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The authors previously presented the paper "An Appraisal of the Death Spiral Hypothesis" before the Midwest Economics Association in March 1987. This article is an adaptation of that paper, shifting the context to today's electric industry, which has undergone radical changes since 1987. This article also expands on some of the topics discussed in the earlier paper. The authors find it somewhat amazing that the "death spiral," after over 25 years, has once again become part of the policy discourse on the electric industry.

Electric Utilities' 'Death Spiral': Hyperbole or Reality?

The context may have changed, but the notion of a death spiral refuses to die: these authors wrote about it 27 years ago. However, the current Cassandras may be overstating the severity of the problem and underestimating the policy options open to utilities and regulators to reverse a temporary unstable situation. Their predictions seem rigidly grounded on tacit assumptions that utilities are inert in responding to a more competitive environment. It is more likely utilities will work with their regulators to avoid serious financial problems while promoting efficient competition that serves the public interest.

Kenneth W. Costello and Ross C. Hemphill

The death spiral occurs when an electric utility finds a price increase to be futile in raising sufficient revenues to cover its total costs. It starts with the utility having to raise prices. Lower sales follow. Hence, fewer units of electricity recover the utility's fixed costs and a further price increase becomes necessary. This higher price results in even

greater sales declines, which requires yet another price increase. As the utility attempts to recover its fixed costs through higher prices, it actually makes less profit. A death spiral sets in. According to this definition, a death spiral refers to an upward movement along the demand curve.

Historically, the death spiral related to price increases resulting

from radically higher utility costs. Back in the 1980s, for example, the term “death spiral” was part of the lexicon over the growing public discontent over the sharp rise in electricity prices from large utility construction programs. The concern was whether the sharp rise in prices would cause electric utilities to suffer enduring financial distress. The death spiral in the present context refers to retail customers migrating from full-requirements utility service to the combination of self-generation and partial-requirements service.¹

Those observers who advanced this scenario have argued that high rate increases will lead to severe sales repression jeopardizing a utility’s long-term financial stability. Some of these proponents were conservationists like Amory Lovins who claimed that new power plants were uneconomical and unaffordable to utility customers.² Their prognosis was that “overbuilding” of generation capacity spell inevitable doom for the electric industry from a “self-perpetuating” growth of excess capacity and rates.

Moving ahead 30 years to the present, we once again see common reference to the “death spiral.” This time the context is the entry of new distributed generation (DG), like rooftop solar PV systems, eroding utilities’ retail sales increasingly over time. Specifically, the story goes something like this:

Once losing sales to DG, utilities will try to recover lost revenues by increasing their rates to a fewer number of customers. This attempt to regain lost profits will aggravate the problem of yet more customers leaving the utility system for DG.

Just like back in the 1980s, one scenario is that a death spiral will inevitably set in that will make it futile for utilities to avert financial disaster danger by increasing their prices. The death spiral, in

Back in the 1980s, the term ‘death spiral’ was part of the lexicon over the growing public discontent over the sharp rise in electricity prices from large utility construction programs.

other words, represents an unstable dynamic process that dims the prospects for financially viable utilities. Utilities will be unable to recover their costs and earn a normal rate of return.³

Reference to the death spiral has come from different quarters. Electric utilities have referred to it, implicitly if not explicitly, as a conceivable scenario if current ratemaking practices continue. Others have warned that a death spiral could afflict those utilities that try to fight DG rather than accommodate it as an inevitable force. One commentator even

remarked that the death spiral can spread faster than a “zombie plague.”

Wall Street’s perspective is that, while DG and other technologies have the potential to erode utilities’ profits, as of now the problem has not become serious. The following remarks typify this position:

It is easy to imagine a scenario where a mass-market adoption of a disruptive technology can destroy the traditional utility business model. As solar-power installation costs continue to fall, more residential customers will be incentivized to install solar technology. Combined with storage, energy efficiency and conservation efforts, we can see why some customers might opt to drop off the grid – assuming it can be done safely and with a cost-effective alternative. But this scenario goes way beyond just rooftop solar installations, so although we see the threat as possible, we do not view it as probable, at least not now. . . Still, distributed generation can impose significant cost shifts on non-adopters and in an extreme scenario threaten the utility industry’s profitability and undermine its business model.⁴

With hindsight, past death-spiral claims for the electricity industry turned out to be exaggerated. Although utilities did endure difficult financial times, both utilities and their regulators responded to the then-changing environment by taking actions, sometimes fundamental in nature, to avoid a long-term financially unsustainable situation. Today, the relevant questions are:

1. Is the current concern also exaggerated?
2. What conditions are necessary for a death spiral?
3. How likely are they to occur?
4. How can both utilities and regulators avert a death spiral?
5. Why should regulators want to avert a death spiral for utilities?
6. Can averting a death spiral have a downside?

This article will attempt to address these questions. It will first discuss the “death spiral” as a market phenomenon that often afflicts those industries that have endured disruptive technologies dramatically changing the market landscape.

I. The ‘Death Spiral’ as a Market Phenomenon

Some firms in industries facing what analysts call “disruptive technologies” confront the possibility of financial disaster. By definition, disruptive technologies make alternative products and services more affordable to a broader population. They have a direct effect on how businesses operate and their internal organization. Typically, they require firms to give up their old business practices and revamp themselves to better compete and survive.

Firms also face serious challenges when they try to raise prices in the face of growing competition. In the confines of this article, a death spiral relates to an existential crisis whereby a firm has limited ability to raise its

prices to sustain financial viability in response to adverse events. In a competitive environment, by definition, individual firms have no control over the price and will experience financial disaster if they tried to raise their price above the market price. In non-competitive industries, firms can exercise some control over the price they receive, but even then they can encounter lower profits when they price their product or

Some firms in industries facing what analysts call ‘disruptive technologies’ confront the possibility of financial disaster.

service too high.⁵ These firms face a downward-sloping demand curve in which consumers will buy less at higher prices.

Examples of firms, other entities, and industries enduring disruptions or events that threaten their financial viability include Eastman Kodak, newspapers, small colleges, cable companies, privately operated urban transit (trolley cars and streetcars), companies making mainframe computers, the U.S. Postal Service, telecommunications companies, and natural gas in the 1980s.⁶ For example, small colleges face serious challenges because of: (1)

soaring student debt, (2) competition from online programs and (3) decreased college enrollment due to poor employment prospects. Some experts predict that many small colleges will likely fold in the next decade.

A second example is cable companies which expanded their service offerings and competed in other markets, rather than expending substantial resources to compete with the satellite companies in the old product market. They went from being television-only providers to providers of Internet and phone service, sold both individually and in bundles.⁷

As a third example, the demise of trolley cars and streetcars started with a dramatic demand drop because of increased popularity of autos and the migration of people from cities to suburbs. The decline of the urban transit industry since World War II may have some relevance to the electric industry. Evidence has shown that urban transit is an inferior good (i.e. when people have higher income, they consume less of the good). There was also a drastic effect from people moving out to the suburbs, making bus service inconvenient and costly in terms of time for many people working in the central city. Studies have suggested that the price elasticity for bus service is around -0.3 to -0.4 , so the efforts of bus and streetcar companies to increase fares so as

to generate additional revenue were not flawed. Actually, their demise was more the result of migration of people to the suburbs and the increased ability of people to afford cars because of rising income levels (i.e. the demand curve for urban transit shifted drastically to the left). The cumulative impact of repeated fare increases resulted in the failure of many privately owned urban transit companies in North America, necessitating municipal ownership.

The serious challenges of the U.S. Postal Service derive from different sources: Falling or stagnant revenues, large fixed costs, inflexible pricing, increasing costs, and a rigid business model.

History has identified three primary factors of why certain firms and other entities suffer financial disasters in a dynamic world. They are, inertia and complacency, poor management strategies, and unstoppable market trends (e.g. inexorably falling demand for a firm's product or service). Sometimes a firm, for example, encounters a sudden collapse in demand for the product or service it has been providing for years (i.e. a structural demand crisis). Other times firms err by staying the course when events dictated that they revamp their business model. A business model concerns how a firm (1) creates value for its customers through its operations, products

and services and (2) generates sustainable operating and financial performance.

At the other end of the spectrum, firms and other entities that successfully confront a death-spiral threat exploit new technologies, change their management practices, and eliminate or modify old practices. A firm may not necessarily have to embrace new technologies; it can instead improve its

The term 'death spiral' did not appear in the lexicon of electric utilities and regulation until the 1980s.

performance adapting old technologies to a more competitive environment.

As discussed later, death-spiral threats are more prevalent in a competitive environment, for an entity with high fixed costs, and in the absence of regulatory and other governmental protections (e.g. the erection of entry barriers for potential competitors). In these situations, it becomes more imperative for entities to be proactive rather than staying with old practices and strategies and hoping that things will return to what they were.

II. Past Difficulties for Electric Utilities

The term "death spiral" did not appear in the lexicon of electric utilities and regulation until the 1980s. As early as the late 1960s, however, concerns over rising costs and their effect on electricity rates, customers and utility finances started to appear:

The inflation and rising nominal interest rates in the late 1960's and early 1970's wreaked havoc on this [regulatory] process that appeared to function so smoothly before. Firms [electric utilities] found that their nominal production costs were rising rapidly, as were their debt costs. Real and nominal rates of return began to decline. Interest coverage plummeted and most major firms found that they had to raise prices (some for the first time in 25 years) and trigger formal regulatory reviews. State commissions that were "geared-up" to handle perhaps one or two major rate of return cases per year (many states handled one or two in five years) now found themselves faced with almost all the major companies in their jurisdictions requesting major price increases. Many state commissions had neither the staff nor administrative resources to deal with this tremendous increase in rate of return.⁸

The nuclear era and other events, starting in the late 1960s and lasting through the 1980s, placed much financial stress on electric utilities. In the 1970s and 1980s, regulators exhibited hesitancy toward meeting all the utilities' request

for large rate increases, especially for expensive new power plants.⁹ They scrutinized the likely consequence of large rate increases on customers, and utility sales and revenues. The term “sales repression” became a topic in rate cases, inferring that large rate increases could spiral utilities’ sales and profits in a downward direction. In some instances, utilities proposed an addition to their rate increase to compensate them for an elasticity effect (i.e. for lower sales from a higher rate that they requested).

The electric industry faced unprecedented challenges caused by a confluence of events during the 1970s and 1980s. It was a time of (1) frequent rate cases filed by utilities to maintain their financial stability, (2) increasing environmental demands, (3) active consumer advocacy, and (4) energy supply problems. One prominent economist described well the turmoil during this period:

It was the economic shocks starting in the early 1970s that led to economic and political turmoil and resulting pressures for change. These shocks included large increases in fossil fuel prices in 1974–75 and again in 1979–80 and new environmental constraints on air and water emissions from power plants that increased the costs of building and operating fossil-fired plants. Unexpectedly costly nuclear power plants and opposition to nuclear power based on economic, environmental, and safety concerns were also important, as were an increase in the general rate of inflation and high

interest rates. Finally unanticipated reductions in the rate of growth of demand (the annual compound rate of growth in electricity consumption dropped from 7.3 percent a year between 1960 and 1973 to 2.5 percent a year between 1973 and 1985) resulted in substantial excess generating capacity. These economic shocks fell heavily on the generation component of electricity supply, which accounted for 75 percent of operation and maintenance costs and 65 percent of capital costs in 1986.

Many industry observers viewed the combination of growing competition and industry restructuring in the 1990s as undermining the stability of electric utilities.

As a result, the pressures for regulatory and structural changes focused on generation.¹⁰

Without regulators adapting new ratemaking practices, electric utilities would have encountered more serious financial problems than they did.¹¹ One lesson learned from this period is that state utility commissions do consider the merits of new ratemaking mechanisms and rate designs in the face of changing market, economic, operating, technological, and other conditions. History has shown that commissions tend to undertake major reforms,

including ratemaking ones, only when continuation of the status quo would bring disastrous results that disrupt the political equilibrium. These results can include: (1) utilities losing customers to competitors and suffering serious financial problems and (2) the suppression of a social objective (e.g. advancing energy efficiency) to which a commission gives high priority.¹²

Moving ahead in time, many industry observers viewed the combination of growing competition and industry restructuring in the 1990s as undermining the stability of electric utilities. Both utilities and regulators prepared for a changed future. They considered new ratemaking paradigms that were more compatible with a mixed competitive-monopoly environment. Utilities repositioned themselves to improve their competitiveness. Some, for example, reduced their costs, restructured their operations, and petitioned their regulators for performance-based regulation that allowed them more pricing flexibility and opportunities for financial viability.¹³

In just the past two years, several utilities along with the Edison Electric Institute have expressed concern over the financial implications of DG in view of current ratemaking practices. They recommend new rate designs, a revisiting of net energy metering, and cost

recovery for standby and other utility services from DG customers. In short, utilities' worries are cost shifting, free riding, and grid integrity. Moody's expressed some of these concerns:

Utilities' concern about distributed generation centers on the cost-shifting problem caused by residential customers and, to a lesser extent, commercial customers, who choose to self generate. The cost-shifting problem is a problem in rate design. For industrial and large commercial customers, utilities recover their transmission and distribution mainly through a fixed charge, which roughly matches their transmission and distribution costs, which are also largely fixed. . . For residential and small commercial customers, utilities mainly recover their transmission and distribution costs, and public-service programs in California, through a volumetric charge (i.e., the charge varies with energy usage). With the advent of net energy metering, customers who self-generate can reduce their net energy usage, thereby reducing their volumetric charges and their contribution to the utilities' transmission and distribution costs. To remain revenue neutral as some customers self-generate, utilities would need to raise electric rates on all of their customers. Thus, the cost shifts from customers who self-generate to those who do not.¹⁴

Overall, the past concerns over a death spiral were exaggerated. Although few electric utilities faced bankruptcy scares, many did suffer short-term financial difficulties. Both

utilities and their regulators generally responded to these difficulties by undertaking actions that avoided more serious problems. Today, the relevant questions are: Is the current concern also exaggerated? What conditions are necessary for a death spiral? How likely are they to occur? This article will next address these questions.



III. Recent Events Conducive to a Death Spiral

Recent developments have imposed serious challenges on electric utilities. The contemporary discussion on the death spiral has focused on how disruptive technologies and other factors will affect the finances of electric utilities. A death-spiral outcome for the electric industry, at least on the surface, seems more than remote given the confluence of several events that tend to have a negative financial effect on utilities. The major ones include:

1. *Recent growth of DG and their continued improved prospects for increased market share in the electric retail market; unknown at this time is whether DG will become a disruptive technology with mass appeal or just a "boutique" technology.*¹⁵ In any event, DG increases competition behind the meter, eroding utilities' monopoly power;
2. *Permanent slowdown in demand growth (or secular and not cyclical drop in sales growth), because of stagnant or falling demand from full requirements customers and from customers whose primary electricity source is DG*¹⁶;
3. *Public policies providing subsidies and incentives for less electricity usage and non-utility generation, both tending to adversely affect utilities' finances;*
4. *Rising costs placing pressure on utilities to increase their rates;*
5. *Free riding by rooftop PV solar generation when they pay less than their fair share of utilities' fixed costs;*
6. *Increased customer demands for reliability and higher quality service; and*
7. *Higher ratio of fixed to variable costs that limits short-term cost savings from reduced sales.*

In sum, electric utilities face difficult times ahead to maintain their financial viability. The future calls for stagnant-to-declining revenues and increasing expenses, conditions conducive to daunting challenges and a less-than-optimistic outlook for electric utilities.

IV. A Narrative of How Utilities Can Fall Off the Cliff

A. The dynamics of instability

The sequence of events that could lead to a death spiral goes something like the following: Subsidies and falling technology costs are making distributed solar power cost-competitive with retail electricity prices in places like the Southwest.¹⁷ Utilities sell less electricity to customers that switch to solar; in the vast majority of states customers also have the right to sell surplus power from their solar systems back to the utility at what many observers consider inflated prices. The result is that utilities must spread their high fixed costs over fewer kilowatt-hours, making solar power even more competitive¹⁸ and pushing more utility customers to install solar systems, creating an inevitable spiral.¹⁹ At some level of demand, customers are willing to pay less for electricity than the average cost of the utility. As the utility increases its rates to recover its fixed costs, in other words, electricity demand will fall enough to lower profits. Eventually, a rate set at average cost will cause demand to fall precipitously; a utility will be unable to recover its revenue requirement (i.e. the utility earns less than a normal profit). A self-perpetuating cycle of doom or

“mortal threat” eventually befalls the utility.²⁰ As formally presented later, a death spiral exhibits an unstable condition in which attempts by the utility to recalculate the price schedule to recover fixed costs as usage declines result in higher and higher rates and, ultimately, a collapse of demand.



As one Wall Street analyst has remarked:

Lost revenues from DER [distributed electricity resources] are being recovered from non-DER customers in order to encourage distributed generation implementation. This type of lost revenue recovery drives up the prices of those non-participating customers and creates the environment for ongoing loss of additional customers as the system cost is transferred to a smaller and smaller base of remaining customers.²¹

The starting point for a death spiral is either a sales drop or rapid cost increase, or both occurring together. These events can originate from the increased

economic attractiveness of new technologies, high inflation, a depressed economy, or other major shocks to the electric power market.

When customers no longer are willing to pay the utility a sufficiently high price to cover the utility's average costs, the zero profit “natural monopoly” equilibrium becomes unstable. Stability occurs when the tendency is to move back toward equilibrium or where the market will settle when an external event (e.g. discovery of a new way to save electricity) moves the market from equilibrium. As shown later, the sufficient condition for a death spiral is that when the utility increases its rates, the elasticity effect causes revenues to fall by more than the costs.²² Thus, the demand elasticity facing the utility must exceed 1 but that, by itself, is not a sufficient condition for a death spiral. Other than customer response to a rate increase, rate design is a crucial factor, as shown later.

In examining a death spiral possibility, the relevant question is: When a utility tries to increase its rates, what is the effect on the quantity demand (or upward movement on a single demand curve) and the utility's earning? Under a death spiral scenario, the utility would end up with lower revenues and earnings.

B. An existential threat

As the spiral evolves, the utility finds it increasingly difficult to increase its rates to cover its costs and, eventually, it faces an existential threat.²³ The combination of a high price elasticity of demand for utility electricity, a high ratio of fixed to variable costs, and a volumetric-oriented rate schedule makes it more conceivable that the utility is unable to raise rates sufficiently to meet its revenue requirements.²⁴ The dynamics outcome is an unsustainable path²⁵ in which the utility inevitably falls short of recovering its costs when it attempts to raise prices. Demand inexorably drops, as the utility's effective price is continuously higher than what customers are willing to pay at a given quantity of demand; that is, the utility's effective price never equates with customers' willingness to pay, which is the equilibrium condition under normal circumstances.²⁶ In fact under a death spiral scenario, the market is unstable as it departs further from the equilibrium condition.²⁷

Under a death spiral, the utility's financial condition worsens over time. There is no escape once it begins: It is unavoidable or inevitable unless the utility is able to halt the "spiral." To say it differently, the utility faces an unstable condition where the entry of competing providers, for example, precludes the utility from earning normal profits

under average-cost pricing. The end result is financial collapse for the utility.

C. The importance of rate design

Certain rate designs aggravate financial risk on utilities when sales decline. Most electric utilities recover a large portion of their



fixed costs in the volumetric charge. When sales decline, this rate design causes utilities to (1) recover less of their fixed costs, even those previously approved by regulators as prudent and (2) lose more revenues than what they save in costs.²⁸

Assume that the following expression represents the breakdown of a customer's bill by fixed and variable costs; it typifies the standard two-part tariff for base rates²⁹ set by electric utilities:

$$TB = \alpha F + Q \left[(1 - \alpha)F/Q_{ty} + v \right]$$

where TB equals the total bill, F is the utility's fixed costs allocated to the customer, Q is actual sales, Q_{ty}

is test year sales, " v " is variable cost per kWh, and " α " is the share of the utility's fixed costs recovered in the fixed charge (e.g. monthly customer charge or service charge). The second term on the right-hand side of the equation represents the volumetric charge, or the unit charge based on variable cost plus the share of fixed costs not recovered in fixed charge.³⁰

With a higher share of fixed costs recovered in the volumetric charge (i.e. a lower α), the utility's earnings fluctuate more for a given increase or decrease in sales. The utility has a stronger incentive to increase sales – for example, to grow sales beyond the level in the test year underlying current rates. On the other side, the utility suffers a higher earnings loss per unit decline in sales. For example, $\partial TB / \partial Q = (1 - \alpha)F / Q_{ty} + v$ and setting total cost as $TC = F + vQ$, $\partial TC / \partial Q = v$. Thus, for each unit decline in sales, earnings (E) would drop by $\partial TB / \partial Q - \partial TC / \partial Q = (1 - \alpha)F / Q_{ty}$.

Illustrating with a numerical example, assume that in the last rate case, the test-year number of residential customers was 200,000 and the test-year average monthly sales per customer were 600 kWh (or 7,200 kWh per year). Assume also that the utility's test-year fixed cost was \$60 million and the variable cost was \$72 million.³¹ The average price established would then equal the average cost, or 9.167 cents per kWh.³² Assume that the rate

design reflects the intent by regulators for the utility to recover 60 percent of its fixed costs in the volumetric charge and the 40-percent remainder in the monthly customer charge.³³

The average residential customer, therefore, has a monthly customer charge of \$10 and an average monthly bill of \$55.³⁴ Assume now that the customer reduces her usage by 10 percent because of energy efficiency³⁵; this translates into a bill saving of \$4.50 for the customer and a revenue loss to the utility of the same amount. The cost savings to the utility is \$3, leaving the utility with an earnings loss of \$1.50. Instead, now assume that the customer bypassed the utility by becoming fully dependent on a solar PV system for her electricity needs. In this scenario, the utility loses \$55 in revenues and reduces its costs by \$30, raising the earnings loss to \$25. We can readily see that the financial effect on the utility of a customer leaving the system is much more severe than if the customer simply cut backs

her electricity usage because of a price-elasticity effect.

This example reflects the fact that DG or other nonutility sources of supply would more likely have a death spiral effect than utility customers simply cutting back on electricity usage because of higher prices, a slow-down in the economy, energy efficiency, or other reasons. In those instances, customers would remain on the utility system as full-requirements customers, with the utility recovering at least a portion of its fixed costs from them. Another observation is that a death spiral is more likely when the utility recovers more of its fixed costs in the volumetric charge.³⁶ As a side note, decoupling is often proposed as a solution for this problem as it theoretically recompenses the utility for the loss of sales (either from DG, energy efficiency, or other means to reduce consumption from the grid). Yet, decoupling can exacerbate the problem we discuss here if not designed correctly.

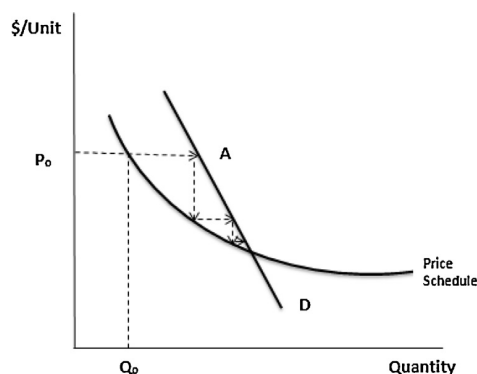


Figure 1: Stable Market

V. An Economic Analysis of the Problem: How Realistic Are the Conditions?

A. The demand curve facing the utility

The analyst must view the necessary conditions for a death spiral from a price increase on a utility-by-utility basis. The most important factor is the demand curve facing the utility.

Assuming the utility is the only provider of retail electricity, the demand curve facing it is the market demand curve. Otherwise, the pertinent demand curve relates to three factors. Specifically, we can express the residual demand elasticity for the dominant firm (e_d) as

$$e_d = \frac{e_m}{MS_d} - \frac{(1 - MS_d)e_s}{MS_d},$$

where e_m is the market demand price elasticity, MS_d is the market share of the dominant firm (e.g. the utility), and e_s is the price elasticity of fringe supply (e.g. DG providers).³⁷

When the utility has a pure monopoly ($MS_d = 1$), the demand curve it faces is the same as the market demand curve. With the increased competitiveness of DG, the utility has a lower market share. Improvements in DG technologies also reflect a higher price elasticity of supply of fringe supply. As DG and energy efficiency become better substitutes for utility electricity, the demand curve facing utilities

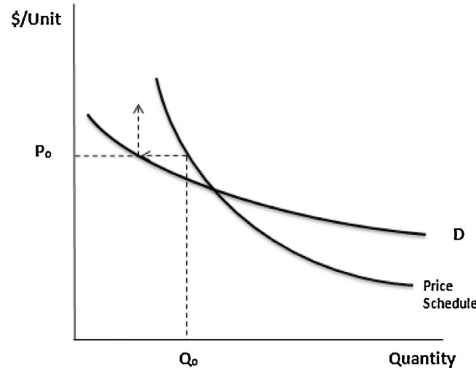


Figure 2: Unstable Market

becomes more elastic, which translates into less market power for the utility.³⁸ An additional point is that even if market demand is relatively inelastic, an elastic supply by the fringe can substantially increase the elasticity of the dominant firm residual demand, i.e. fringe supply can discipline a dominant firm's pricing.³⁹

Illustrating the measurement of the residual price-demand elasticity, assume the utility dominates the local retail for electricity with a competitive fringe composed of DG providers. The dominant firm typically has a high market share, with the price-taking firms (fringe firms) each having a very small share of the market, although collectively they may have a substantial share of the market. Specifically, assume that electricity has a market demand elasticity of -0.6 and that the price elasticity of fringe supply is three, and that the dominant firm has a market share of 80 percent. The residual demand elasticity for the utility is then -1.5 .⁴⁰

B. Formalized conditions for a death spiral

Our discussion begins with defining the three functions that interact to cause a death spiral effect: Demand, cost, and the regulated rate schedule. We assume that the demand curve reflects a well-behaved downward sloping demand curve between price and quantity with a price elasticity greater than one. With an elastic demand, any price increase will lower the total revenue recovered by the utility.

We assume total cost equals

$$TC = \sum k_i Q_i + F$$

where $k_i Q_i$ is the variable costs of service class i , and F represents the total fixed costs for the utility. The fraction f_i denotes the portion of fixed cost allocated to service class i ; thus, $f_i F$ is the total fixed costs allocated to class i , and the summation of f_i across all i equals 1.

Typically, as discussed earlier, electric rates include a fixed and variable portion (commonly referred to as a two-part tariff) such that the following equation

represents the total bill for class i :

$$TB_i = a_i + b_i Q_i$$

where TB is the total bill paid by customers, " a " is the fixed charge, " b " equals the variable charge so that bQ is the total variable portion of the bill.⁴¹

Note that changes in usage cause total revenue from class i to fall by the amount of b_i times Q_i . We assume here a non-bypass situation (e.g. a full-requirements customer using less electricity).

Average price for service class i is

$$P_i = \frac{TB_i}{Q_i} = \frac{a_i + b_i Q_i}{Q_i} = \left(\frac{a_i}{Q_i} \right) + b_i.$$

Henderson (1986)⁴² provides a detailed analysis that reflects the regulators' behavior in response to the death spiral effect. Figure 1 shows his graphical depiction of the demand and price schedules⁴³ for an electric utility during stable market conditions. On this graph, the horizontal axis represents the quantity demand and vertical axis shows the average price. A demand curve that is steeper than the average price curve signifies a stable market.⁴⁴ To understand this, suppose that the market is out of equilibrium, with the regulated price at P_0 and the sales volume at Q_0 . At this price, demand is at point A and sales will increase. At the subsequent rate determination, the regulator will adjust the price downward. As shown, the dynamics will ultimately reach a stable equilibrium. As Figure 1 illustrates, stability means that any price

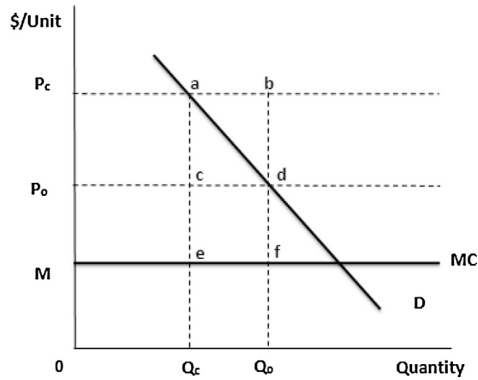


Figure 3: Average Price Above Marginal Cost

change will move the market toward where demand equals average cost (i.e. average revenue equals average cost).⁴⁵ The utility would, therefore, have the ability to change its prices so as to earn a normal profit. This goal is an integral part of ratemaking, i.e. the utility has an opportunity to earn normal profits once new rates are set. In the short run, a utility typically will earn above or below normal profits because of the deviation of costs and revenues from the test-year calculations.

Alternatively, if demand is less steep than the price schedule, a condition such as depicted in **Figure 2** develops. Here the dynamics of recalculating the price schedule to recover the fixed costs as sales decline results in higher and higher rates and, ultimately, a collapse of demand. Henderson refers to this scenario as the unstable market where a death spiral outcome can evolve under certain conditions. Unstable market conditions arise from the process of recalculating prices to recover the same amount of fixed costs. This

process causes even higher rates and an eventual collapse of demand. The presumption is that at a given level of demand, customers are willing to pay less than the average cost of the utility. Thus, as the utility tries to increase its rates to recover the fixed costs, the quantity of electricity demand will fall enough to lower profits. Eventually a price set at average cost will cause demand to drop toward zero. A utility will be unable to recover its revenue requirement.

Henderson mathematically presents his analysis using a restatement of the average price function, namely:

$$P_i = b_i + \frac{f_i F}{Q_i}$$

where $f_i F / Q_i$ represents the average fixed rate to class i . Specifically, $f_i F / Q_i$ represents the fraction (f) of fixed cost (F) allocated to customer class i 's price schedule, on a kWh basis. (This is identical to the a_i / Q_i component of the average price provided above.) The slope of the average price schedule is dP_i / dQ_i , which

equals $(f_i F / Q_i^2)$ and its price elasticity is $(P_i - b_i) / P_i$. With the condition that $MC_i = MR_i$ is the unregulated monopoly's optimal level of output, Henderson's analysis finds that a stable demand-rate schedule relationship exists if

$$\frac{P_i - b_i}{P_i} = -\left(\frac{1}{e_i}\right),$$

which says that the regulated market is stable if and only if the price that results from the constant fixed cost allocation is less than the unregulated monopoly level; e_i is the price elasticity of electricity demand for class i . We can restate the above condition as

$$\frac{f_i F}{P_i Q_i} > -\frac{1}{e_i}.$$

Thus, a death spiral occurs when the proportion of average price recovered through a fixed charge is greater than the inverse of the price elasticity.⁴⁶ Since we can show that under monopoly pricing the above relationship is an equality, the conclusion reached is that the electric utility, with a constant allocation of fixed costs, is stable if and only if the price that results from such an allocation is less than the unregulated monopoly level.⁴⁷ Setting a price for a service at or above the unregulated monopolist level results in undue price discrimination in that the utility is selling at least one other service below cost.⁴⁸ Within the "death spiral" price range, higher prices lead to lower profits since at such a price demand is sufficiently elastic that

further price increases result in revenue reductions larger than the cost savings. A price within this range jeopardizes the financial solvency of the utility; thus, the utility along with its regulator will want to avoid prices within this unstable range. By lowering price from this range, the economic welfare of all customers will improve. Hence, this outcome represents a Pareto improvement that the regulator will presumably want to achieve: All rates will potentially decrease and the utility receives higher profits.⁴⁹

Looking at the potential revenue and profit implications of the death-spiral phenomenon from a different perspective, we independently arrive at the same outcome that Henderson did. First, we define the death spiral as a condition for which a utility's profits decrease with a higher price⁵⁰; that is, revenues decrease by more than the cost savings from lower sales. This outcome can occur when the original price charged by the utility (P_o) is above marginal cost, as shown in Figure 3. We see that increasing price from P_o to P_c reduces the utility's revenue by area $OP_o dQ_o$ minus area $OP_c dQ_c$, which is area $P_o P_c ac$ minus area $Q_c c dQ_o$.

The avoided cost of decreasing sales from Q_o to Q_c equals area $Q_c efQ_o$. The lost revenue may exceed the cost savings, which would require the utility, in some way, to increase its revenues to recover the same fixed costs.

Specifically, the condition for a death spiral is the following:

$$e > \frac{P_i}{P_i - MC_i}$$

The remainder of this article will use this specification of the death spiral condition. It is identical to Henderson's findings of $f_i F/P_i Q_i > -1/e_i$.⁵¹ As an illustration, when P_i is 12 cents



per kWh and MC_i equals 8 cents per kWh, the price elasticity for service class i must exceed 3 (in absolute terms) for a death spiral to occur; when MC is as low as one-half of average price, the price elasticity would have to be at least 2.⁵²

To summarize our discussion up to now, the necessary and sufficient conditions for a death spiral are (1) the price elasticity of electricity demand facing a utility must exceed 1 and (2) the absolute value of the elasticity (e) must exceed the ratio of average price to the fixed component of average price $[P_i/(P_i - MC_i)]$.

The above analyses treat the death spiral (demand curtailment) using average price, i.e. $(a + bQ)/Q$, which implicitly assumes that demand curtailment requires leaving (or bypassing) the utility system. If the customer reduces usage without bypassing the system (which historically for electric utilities accounted for a high share of the elasticity effect), the fixed portion of the rate does not constitute lost revenue. The change in revenue in these instances is the variable portion of the bill (bQ). Therefore, if a customer reduces consumption by $Q_o - Q_1$, the revenue reduction is $b(Q_o - Q_1)$, not $P_1(Q_o - Q_1)$. Hence, under the situation of non-bypass customers, the necessary but (but not sufficient) condition for potential death-spiral effects is that $b > MC$. This is to say that, to avert a death spiral, the usage or volumetric charge should closely approximate the marginal cost of service.⁵³

One can view these characteristics of the utility and its service area as determinants of the above-stated necessary and sufficient conditions. For example, a small utility with a large construction project could be a prime candidate for a death spiral. One can imagine how such a situation can lead to a high proportion of the revenue requirement composed of fixed costs. Hence, once usage declines the increase in price necessary to make the utility financially solvent is greater than otherwise. Other utility-specific

characteristics conducive to an unstable market include relatively high usage by a one or more customers, readily available bypass technologies or demand substitutes, weak local economies, and rate disparities with nearby utilities. Such conditions can lead to a high proportion of the load from swing industries, inferring high elasticities and a high potential drop-off rate.

C. Likelihood of conditions

Summarizing the last section, the following five conditions for a death spiral must hold:

1. **The price elasticity facing a utility must be greater than unity.** This elasticity increases as the utility loses market share and DG and other nonutility source of electricity become more economic attractive and competitive.⁵⁴

2. **The price elasticity facing a utility must exceed the ratio $[P_i/(P_i - MC)]$ where P_i is the average price of electricity and MC is marginal cost.**

3. **Competition has grown where the prospects for a sudden drop in demand can happen because of a disruptive technology, or an inexorably declining demand for utility electricity.** For example, the utility encounters a large number of full-requirements customers migrating to DG. Some doubt still exists over whether DG and other new technologies in the electric industry are truly

disruptive technologies or will assume a more modest role as "boutique" in nature. Nevertheless, the potential for large-scale migration can pose a serious problem for utilities.

4. **Utilities are unable because of regulators' disapproval, or for other reasons, to offset revenue losses from fewer**



full-requirements customers by providing additional services and exploiting the new technologies as a profit source.

5. **Utility management and regulators may face legal or political restrictions in adjusting rate schedules or acting in other ways to avert a spiral.** While regulators, historically, have protected utilities against severe financial problems, they might confront strong opposition from stakeholders and other entities. This opposition could occur when continuous price increases have reached an inflection point where further increases would trigger a public backlash.

VI. How to Avoid a Death Spiral

A. What can regulators and utilities do?

The condition implicit in the death spiral analyses that gives us the most pause is the inert behavior of utility management and the regulator. This presumption of unchanging actions is evident throughout each phase of the spiral effect, which assumes that utilities facing financial distress will not attempt to (1) cut their costs (reflected in a downward shift in the MC and AC curves), (2) shift more of the fixed costs to the most price inelastic customers, (3) phase in large cost increases over time, (4) respond in ratemaking and other ways to the increased penetration of DG and other competitive sources, or (5) use any other creative means of diverting the spiral from its otherwise inevitable course. In other words, the death spiral analyses assume no adjustment on the part of the utility or regulator to disrupt the destructive path. The most obvious course of action would be to change rate design. Regulators can help to head off any serious problems by affecting the $f_i F$ portion of the price schedule. Changes to the allocation of fixed costs to each customer class may alleviate the problem before it ever starts. The only situation where adjustments to the f_i allocation will fail to dampen the effect is in the unique situation

of a monopsonistic or oligopsonistic service territory.

Henderson⁵⁵ concluded that it is inconceivable that prices set by regulators for specific customer classes will be above unregulated monopolist levels; therefore, the chances of a death spiral are remote. He also showed that the instability of regulated markets is less likely because of the limits of three-degree price discrimination: Regulatory commissions have disincentives to set a price that is unduly discriminatory and that would lead to unstable conditions.⁵⁶

We expect a utility in financial distress, if not recognized by the regulator, to respond in one or more of the following ways: (1) price-discriminate in favor of those customers who are most price-elastic, (2) redesign rates and cost recovery mechanisms so as to lower the risk of financial insolvency, and (3) seek government/regulatory protection, if it can, to avert a serious financial problem. In short, we view the theory and the real world as offering both utilities and regulators a package of options to avert a death spiral.

Overall, we see the discussion on the death spiral to be useful for identifying options available to regulators in order to avoid the dire financial conditions that can lead to a utility's demise. Those who profess that the electric utility sector is in danger of a death spiral may, however, be overstating the severity of the problem and underestimating the policy

options open to utilities and regulators to reverse a temporary unstable situation. Looking back, when the electric industry underwent radical changes in the 1990s, many observers predicted that utilities would not fare well in the new competitive environment. But they were wrong: Most utilities evolved and adapted well to the new marketplace, with



some utilities actually improving their financial condition.

While the threat of a death spiral is real, especially as fringe suppliers encroach on a utility's service area, utilities together with their regulators can avert it with appropriate actions. In the short term, regulators can make sure that customers who turn to DG pay their fair share of the costs incurred by a utility to provide them with required grid and standby service. Regulators should revisit ratemaking practices to assess whether they meet their objectives in a new market environment. In the longer term, regulators should contemplate whether the current utility

business model allows utilities to remain financially sustainable. For example, changed conditions may require a different business model⁵⁷; namely, utilities would have more liberty to exploit the benefits for themselves from the improved economics of DG and other technologies that would otherwise threaten their long-term financial viability and existence.

B. Specific regulatory options

Regulatory protection of utilities during an onslaught of competition is a double-edge sword. Regulators will be as intent to avoid financial disaster for a utility as they have in the past.⁵⁸ Most regulators view a financially distressed utility as not serving the general public. Utility financial burdens can translate into long-term harm to customers: If a utility expects not to recover its full costs for an investment, it will tend not to voluntarily offer to make the investment.⁵⁹

On the other hand, regulators may decide not to protect utilities for political or "public interest" reasons. The public may view traditional regulatory solutions to insulate utilities from competition as exemplifying a one-sided approach that harms the long-term interests of customers and society at large. Some analysts would even argue such an approach increases the utilities' risk whereas a more proactive strategy would improve the

position of utilities by replacing risk with opportunities to benefit from change.⁶⁰

A primary concern of state utility commissions is to keep utility prices from increasing radically⁶¹; thus, regulators might impose limits on protecting utilities from competitive technologies that require large short-term rate increases to compensate them for transition costs and lost revenues.⁶²

Examples of what actions regulators can take including the following:

1. *Approve new ratemaking practices to mitigate financial challenges for utilities.* For example, they might strive to end cross-subsidies that motivate certain customers to uneconomically bypass the utility system,⁶³ although beneficial to those customers.⁶⁴ While ratemaking reforms by themselves may not fully head off all future financial problems, regulators should consider them a good place to start.⁶⁵

2. *Support for a new utility business model.* The new model can allow utilities, for example, to profit from offering distributed generation services or owning PV solar systems, while maintaining a competitive marketplace that precludes utilities from having an unfair advantage. A future business model for utilities should be both (a) responsive to new technological and market developments and (b) supportive of traditional regulatory objectives underlying just and

reasonable rates (e.g. cost-based rates, utility recovery of prudent costs, fairness across different customer groups).

3. *Determination of whether the problem is a bad business model or bad utility management.* The current business model might still be appropriate, but management itself might fail to adapt adequately to an increasingly



competitive and more challenging environment. Scrapping the current business model when not warranted can lead to unnecessary transitional costs.

4. *Avoidance of excessive costs imposed on utilities.* In coping with the challenges that electric utilities face, regulators can help protect utilities from uncalled-for costs. Regulators might want to also provide utilities with stronger incentives for cost efficiency and innovations. If utilities lack incentives for adopting new technologies, then they are less likely to fare well with DG and other behind-the meter competitors.

As a practical matter, regulators should distinguish incremental from radical actions. One option is for regulators to get the price right before pursuing longer-term initiatives.⁶⁶ These initiatives would require regulators to consider whether utilities should (1) offer new services, (2) change the role they play in the retail market, and (3) have more flexibility to compete. The big question regulators should ask is: *What is necessary to sustain a utility financially while not stifling competition and other developments that are likely to benefit consumers and society as a whole in the long term?*

C. Proactive utilities

If the new technologies are truly disruptive, utilities should take an aggressive stance. A purely defensive posture of protecting the current business model and profits may temporarily avert short-term financial distress but not long-term problems.⁶⁷ Utilities can adopt different pricing strategies. One strategy is what economists call “myopic pricing,” where the utility attempts to maximize short-term profits or minimize short-term losses but at the risk of suffering lower market share over time. Another strategy called “limit pricing” would involve the utility setting a price that is low enough to discourage fringe suppliers or new entrants. In the first strategy, the utility would tend to recoup its losses from customers departing to DG by

charging higher prices to full-requirements customers. The risk is that the higher prices will lead some of those customers to invest in DG. Limit pricing, while discouraging some customers to invest in DG in the short term, may produce large losses to the utility over an extended period. One way around the latter problem is for the utility to first identify those customers who are most inclined to invest in DG and then to offer them a special or discounted rate. Other customers could pick up the “revenue losses” from the discounted rates. Regulators may frown upon such discriminatory pricing.

One proactive action is for utilities to develop a path to a mutual gain for customers and its shareholders. The question they would ask is: “As opposed to fighting solar, how can we exploit new technologies to better serve both our customers and shareholders at the same time?” Some utilities have already invested in solar and energy efficiency to improve their earnings. Others are considering additional services to offer their customers. For utilities, new technologies can present either incremental possibilities or threats. Often, major new technologies result in more competitors and make existing business practices obsolete. By revamping their business model, utilities could embrace, accommodate or invest in new technologies, in addition to better serving their customers. One rationale for a

changed business model is that technological and economic dynamics have affected utility sales and revenues to the degree that the status quo inevitably will lead to an unsustainable financial outcome. Despite this serious challenge, utilities possess many relevant resources and capabilities placing them in an advantageous position to adapt and thrive in an increasingly competitive environment.⁶⁸

VII. Conclusion

Electric utilities face tough challenges in years ahead from a confluence of factors that can financially harm them. It is not just because of the threat of DG but also because of stagnant sales from full-requirements customers and escalating costs from new environmental mandates and other federal and state policy demands.⁶⁹ The objective of public policies has imposed intense pressures on electric utilities by both increasing costs and reducing sales. These events may require innovative actions by both utilities and regulators. One possible action is for regulators to allow utilities more flexibility and leeway in their operations and offering of services. The result is that utilities can better avoid a death spiral outcome from DG penetration and other developments that challenge utilities’ financial stability.

The current death spiral concerns differ fundamentally

from past ones by presenting a real threat to utilities’ retail monopoly status as a full-requirements service provider. Although a scenario of utility financial calamity is remote, it can occur under the right conditions, for example massive migration of customers to DG under current ratemaking practices. Industry observers exaggerated past death spiral threats and we believe the same hyperbole holds for the current threat. We believe that claims of an inevitable death spiral because of DG are, therefore, premature: Such predictions seem rigidly grounded on tacit assumptions that utilities are inert in responding to a more competitive environment. Instead, we expect utilities to work with their regulators to avoid serious financial problems while promoting efficient competition that serves the public interest. One option is for utilities to change their old practices and operate under a new business model. Some utilities have already taken this step and others will likely follow.

This paper supports regulatory policies that would avert a death-spiral outcome for utilities. After all, a financially struggling utility would find it difficult to fund new investments.⁷⁰ A death spiral outcome would hurt customers in the long term, since they will still rely on the utility grid as a platform for delivery and new services. One essential policy that would benefit utility customers as a whole would be to

fairly allocate utility past capital expenditures between full-requirements and DG customers.

Finally, this article warns regulators that overprotecting utilities from inevitable competition is not in the public interest. If material changes toward DG do evolve or are on the horizon, regulators should expect utilities to transition to a new environment in which nonutility generation behind the meter becomes an important element. In the interim, regulators should treat utilities fairly, but they also should demand that they move ahead in accommodating those developments that best benefit their customers in the long term.■

Endnotes:

1. The presumption is even if a customer invests in distributed generation he will still need standby service from the utility.

2. Lovins argues that:

The long-run own-price elasticity of demand for electricity is extremely large; so large that higher prices will probably reduce utility revenues. A utility which raises its rates will probably lose more on the number of kilowatt-hours it sells than it makes up by charging more than kilowatt-hour. If so, new construction will require more revenue but yield less – recipe for bankruptcy. Long-run revenue can be increased only by lower price, not by higher price.

[Lovins, A.B., 1985. Saving gigabucks with megawatts. Public Utilities Fortnightly, Mar. 21, 21.]

3. Carlson and Thomas remark that:

A death spiral occurs when a utility cannot fully recover its costs from its customers. At a level of

price increase necessary to cover increased costs, customers reduce purchases enough to reduce revenues below costs. At some point, price increases can produce revenue decreases. If costs are largely fixed, further price increases simply mean more losses and thus the death spiral.

[Carlson, R.C., Thomas, T.C. The Death Spiral: Implications for Regulators. QED Research, Palo Alto, CA, mimeo 1.]

4. Moody's Investors Service, 2013. Rooftop solar, distributed generation not expected to pose threat to utilities. Special Comment, Nov. 8, 2.

5. The optimal output for these firms is where marginal revenue equals marginal cost.

6. Tussing discusses the possibility of a death-spiral condition in the natural gas sector:

Gas producers, pipelines, and distribution companies could try to impose higher prices on consumers, according to the terms of their 'lawful' contracts, tariffs, and rates. But try as the companies might, consumers would not yield any more revenue. In mid-1983, the desperate attempts by each sector of the industry to recover rising costs and also to obtain its allowed return in investment was threatening to plunge them all into a death spiral – the self-perpetuating collapse in demand.

[Tussing, A.R., 1984. The Natural Gas Industry: Evolution, Structure, and Economics. Ballinger, Cambridge, MA, p. 230.]

7. One example is Comcast's Triple Play service.

8. Joskow, P.L., 1974. Inflation and environmental concern: structural changes in the process of public utility regulation. J. Law Econ. 17, 291–327. Joskow discusses how the combination of inflation, oil price shocks, and stricter environmental standards caused steep increases in electricity generating costs in the late 1960s and early 1970s. Utilities could

not incorporate these cost increases (to a large extent beyond the control of utilities) into rates fast enough to keep profits from falling. Eventually regulators allowed fuel adjustment clauses (and, to a lesser extent, future test years) to reduce regulatory lag and avert more serious financial difficulties.

9. One analyst observed that in covering continuous demand losses from previous rate increases, utilities would tend to return quicker and more often for yet another rate increase. He argued that electric utilities could find themselves in a difficult "downward spiral." Their situation becomes aggravated when customers react quickly and strongly to changes in the electric rate while utilities had to suffer financially from long lead-time power plants under construction. He suggested that the best way for utilities to improve their situation was to shorten the length of the construction delay and slow down demand growth to decelerate the need for new generating capacity. Utilities could achieve slower demand growth by promoting conservation programs. [Ford, A., 1997. System dynamics and the electric power industry. Syst. Dyn. Rev. 13 (Spring (1)), 57–85.] Lovins concurs with Ford by arguing that the higher price of electricity attributable to utility construction programs will dampen demand growth below what the utility forecasted. This outcome would necessitate greater rate increases just to cover the fixed costs of the new plants and to keep the utility financially solvent. [Lovins, *supra* note 2.]

10. Joskow, P., 1989. Regulatory failure, regulatory reform, and structural change in the electrical power industry. Brookings Papers on Economic Activity: Microeconomics, pp. 149–151.

11. Joskow, *supra* note 8.

12. See, for example, Joskow, *supra* note 8; McDermott, K., June 2012. Cost of Service Regulation in the Investor-Owned Electric Utility Industry: A History of Adaptation. Edison Electric Institute, Washington, DC; Costello,

K.W., Jones, D.N., 1995. Lessons learned in state electric utility regulation. In: Enholm, G.B., Malko, J.R. (Eds.), *Reinventing Electric Utility Regulation*. Public Utilities Report, Vienna, VA, pp. 69–92.

13. Costello and Jones, *supra* note 12, 75.

14. Moody's Investors Service, *supra* note 4, 2.

15. For example, the economics of rooftop solar varies by region and depends on a number of factors, including the price of utility electricity, the physical capability of a rooftop to handle a solar system, and local and state financial incentives.

16. Most experts now see the recent slowdown in electricity demand growth as a long-term phenomenon, rather than as cyclical.

17. A major factor for where solar gets cheapest and grows fastest in the U.S. is the maturity of *third-party* solar financing markets. Third-party financiers could include banks, solar leasing companies, or other entities that can help households and businesses pay less upfront costs for their investments in solar panels.

18. Analysts also expect PV solar and other DG technologies to fall in costs over time relative to conventional generation technologies.

19. The worry is that cost-shifting will grow rapidly, too. The vicious cycle commonly mentioned is that as rates rise because of cost-shifting, full-requirements customers have more incentive to install a solar system, which in turn causes rates to go up even higher. In an extreme hypothetical scenario, the utility would have few full-requirements customers to shoulder the utility's fixed costs.

20. To say differently, when customers buy a PV solar system, the utility sales drop and it earns less above marginal cost to cover ongoing fixed costs. To offset the lost revenue, the utility raises rates, which further improves the economics of PV solar.

21. Kind, P., January 2013. *Disruptive Challenges: Financial Implications and Strategic Responses to a Changing Retail Electric Business*. Prepared for the Edison Electric Institute, p. 17. Kind specifically says that a 10-percent decline in load, some of which might involve customers leaving the utility grid, could cause utility prices to rise by at least 20 percent (at 5).

22. As shown formally later in this article, a death spiral requires the revenue losses from reduced sales to be greater than the sum of the avoided costs and the revenue gains from charging a higher price for the electricity that consumers continue to purchase.

23. Increasing rates may boost revenues immediately or in the short term, but would risk depressing sales and revenue in the long run, in part by accelerating customer investments in DG and energy efficiency. Utilities can offset revenue losses by offering new products and services, if allowed by their regulators.

24. Some analysts refer to the death spiral as the "spiral of impossibility." This term conveys the frustration of a utility trying to raise prices sufficiently to meet its revenue requirements.

25. The perspective is from the long term. Often, a utility's revenues fall short of its revenue requirement between rate cases. If the gap is large and expected to hold in future years, the utility would likely file a general rate case.

26. In equilibrium, the utility covers its revenue requirements and earns a normal rate of return.

27. An unstable condition exists when the utility market fails to gravitate toward equilibrium where price equals average cost after an external shock. In a somewhat different sense, the unregulated monopolist faces an unstable situation since it makes pure profit that other firms would like to compete away. Despite the fact that a monopolist is the sole firm in the market, the threat of entry can diminish its ability to price above marginal cost.

28. That is, $\partial TR/\partial Q > \partial TC/\partial Q$, where the change in total revenue (∂TR) is greater than the decrease in costs (∂TC) for each unit decrease in sales (∂Q).

29. It excludes fuel and other costs recovered by a utility through a tracker or other rate mechanism outside of a general rate case.

30. The second component derives from the previous rate case in which the fixed costs not included in the fixed charge $[(1 - \alpha)F]$ divided by the test-year sales (Q_{ty}) become part of the volumetric charge.

31. The variable cost per kWh is (\$72 million/(200,000-7,200 kWh)) or 5 cents.

32. $(\$60 \text{ million} + \$72 \text{ million}) / 200,000 - 7,200 \text{ kWh}$.

33. This ratio assumes that the actual sales would equal the test-year sales. When, instead, actual sales lie below test year sales, for example, the utility is recovering more than 40 percent of its fixed costs in the monthly customer charge.

34. $[0.4(\$60 \text{ million}/200,000)] / 12 + 600[(0.6 \cdot \$60 \text{ million}) / (7,200 \text{ kWh} - 200,000) + \$0.05]$.

35. The assumption is that the customer would have consumed 600 kWh without energy efficiency and 540 kWh with it.

36. See, for example, Felder, F.A., Athawale, R., July 2014. The life and death of the utility death spiral. *Electr. J.* 27 (6), 9–16. A utility may mitigate sales losses if a rate increase affects only the inframarginal "blocks" of consumption. For example, if the entire rate increase (needed to cover revenue requirement) goes into the customer or service charge, the effect on electricity usage would presumably be smaller assuming departure of customers to another supplier. As long as consumer surplus *post* rate increase is still positive, customers would not discontinue service from the utility. Alternatively, customers would more likely leave the utility system if the fixed charge exceeds consumer surplus at a price

equal to marginal cost. *See*, for example, Wenders, J.T., 1984. Two-part tariffs and the 'spiral of impossibility' in the market for electricity. *Energy J.* 5 (1), 177–179.

37. *See*, for example, Kahai, S.K., et al., October 1996. Is the 'dominant firm' dominant? An empirical analysis of AT&T's market power. *J. Law Econ.* 39, 499–517. The elasticity equation make three assumptions: (a) the utility has a relatively high share of the market, (b) the competitive fringe consists of much smaller firms and takes the utility's price as given, and (c) the product sold is homogeneous. One difference between the price charged by an unregulated dominant firm and a regulated utility is that, unlike the dominant firm, the utility is unable (assuming effective regulation) to charge the profit-maximizing price where marginal revenue equals marginal cost. A regulated utility is like an unregulated monopolist in that if it wants to increase sales it has to lower its price, which is unlike a competitive firm which can sell as much as it wants without affecting the price it receives. The problem for the competitive firm is that would lose all sales if it wants to sell above the market price.

38. In our definition, the death spiral confines its effect on movement along a demand curve. DG and energy efficiency are substitutes for utility electricity, so as the substitutability for utility electricity increases, the demand facing a utility becomes more elastic. The implication of this outcome is that a death spiral or unstable equilibrium is more likely. The explanation is that with a more elastic demand curve, for a given price increase the utility will experience higher sales losses.

39. The elasticity of fringe supply (e_s) measures the ability and willingness of (say) DG competitors to enter the market or to expand in response to any utility price increase. It depends on several factors, including barriers to entry imposed by the market or the utility, net metering rates for rooftop

solar, and the homogeneity of DG electricity with utility electricity.

40. $e_d = -(0.6/0.8) - (1 - 0.8) \cdot 3/0.8$.

41. We previously labeled the variable charge as the volumetric charge. The term "b" normally includes a portion of the utility's fixed costs, as discussed earlier.

42. Henderson, J.S., 1986. Price discrimination limits in relation to the death spiral. *Energy J.* 7 (3), 33–50.

43. The price schedule shows the relationship between price and quantity under a two-part tariff ($F/Q + v$), assuming constant variable cost.

44. The downward-sloping demand curve facing a utility represents the average revenue that the utility receives for different levels of sales. To sell more, the utility must lower its price, thus a large quantity of sales means a lower average price for the utility. The slope measures how much a utility has to reduce its price to increase sales.

45. For a discussion of stable market-equilibrium conditions, *see* Becker, G.S., 1971. *Economic Theory*. Alfred A. Knopf, New York, pp. 91–94.

46. In deriving this relationship, we calculate the slope of the price schedule as $f_i F/Q^2$ and the slope of the demand curve as $P/e_i Q$. As Figure 2 shows, an unstable condition occurs when the slope of the price schedule is steeper than the slope of the demand curve. That is, when $f_i F/Q^2 > P/e_i Q$. By rearranging terms, we get $f_i F/P_i Q_i > 1/e_i$, which equals the condition presented by Henderson for a death spiral.

47. At equilibrium (i.e. marginal revenue equals marginal cost), the unregulated monopoly price is equal to

$$P_m = MC_i \left[\frac{e_i}{e_i - 1} \right]$$

where MC_i is the marginal cost of electricity. By rearranging terms,

$$\frac{P_m - MC_i}{P_m} = \frac{1}{e_i}$$

or,

$$\frac{(P_m - MC_i)Q_i}{P_m Q_i} = \frac{1}{e_i}$$

that is, the proportion of revenues recovered from the fixed charge equals the inverse of the price elasticity (in absolute terms). When price exceeds P_m , the left-hand side is greater than the right-hand side.

48. Henderson, *supra* note 42.

49. One way for a utility to move away from the range of "death spiral" prices is to increase its sales – for example, offering rate discounts to induce higher electricity usage by industrial customers. Since a death spiral condition only occurs when average cost exceeds marginal cost, a utility facing financial difficulty might find it profitable to promote sales by offering lower rates to price-sensitive services or customers, not to reduce sales by subsidizing energy efficiency.

50. We assume that competition from DG has provoked the price increase to regain lost revenues and profits.

51. We express the price elasticity of demand, e_i , in absolute terms.

52. The obvious question is then: How likely is it that the price elasticity facing a utility exceeds the threshold level?

53. Accordingly, imposing required rate increases on inframarginal "blocks" of usage can minimize lost sales. For a two-part tariff, as an example, a rate increase could fall entirely on the customer or service charge to mitigate reductions in lost sales. *See* Wenders, *supra* note 36. The basis for Wender's argument is that when deciding to consume more or less electricity, the marginal price becomes the crucial factor. Studies have shown that customers are generally unresponsive to the level of their customer charge, for example. That is, customers are unlikely to leave a utility's system simply because of a higher customer charge. One qualifier is that where DG has become a viable alternative to utility electricity for many customers, the average price of electricity (which includes fixed costs)

becomes increasingly relevant. Placing more of a rate increase on the customer charge (or inframarginal energy blocks) may, therefore, have little effect on customers' decision to invest in DG.

54. See the previous discussion on the residual demand elasticity for the dominant firm.

55. Henderson, *supra* note 42.

56. State statutes also explicitly prohibit commissions from approving rates that are unduly discriminatory.

57. A business model focuses on the utility's products and services, their value relative to their cost, and how efficiently and effectively the utility creates, produces, delivers and supports those products and services in their designated franchised area.

58. From experience, regulators seek to minimize extreme financial outcomes for utilities. They are also subject to legal constraints imposed by legislatures and the courts.

59. A breakeven constraint (i.e. total revenues equal total costs) is a necessary condition for assurance of adequate service utility service in the long run.

60. One good example is cable companies that exploited new technologies to expand their services and bundle them profitably. See Graffy, E., Kihm, S., 2014. Does disruptive competition mean a death spiral for electric utilities. *Energy Law J.* 35 (1), 1–44.

61. Joskow, *supra* note 10.

62. To "conceal" the rate increases by avoiding general rate cases, commissions may consider allowing

utilities to recover these costs through trackers or surcharges.

63. Bypass could have a more serious effect on the utility, as the former customer would no longer pay fixed charge. If, instead, the customer merely cuts back on electricity usage but remains on the utility as a full-requirements customer the utility would still recover some of its fixed costs. One mitigating factor is that the utility could still recover at least a portion of the fixed charge by providing standby service or other service to the bypassed customer. At least over the next few years, storage will unlikely be cost-effective for DG customers to completely bypass the utility system. Even if it is, DG customers placing a high value on reliability may still be hesitant to wean themselves off the utility grid.

64. Analysts sometimes used the term "uneconomic bypass" to describe this condition.

65. One article expressed the view that "the current rate design cannot economically or politically support a large cross subsidy from non-DG to DG customers." [Felder and Athawale, *supra* note 36, 14.]

66. A major problem in California was that the high-tail increasing block rates were not sustainable as solar got cheaper. It became economical for certain customers to invest in solar systems. One may argue, though, that the decision to install solar is inefficient because of a rate structure that exhibits large cross-subsidies and motivates economic inefficient decisions. In California, because of distorted rates we cannot say with any confidence whether the

increased penetration of solar reflects efficient entry into the retail electricity market.

67. As one article points out, while in the short run these actions can insulate the utility from solar PV competition, they may create "substantial medium- and long-term risks, including those of customer backlash, deferral of adaption, and stimulation of enhanced competition." [Graffy and Kihm, *supra* note 60.]

68. Consistent with Schumpeter's process of "creative destruction," the scenario described above suggests that the traditional business model of electricity distribution network utilities is unsustainable; thus, incumbents will need to transform themselves if they are to adapt and survive the paradigm shift in the generation and delivery of electricity to retail customers. [See Schumpeter, J.A., 1950. *Capitalism, Socialism, and Democracy*. Harper and Brothers, New York.]

69. Pressure on inflating utility costs comes from various sources: new environmental regulations, replacement of aging infrastructure, grid modernization, transition costs to accommodate more renewable energy, integration of new technologies, cyber security protection, public demands for improved "superstorm" response, and customers' demands for higher reliability and overall quality of service.

70. Deteriorating financial conditions for a utility can mean lower actual equity returns, higher required investor returns, and lower credit quality.