex, for example the constructive units model used by U.K. regulators (Jamasb and Pollit, 2007). This effort of the regulators, made in order to avoid asymmetries of information and moral hazard, serves as base to improve the regulatory process and accommodate the emergent need for more sophisticated regulations and evolution of practice that incorporates resilience into the ratemaking process.

Our point is simple: Investments should be aimed to reduce the risks and not necessarily be limited only to some level of readiness for a forecasted extreme event. The discussion on enhanced resilience should focus on effective technological changes required to avoid certain risks, for example, changing from overhead lines to underground cables. We introduce two specific factors to be included as explicit considerations depicting the ''value-of-electricity'' ascribed to resilience in the ratemaking process to capture the customers' loss of value.

The components for enhanced investment in resilience are defined as:

(i) monetary cost to the utility divided by the reduction is system restoration times $\$_u/T_r$, different proposed investments could be analyzed, and

(ii) customers' damage functions for different sectors and types of customers provide the economic losses per unit of interruption time $\$_c/T_i$.

If both measures are combined, the proposed framework addresses the challenge highlighted by Mitnick:

> A utility's cost translates directly into customers' costs, in principle. In reality, a utility's cost translates fairly close to directly into customers' costs if not directly. (Mitnick, 2013)

It can be argued that an investment in reducing restoration times is actually paid by the customers thus $\$_u \propto \$_c$. This means that each investment can be evaluated in terms of how much of customers' costs increase in order to reduce the losses due to interruption times in extreme cases. In **Figure 3**, the limit of customers' acceptability to a rate increase to avoid losses is represented by the solid line, since the cases above that line are those where the costs of reducing interruption times are higher than the loss of value, thus answering the question of where is the limit when higher costs do not drive up value or, as Mitnick states it:

> The point where the net value that customers receive peaks, and thereby where the utility best satisfies the public interest. (Mitnick, 2014)

Figure 3 also shows three cases, two of which are below the line (1 and 2) and one above it (3), from two points within acceptable costs 2 is more cost effective than 1, as it allows higher saving with almost the same investment.

The underlying challenge with this approach is to find a consistent way to measure the willingness of customers to pay for the risk

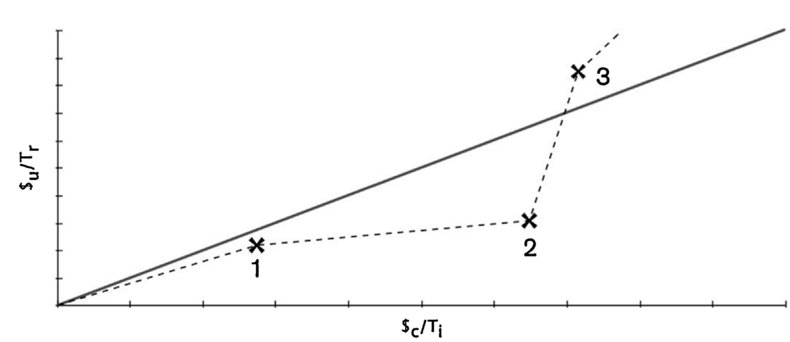


**Figure 3:** Cost-Value Limit for Rate Increases

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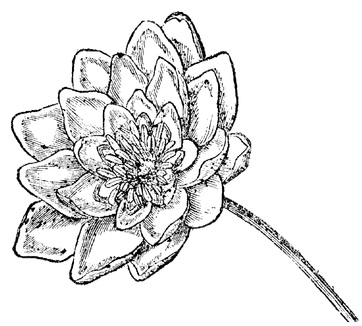
reduction; however, the proposed approach is based in customers damage functions that can developed to provide as much detail as required to make them binding. This proposal solves the issue of ''utilities incurring in to too much cost for too much local grid resilience'' (Mitnick, 2013). For the ratemaking process this will require a thorough analysis of the whole customer base and their economic activities, which in the past hindered its use. Yet, given modern data collection techniques widely used by utilities, the new trends of using very detailed models of the grid assets adopted in regulation practice for benchmarking, as in the case of U.K., Spain, and Norway suggests the application of damage functions can become feasible in practice.

The second and complementary approach proposed also uses customers' damage functions and aims to find the expected loss of value to customers given certain events. The proposal is similar to the one proposed by Momoh (1997), yet with a reformulation to adjust it for extreme events and grid resilience regulation.

The expected economic loss from a group of customers in an area affected by a prolonged interruption is given by:

$$E(e_{loss}) = \sum_{c} \pi_{ci} C_c(T_i)$$

where $\pi_{ci}$ is the probability of a certain customer or group of customers to have a long interruption of length $T_i$ and $C_c(T_i)$ is the damage function for that particular customer or group. In this way, if an investment performed by the utility can reduce $\pi_{ci}$, the total benefit for the customers can be evaluated. The shortcoming is the calculation of the probabilities for different events and how the investments can reduce those probabilities. As mentioned earlier the regulatory



policy regarding grid resilience must be focused on the preventing activities and not so much on the aftermath costs.

## VI. Grid Access to Shape Future Reliability Requirements

Economic value is primarily created through electricity consumption and the focus of this discussion has been on how customers may lose value if service is interrupted. However, given emergent technological changes such as inclusion of distributed energy sources, electric vehicles with the potential for bi-directional flow of power (as a load as well as a power source at peak times), and the ubiquitous availability of next-generation ICT solutions through data mining and data analytics, the value to be delivered to society as a whole will set the direction for the distribution grid to become more than a delivery medium, solely, of electric energy from bulk power station to consumers.

These changes basically force the industry to review the role of customers form passive consumers to active agents, bringing with them new costs and more value from the service provided by the grid. At the present time there is no consensus on how to address new costs for the network due to the presence of these new technologies, particularly because there is no precedent, and there is even less discussion on how to calculate this new value that customers may obtain from the grid.

As technological developments redefine customers' expectations of grid services in light of electrification of transport, distributed generation, and a smarter grid enabled through sensors and smart appliances, the discussion to seek a better definition of grid resilience is timely and developing better ways to incorporate it into ratemaking is necessary. As technology progresses and communication technologies get more and more embedded into everyday life, the societal value of continuous electric power

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increases. It is in this spirit that we need to acknowledge that the time may well be upon us to turn the page on ''cost-of-service'' regulation and modernize the regulatory framework to better reflect the ''value proposition'' inherent in electricity service.

## VII. Conclusion

Two issues are intermingled in a single debate as it relates to the provision of electricity service and the regulatory compact for investments in the grid: the primacy of cost versus the value to customers. The requirements of quality of service (QoS) standards for regulation and the need for an explicit consideration of investments for grid resilience as a new requirement must be reconciled within the ratemaking process. Regulatory bodies around the world have addressed these issues with varying emphasis and different mechanisms with different results. In the case of the U.S., historical precedent suggests limited application of QoS as the basis for regulation, thereby, reducing the potential value customers can derive from electricity.

Given that all customers will, ultimately, bear the direct costs of grid reinforcement, the investments identified specifically for the purposes of enhancing resiliency should be evaluated against the economic losses. We have proposed the need for a detailed and a comprehensive assessment of customer damage functions to allow us to close the yawning gap between the value of electricity service and the cost of electricity service. This will impose a requirement on the regulators and the industry to develop models in order to assess ex ante the costs of long-term interruptions.

As the value that customers derive from the distribution grid service increases, new expectations will shape the debate and it will become increasingly important to shine a searchlight on the value chain of electricity as it changes with the emergence of new technologies.■

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