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Resilient Electricity Requires Consumer Engagement

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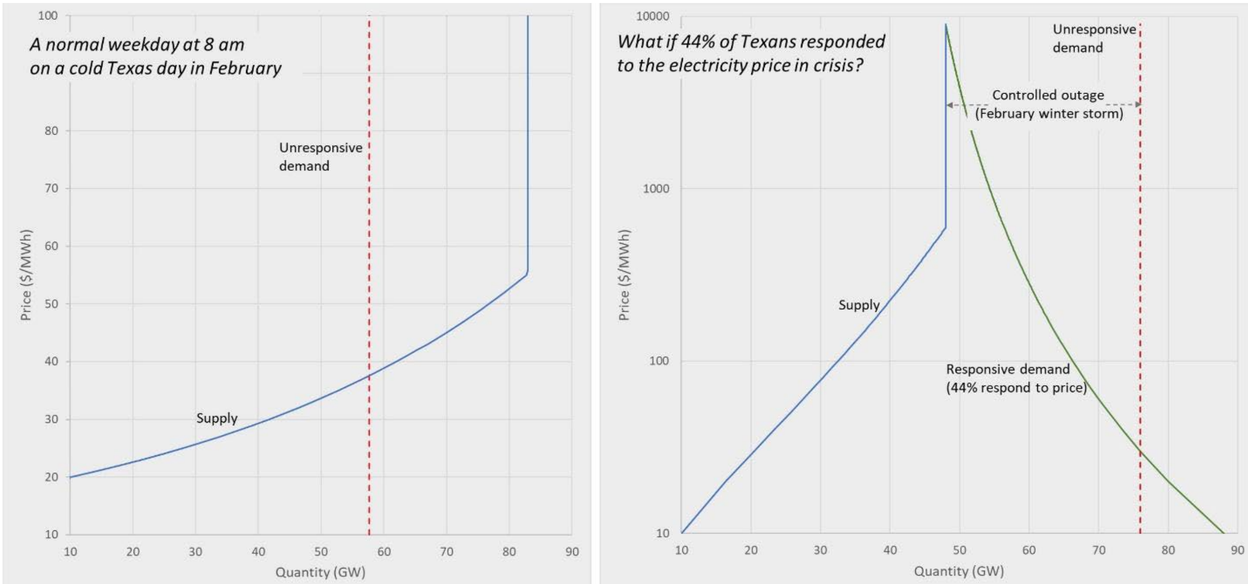

Resilient electricity requires consumer engagement

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Active consumers are essential to mitigate systemic outages

In February 2021, winter storm Uri blanketed Texas with extreme cold for several days. Thermal generators failed, and heating demand surged, creating a 37% shortfall between electricity demand and supply. The system operator, ERCOT, had no choice but to order controlled outages to keep the system in balance and avoid a cascading blackout. Over four million Texans were without power for several days. Many were without water as the interconnected critical infrastructures failed—first gas, then electricity, then water. Hundreds died. Dollar damages totaled many tens of billions.[1]

Climate change makes extreme events more salient, frequent, and extreme.[2] Research on how to make critical infrastructure more resilient to extreme weather is needed. Here we provide evidence that demand-side policies promoting energy efficiency and price responsive demand are critical to resiliency. They are an essential part of any least-cost approach to improving resiliency—a lesson relevant to electricity markets worldwide.

Electricity markets are carefully designed for reliability.[3] Reserves are maintained so that the system can handle inevitable shocks to supply and demand. Extra capacity is built to cover the daily and seasonal peaks, recognizing the likely low production of intermittent renewables during scarcity. The left panel above illustrates a typical winter peak in Texas. There is ample supply to meet demand. The market clears at a typical price under $40 per megawatt-hour. These reliability efforts work well at avoiding system-level outages in all but exceptional circumstances.

Yet, the Texas storm is best characterized as a resiliency event. The extreme and sustained cold induced systemic failure—a simultaneous drop in supply and spike in demand systemwide. The Texas market was not resilient to extreme cold.

The right panel shows the supply and demand picture during the height of the crisis. Demand, the red-dashed line, was unresponsive to price for the simple reason that 99.75% of Texas households neither see nor feel the high shortage price of $9000 per megawatt-hour. Instead, they pay a fixed price of about $110 per megawatt-hour, only 1.2% of electricity's value in a crisis. Electric heating caused demand to surge about 20 gigawatts higher than prior winter peaks. Generating outages caused supply to fall about 35 gigawatts less than expected. The gap between demand and supply during the height of the storm was this difference between the red dashed line and the maximum supply: 76 – 48 = 28 gigawatts or 37% of demand.

What would have happened if some fraction of Texas consumers were price responsive? To answer this question, we look at the behavior of price-responsive consumers in Britain.[4] Octopus Energy provided us with electricity consumption on a 30-minute basis for 15,000 individual households for one year. The sample was divided equally among three contract types: one-third had the *dynamic* rate with a price that tracked the day-ahead wholesale price, varying every thirty minutes; one-third had the traditional *fixed* rate—a constant per kilowatt-hour charge; one-third had an *electric vehicle* rate with time-of-use pricing—a low price at night for charging.

These data allowed us to estimate the price elasticity of demand to be -0.26; that is, a 1% increase in price causes a 0.26% reduction in demand. The 30-minute data over a year allows us to control other sources of variation at the household level.

The green line in the right panel shows what would have happened if 44% of Texas households had a price-responsive rate and responded as the Britain consumers do. The need for controlled outages is eliminated even at the height of the storm. As the price increases, demand falls, shrinking the gap between supply and demand. The gap vanishes at the clearing price of $9000 per megawatt-hour. Thus, with a sizeable minority of Texans price responsive, Texas would have survived the 2021 storm without shortage.

Our point is not to precisely estimate the price responsive demand needed to survive winter storm Uri. Instead, it is to demonstrate the vital role of demand-side measures for resiliency.

There are two ways to address scarcity during resiliency events—rationing with rolling outages or rationing with prices. Rolling outages allocate available power along broad geographical lines without consideration for diverse local needs. The outages can avoid a hospital but not a streetlight at a busy intersection. Also, rolling outages induce socially damaging behavior. Households on a fixed price that have power may choose to heat their homes as much as possible, anticipating power might be lost soon, thus, exacerbating scarcity and the need for rolling outages. Households on dynamic plans recognize the social cost of electricity is $9000 per megawatt-hour. They use only the essential electricity, allowing power to flow to more urgent uses.

The supply side is the other half of the story. We ignore it here since the supply side is already well-addressed in existing and proposed policy. Nonetheless, we urge Texas and other markets to extend the reliability features of the electricity market to the gas market. Reliable electricity depends on reliable natural gas.

We commit two sins in our thought experiment. First, there is selection bias in our -0.26 elasticity estimate. Britain consumers freely selected their retail plans. It seems likely that those that selected the dynamic rate were more likely to respond to price. The price elasticity for the Britain population of consumers is presumably lower. Second, in applying the Britain elasticity to Texas, we extrapolated the result where prices varied by a factor of three to a setting where prices varied by a factor of eighty. The Britain retail price was capped at 35 pence per kilowatt-hour (£350/MWh) during our study.

Is it still plausible that having a significant fraction of demand respond to price would mitigate the shortage and improve resiliency? Absolutely. Our thought experiment is for the future, not the past. We are witnessing rapid innovation in technology that enables consumers to respond to price. Smart thermostats, smart homes, and, most importantly, electricity vehicles enable consumers to respond to price with little effort or discomfort. Soon, consumers will express a preference for savings, and the devices will automatically observe prices and manage electricity consumption to maximize consumer well-being. Early versions of preference expression are available now in smart thermostats, EV chargers, and home battery systems.

The cost of this flexibility is modest, given it is driven by technology that scales with near-zero marginal cost. The exception is electric vehicle batteries. Batteries will remain expensive, but EVs bring many other social benefits. Exploiting demand flexibility incurs little extra cost and creates enormous value for the electricity system. Moreover, costs will fall with penetration.

Once consumers see and feel the real-time price, other good things will happen. Consumers will have an incentive to invest in other resiliency-enhancing technologies. Triple-pane windows, insulation, and caulking improve energy efficiency and save consumers money, especially during scarcity. Insulation means the home stays warmer during extreme cold and cooler during extreme heat. Thus, energy consumption is reduced when it is most expensive.

Consider a Dallas home during the cold snap. With poor insulation and no heating, the temperature quickly falls to -19˚ C, the outside temperature. With good insulation, the home can stay well above freezing with little heating. This is why energy efficiency is so crucial to resiliency. It brings the most significant gains precisely when they are needed.

Managing risk

Regulators are concerned about exposing consumers to price risk, and rightfully so. The 0.25% of Texas consumers that had rates that tracked the wholesale price made sensational news. Reports of multi-thousand-dollar bills were frequent, although the bills were rare. While these dynamic plans save consumers money in the long run, they are a nightmare during a crisis. The Texas Legislature's first law addressing the crisis was to ban rates tied to the wholesale price.

Banning the wholesale-indexed rates was a mistake. Instead, the Legislature should have corrected the fatal flaw in these innovative plans. The early plans did not include a hedge to manage real-time price risk. A hedge is commonplace among industrial consumers and can be implemented in understandable ways for retail consumers. The service provider buys forward the consumer's expected consumption and then only exposes the consumer on the margin to settle deviations from expected consumption. The real-time price is used to reward the consumer for consuming less during the crisis.

For example, consider an electric-heated home on a fixed rate. Suppose the home is near a hospital, so the electricity stayed on throughout the storm and consumed 0.4 megawatt-hours during the 4-day storm, double its typical usage. The household pays 0.4 × $110 = $44 for electricity during the event.

By contrast, suppose the household had the dynamic rate with hedging. The consumer pays the $9000 price only for deviations from expected consumption. The service provider bought the consumer's expected demand of 0.2 megawatt-hours at the $110 forward price, a cost of 0.2 × $110 = $22. The high marginal price motivates the consumer to put jackets on, turn down the thermostat, and consume only one-half of the typical amount. The responsive consumer's bill for the crisis is $22 – 0.1 × $9000 = –$878. Instead of exposing the consumer to downside risk, the price-responsive consumer enjoys the opportunity to be rewarded for being flexible and making a socially beneficial decision—consuming less so that others can warm their houses too. Hedging transforms downside risk into upside opportunity.

The Texas Legislature's ban was an ill-conceived political response to the crisis. Instead, the Legislature should instruct the regulator to prohibit unhedged plans but welcome plans with hedging as an essential innovation. Indeed, the two Texas service providers offering dynamic plans were about to introduce improved plans with hedging when the storm struck.

Social justice

Regulators are concerned about large increases in consumer electricity bills and take steps to limit increases. Britain's retail price cap (£350 per megawatt-hour in 2021) is a good example. The cap limits bills during an energy crisis but reduces demand response and increases providers' bankruptcy risk.

A more thoughtful regulatory response would mandate hedging in plans that expose consumers to the wholesale spot price. Then the market can adequately reward those consumers that offer flexibility critical for the electricity system. Poorer consumers are more price-sensitive because they spend more of their income on electricity and are apt to benefit the most from the flexibility option.

The hedging brings an additional resiliency benefit. It reduces the chances of service provider default during extended periods of high wholesale prices. With retail prices capped at £350 and wholesale prices uncapped, sustained scarcity is apt to cause provider bankruptcies. Britain's 2021 energy crisis demonstrated this vulnerability. A sustained high gas price has led to high wholesale electricity prices, bankrupting inadequately hedged providers.[5] The California 2000-2001 energy crisis had the same root cause.

Rather than limit marginal exposure to spot prices, a necessary condition of economic efficiency, regulators should foster resiliency and social justice with low-income subsidies that promote energy efficiency. The low-hanging fruits are improved insulation, caulking, and other energy efficiency programs. The levelized cost of energy ($/MWh) of energy efficiency programs in the US ranges from $12-49 with an average of $24.[6] By contrast, the levelized costs of energy for the most efficient production technologies are $29-42 for solar photovoltaic, $26-54 for wind, and $44-73 for gas combined cycle.[7] Mandates and low-income subsidies for high-efficiency heat pumps and other appliances are also desirable. These steps create the most significant savings during extreme weather events. Peak demand falls, reducing the need for additional electricity infrastructure.

Energy transition

Price responsive demand is critical for the energy transition. Flexible plans incentivize consumers to shift consumption to periods when energy from renewables is abundant, thus supporting renewable investments. Similarly, price responsive demand increases incentives to invest in slow-ramping resources, like nuclear, because part of the adjustment to balance supply and demand shifts to the demand side.

Also, there is a strong complementarity between the adoption of flexible plans and electric vehicles. EVs are estimated to increase electricity demand by 25% by 2050.[8] EVs motivate consumers to be price responsive. Owners have an incentive to charge at night when the price is low. Additional value can be realized with vehicle-to-grid: smart charging *and* discharging. EV batteries have enormous potential for smoothing the intermittent generation from renewables. Flexible plans can transform electric vehicles from a challenge to an opportunity for the power grid.

With fixed prices or time-of-use plans, electricity consumption is uncoordinated. The onus of adjustment falls on the supply side, straining an electricity system increasingly dominated by non-controllable and slow-responding resources. Investment incentives for renewable resources would be weaker. Incentives for vehicle-to-grid would be absent, leaving the EV storage benefits untapped.

Making it happen

The necessary reforms are already happening. What is needed is a thoughtful acceleration of enabling policy, especially on the demand-side initiatives emphasized here.

To allow price-responsive demand, we must measure real-time electricity use. Smart meters need to be installed in each home. This essential step has been completed in many US markets and Britain but not in Germany.

The regulator needs to promote price-responsive demand either by allowing retail choice so that consumers can select a competitive rate that allows price response or by requiring utilities to offer a rate that tracks the wholesale price with hedging to manage risk. As more consumers select the dynamic rate, resiliency improves. The regulator could nudge consumers in this process by making the dynamic rate with hedging the default rate for those with supporting devices, such as smart thermostats or electric vehicles. If the consumer fails to select a rate, the dynamic rate is the default.

Many markets, especially in Europe, have taken great strides in promoting energy efficiency through mandates and subsidies. Germany is a good example. By contrast, much of the US still has poor energy efficiency, as seen in Texas. The reason is simple. Energy providers, the loudest policy voice, do not benefit from energy efficiency. Consumers benefit, but the gains are often hidden and distant.

Texas illustrates the enormous cost of a multi-day outage in our modern world. Regulators can mitigate this cost with policies that foster electricity resiliency. Price responsive demand and energy efficiency are the low-hanging fruit.

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