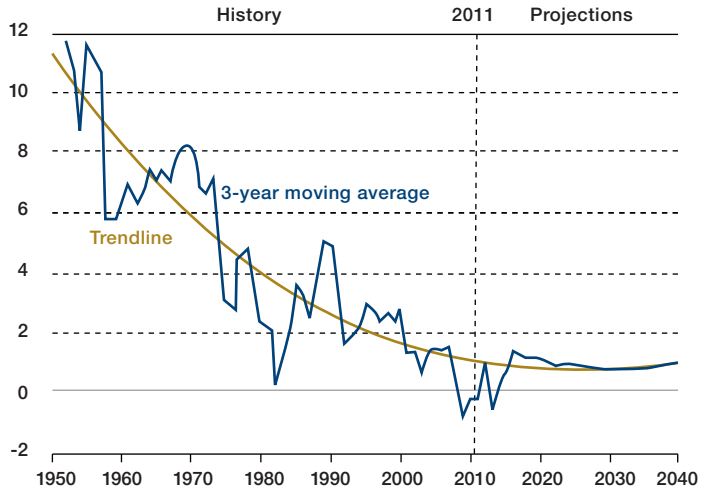
White paper

Transactive energy:
A market-based approach to distribution optimization

As we near the end of 2013, a sluggish U.S. economy has dramatically slowed the growth of electric energy consumption and led to a surplus of electric generation capacity. This surplus helps keep capacity prices low, but it can lull consumers and industry professionals into a false sense of security over our nation's energy future.

According to the U.S. Energy Information Administration (EIA), while growth in electrical consumption has slowed, it is still expected to increase by 28 percent from 2011 to 2040.[1] The same report projects that 15 percent of coal-fired generation will be retired by 2040. Estimates project this decline in coal-fired power generation to result in the loss of up to 100,000 megawatts of electricity across the country.

U.S. electricity demand growth, 1950-2040
(percent, 3-year moving average)



Source: U.S. Energy Information Administration, Annual Energy Outlook 2013.

Some of the loss in generation capacity will be made up by the slight increase projected for natural gas generation. Renewable sources are also expected to increase, but not at the precipitous rates advocates would like to see. In fact, the EIA only projects a growth of about 1.7 percent per year in the share of generation from renewable sources from 2011 to 2040. At that rate, by the year 2040, the United States will still only generate approximately 16 percent of its electricity from renewable sources.

Many utilities and regulators are seeing signs of trouble on the horizon. For example, the Electric Reliability Council of Texas is concerned that demand may outpace the state's generation capacity and released a report identifying existing and potential constraints that could create reliability concerns or increase costs for consumers over the next five years.

"As we see the gap between available generation and peak electric demand become tighter over time, it becomes increasingly important to deliver new power resources to the grid as quickly, reliably, and cost-effectively as possible," said ERCOT CEO Trip Doggett. "These studies help ERCOT, transmission providers, and market participants plan ahead so we can prepare effectively for changing grid and market conditions."

For ERCOT and others, addressing these challenges will require utilities to become even more diligent in their efforts to leverage distributed energy resources and to optimize consumption of electricity at the distribution level. A new concept, *transactive energy*, may help all of us avoid a very dark future.

A balancing act

Optimizing distribution consumption in any market is often a matter of balancing supply and demand. Too much supply and prices fall. Too much demand and prices rise. In regulated markets, consumers are somewhat insulated from the laws of supply and demand, but they still exist below the surface of every industry.

"In its simplest form, improving generation capacity utilization and optimizing electricity consumption at the distribution level is about flattening off the peaks and filling in the valleys," says Gary Rackliffe, VP of Smart grids at ABB. "Levelizing the demand curve by reducing peak demand and shifting load to off-peak hours allows utilities to improve generation capacity utilization and lower the cost of providing a stable, reliable source of energy to consumers. It also helps their business model as they are better able to reduce generation requirements and procure electricity at the best rates."

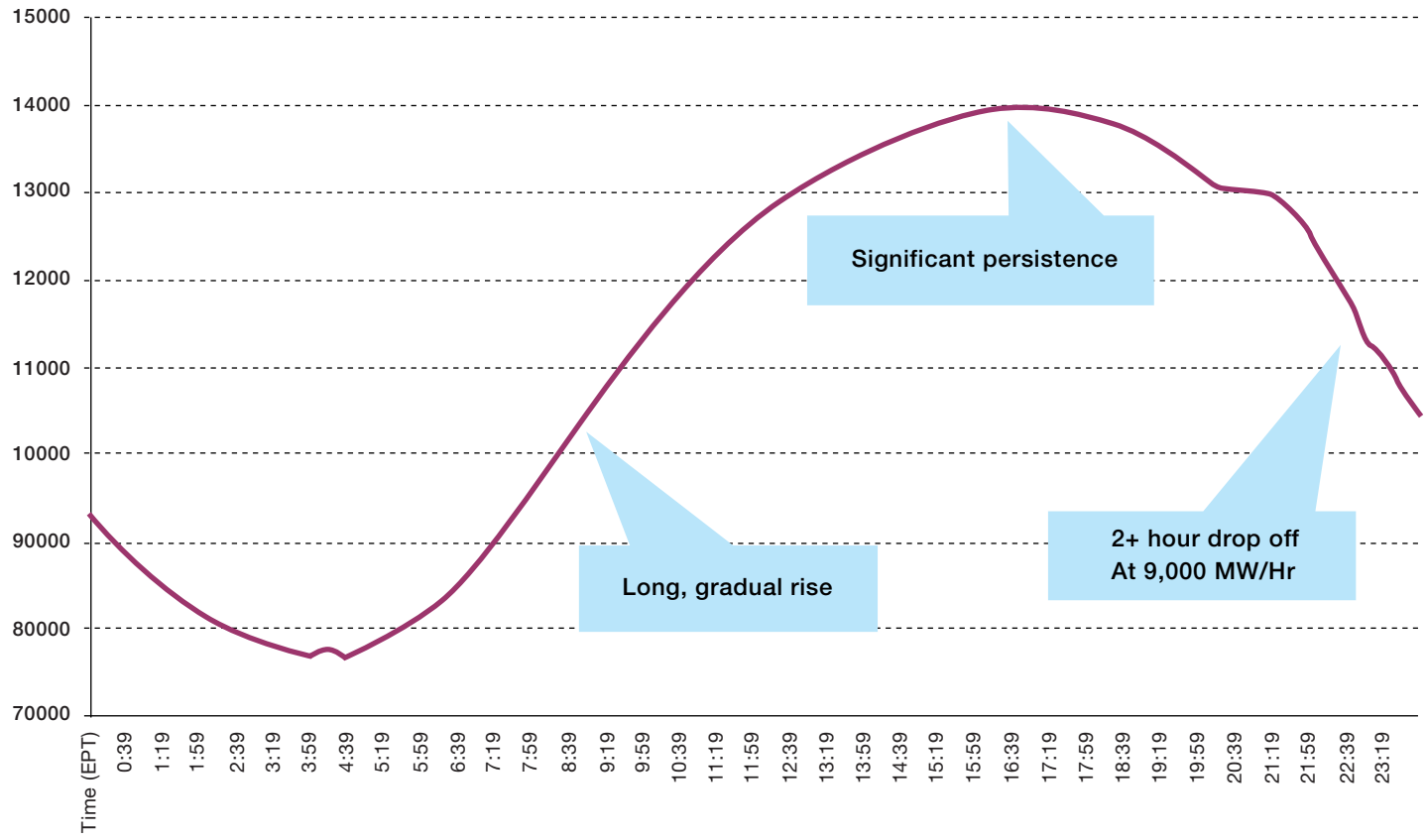
> "The most effective demand response programs are the ones where smart meters and customer systems respond to price drivers automatically," says Rackliffe.

The demand dilemma

Utilities have been enlisting the aid of consumers in shaving peak demand for decades. Many demand response programs have focused on industrial consumers since these customers are large consumers of electricity and have had "smart meters" since the 1990s. Programs such as interruptible rates, time-of-use rates, critical peak pricing, and peak demand changes have helped utilities control energy consumption during times of peak demand while helping the industrial consumer to lower operating expenses.

At the residential level, many utilities, especially public power utilities, have used direct load control to minimize peak demand and the associated generation capacity costs. Smart meters and two-way communications to residential customers are enabling deployment of new demand response programs, but the industry is still largely in pilot mode and moving slowly to implement critical peak pricing and similar demand response programs for residential customers. "The most effective demand response programs are the ones where smart meters and customer systems respond to price drivers automatically," says Rackliffe. An example is a programmable communicating thermostat that can adjust the temperature at the customer location in response to price signal. Demand response programs that do not require a human response once the

Load curve - Summer profile
RTO Load (MW)



technology is implemented are more persistent and deliver more sustainable reductions in peak demand. The success of these demand response programs will depend on the utility bill savings that companies and residential customers can achieve.

Utilities benefit as well. By lowering spikes in peak demand, they avoid the need to build excess generation or to turn to more expensive sources. They can also ensure reliable service by avoiding rotating blackouts or brownouts when demand exceeds capacity.

When there is a surplus of capacity, as is currently the case in the United States, demand response programs are enough to level demand peaks and limit power disruptions in most parts of the ,country. However, many experts predict that the excess supply will quickly turn to a deficit if and when the economy returns to its pre-recession rates of growth. If generation capacity falls below consumption on a more frequent basis, utilities will need to explore generation capacity options and an expansion of demand response programs. Neither of these options is easy.

According to Rackliffe, "In theory, if you give consumers a choice they will make wise, informed decisions. In reality, consumers, especially residential consumers, make decisions based on any number of reasons. Some of their actions can be very emotionally driven."

Smart meters, once widely lauded as the answer to managing peak demand have seen a relatively slow adoption in the United States. As of May 2012, The Edison Foundation reports that only about one third of the approximately 130 million homes in the US have an electronic smart meter installed. That number is expected to rise, but only to little more than 50 percent of homes by 2015.

For the most part, utilities aren't even looking at using smart meters to control peak loads. In a working group survey conducted by the Utility Analytics Institute, remote metering and remote disconnect/reconnect were the top two reasons for deploying smart meters, while enabling load control and time-based pricing programs ranked lowest on the list.

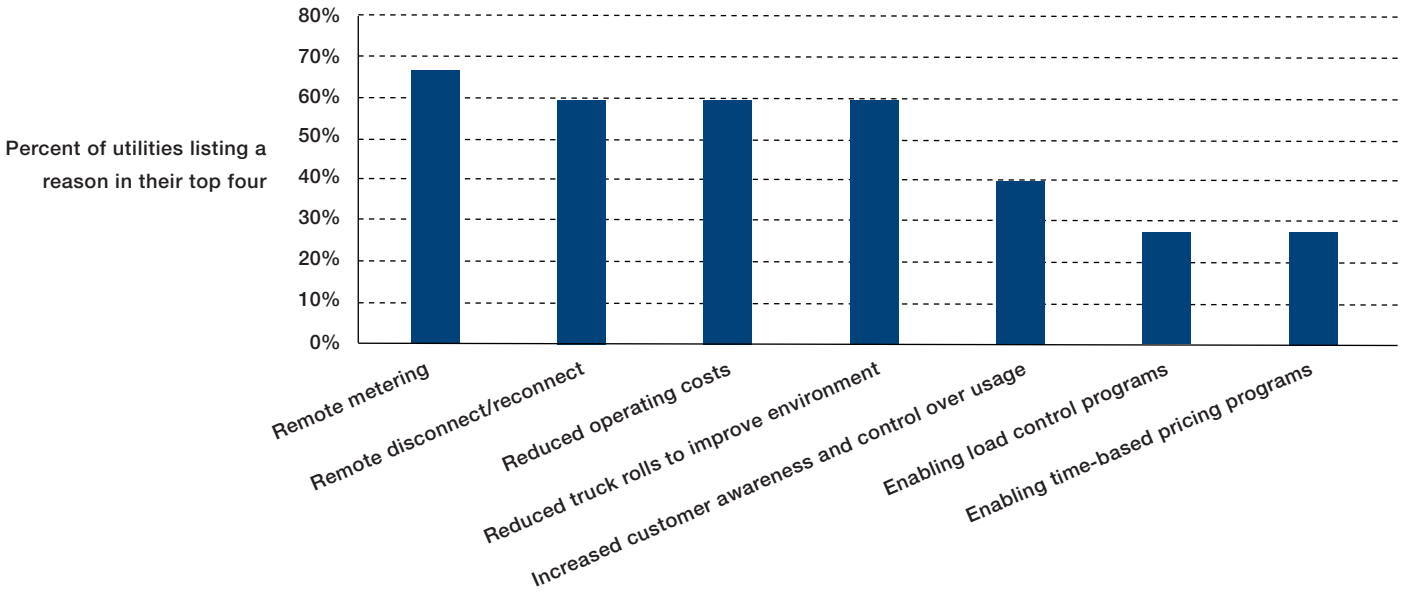
Some suggest that the industry regulations may be to blame. "Part of the problem with enlisting the aid of residential consumers is that they are protected from the impact of price fluctuations by a regulated market," says Rackliffe. "Consumers are insulated from the true cost of their choices within a rate controlled market. To encourage their participation, a utility might offer an incentive, but the monthly amount is often not enough to buy lunch at the local fast food restaurant. When given a choice between an extra four or five dollars in their pocket or the ability to keep the air conditioning running on a hot day, which do you think consumers will choose?"

Distributed energy resources to the rescue?

As if managing consumer behavior weren't complicated enough, the supply side is sure to make things even more complex. As we've already mentioned, traditional generation, especially coal-fired power, is being retired at ever-increasing rates and natural gas and utility-scale renewables aren't projected to grow at rates sufficient to make up for this loss. This leaves many in the industry to wonder if distributed energy resources will provide the answer.

At its simplest level, distributed energy resources refer to anything connected to the distribution system that generates power near the point of consumption. This would even include the old-fashioned diesel generator. More recently, when

Top reasons for deploying smart meters



Source: Utility Analytics Institute, meter data analytics working group survey.

industry experts talk about distributed resources they are usually referring to smaller scale renewables such as roof-top solar or privately owned wind farms.

But even that understanding is limiting. Local power generation might also include newer technologies such as fuel cells, geothermal energy, and biomass among others.

Distributed energy resources might also include an aggregated resource such as a micro grid.

As much as consumers love the idea of distributed energy resources, DERs can be a challenge for utilities. There are very few completely self-sufficient microgrids in operation today. Most require connectivity to the main grid for at least a portion, and in some cases a majority, of the power. Even while privately owned DERs dip into their revenue stream, utilities must ensure that these consumers are safely connected to the grid and that these connections don't cause upstream instabilities.

> "Transactive energy is a means of using economic signals or incentives to engage all the intelligent devices in the power grid — from the consumer to the transmission system — to get a more optimal allocation of resources and engage demand in ways we haven't been able to before."

DERs: what's old is new

DERs are far from a new concept. Residential consumers have been eyeing roof-top solar panels since 1973 when the University of Delaware unveiled Solar One, one of the first houses to use PV panels to provide heat and electricity. More recently, wind turbines have gained in popularity, especially for those property owners with enough land and more wind than sun. Some industrial customers are even investing in their own fuel cells, and as technology continues to advance, we may see fuel cells being installed in residential areas as well.

Industrial consumers are often early adopters of technology that allows them to cut their operating costs. But many mainstream residential consumers are also warming up to the idea of supplying their own energy, perhaps due in part toward a change in consumer sentiment toward utilities. A 2013 study conducted by Accenture shows that less than a quarter of utility customers trust their utility, the lowest level of trust in four years.[2] According to the study, if given the choice, 73 percent said they would consider alternative providers for purchasing electricity and alternative energy-related products and services.

"Managing distributed energy resources can be quite a balancing act for utilities," says Rick Nicholson, Vice President, Transmission and Distribution Solutions at Ventyx, an ABB company. "ABB was a pioneer in the concept of the virtual power plant or VPP. Utilities can aggregate distributed energy resource with their primary load sources and manage them as if they were one big power plant. Demand response is a crucial element of the virtual power plant as it provides the actionable signals that drive effective VPP management."

While current technologies such as demand response and the virtual power plant go a long way toward helping utilities of optimize distribution with an eye toward grid reliability, there is still a missing link in the evolution of the grid toward a clean, reliable energy future.

Transactive energy: the grid evolves

Prosumer has become a commonly used industry term for these consumers who are producers and consumers of energy. Integrating these prosumers into the energy markets requires a much newer concept – *transactive energy*. Transctive energy is such a new concept that the first-ever Transactive Energy Conference was held in 2013 in Portland, Oregon.

At this conference, Carl Imhoff, manager of the electricity infrastructure sector for PNNL, supplied a definition."Transactive energy is a means of using economic signals or incentives to engage all the intelligent devices in the power grid—from the consumer to the transmission system—to get a more optimal allocation of resources and engage demand in ways we haven't been able to before."[3]

Unfortunately, this early definition doesn't shed much light on transactive energy for the utility executive who is trying to understand its benefits. In many ways, it's similar to the definition of demand response used by FERC.

Demand response: *Changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.*[4]

"Transactive energy has the potential to change the industry with the same impact that establishing independent systems operators and energy markets for generation and transmission," says Rackliffe. "It certainly has the potential to revolutionize the business model for utilities and could forever change the way consumers view their part in the electricity supply chain. But at the same time, the concept is really just the next step in development of demand response and an extension of the electricity markets to the end-use customers."

To understand the implications of trans-active energy requires a focus on the last portion of the definition provided by PNNL – "to get a more optimal allocation of resources and engage demand in ways we haven't been able to before."

"Transactive energy goes beyond engaging with demand resources in traditional ways such as smart meters and incentive programs. Now, we're encouraging demand resources to actively engage in energy markets," says Nicholson. "We've had the technology to

integrate these resources safely into the grid for some time, we've just been waiting for the communications and customer engagement models to catch up."

Active engagement of resources could be on the supply side such as when a distributed energy resource, like rooftop solar, is also capable of generating excess capacity that can be used by the grid to address fluctuations in demand. It can also refer to a more sophisticated interaction with the consumer where their energy costs are based on a more real-time market basis.

This is going to require much more sophisticated software solutions and computing power than most utilities have implemented today. "The business model for a utility is comparatively simple," says Nicholson. "Even in most Virtual Power Plant scenarios, they are managing half a dozen sources of generation. It's relatively easy to choose the best source. On the demand side, they are incenting customer behaviors through simply time-of-use rates. A few have smart meter programs, but even these don't add that much complexity."

Now, consider a scenario that some experts predict could happen in less than a decade. Advancements in technology and perhaps a few other unforeseen dynamics have resulted in a boom in privately owned generation. These sources are not generally utility-scale generation so to replace the vacuum left behind by one retired coal plant could require the utility to tap into hundreds of distributed energy resources. This multiplies the number of choices the utility operator needs to make every minute of every day to the point where manual decision-making just isn't feasible.

Transactive energy also assumes greater engagement on the demand side. Exposing consumers to the results of their choices, allows them to make better decisions, but they also want more flexibility in their choices. For example, while one consumer might have no problem with allowing the utility to implement a demand response program that controls their air conditioner or manages the charging of their electric vehicle, they might balk at giving up control in other areas.

Perhaps, utilities should take a page from other industries and start segmenting consumers into more than just *residential* and *commercial*. "A utility could implement a pricing program similar to that use in the telecom industry. A consumer might pay for a flat fee for their expected level of usage, and a higher rate per kilowatt hour if they go above that. Just as the mobile phone companies alert their customers when they're reaching their limits, utilities might send alerts to their consumers."

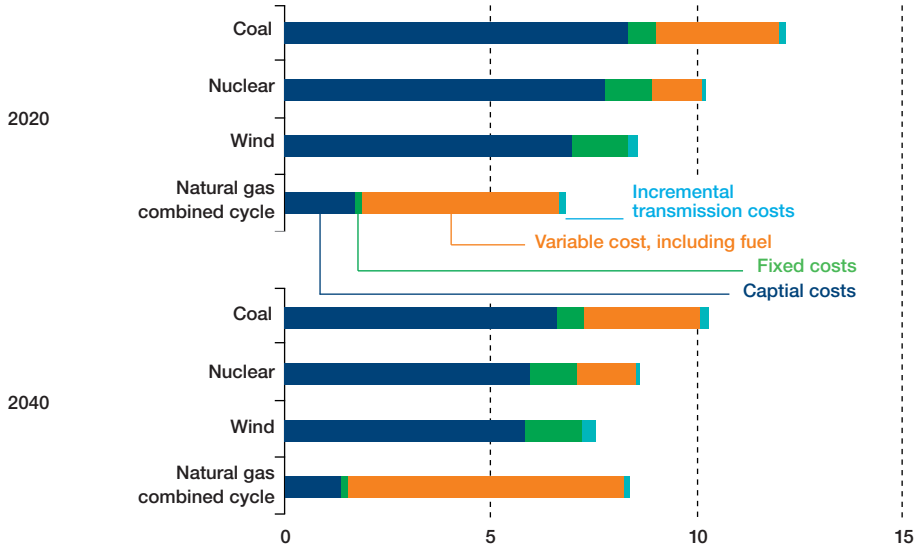
As complicated as transactive energy may sound, the benefits are huge for utilities. It transfers some of the responsibility for controlling rates onto the consumers and alleviates some of the pressure from regulators who are elected to help control rates. Since transactive energy is a market based model, it also gives the utility a more stable financial model. While regulators may insist on controlling profit margins, at least the price charged to the consumer is tied more closely to the real cost of generation.

Another approach being debated in the industry is the decoupling of the rates a utility is allowed to charge from sales. As in most industries, a utility's profits are tied to sales. This causes some unique problems for the energy industry because, although there is an advantage to the utility in leveling out the peaks and valleys associated with energy consumption, the system rewards the utility only when they sell more. Furthermore, the utility is discouraged from participating in other programs such as distributed energy resources that provide tangible benefits but may lower revenues. Perhaps most critically, the focus of the utility is taken away from reliably serving the customers' energy needs and refocused on preserving the balance sheet.

"Profit is necessary for any business, and many utilities have shareholders to which they are accountable. We shouldn't demonize the industry for focusing on the bottomline," says Rick Nicholson, Vice President of Transmission and Distribution Systems at Ventyx, an ABB company. "However, there are ways to address the challenge with industry models that decouple profits from sales volume."

Decoupling assigns a rate of return and aligns it with revenue targets. Then, at the end of the adjustment period, rates are adjusted to meet the target. "It's not a perfect model, and there are other acceptable approaches, but it is worth debate." says Nicholson. "We have to find a way to tackle our current challenges while

Levelized electricity costs for new power plants, excluding subsidies, 2020 and 2040



Source: U.S. Energy Information Administration, Annual Energy Outlook 2013

putting the consumer at the heart of the matter and still meeting the financial needs of the utility companies that service them."

Evolution is never easy

In nature, evolution is never a straight forward process. Some adaptations thrive, while others die a quick death. Trying to control evolution by choosing the winners and the losers is usually fruitless and leaves the entire system weaker. The evolution of the grid is much the same and will require consumers, utilities and regulators to let go of old ways of doing things.

Consumers need to wake up to the realities of the grid. Mainstream consumers, those who only pay attention to the amount of the bill when they write a check each month, may need to adjust their mindset the most and start to think about when and how much electricity they consume. The world where they were insulated from the effect of choices such as running the air conditioner at 68 degrees or charging their electric car during peak demand periods may be gone soon.

Even consumers who think they are energy-aware and working for a sustainable energy future will have some adjustments to make. Clean sources of energy usually come with a higher price tag, especially once you remove the subsidies and incentives. As technology evolves, these sources may reach parity, but by allowing market forces to work through transactive energy, those that are the most viable will thrive.

Utilities need to prepare now for this next stage in the evolution of the grid by getting their infrastructure in place. Implementing a smart meter program, expanding demand response, and increasing the flexibility of the distribution grid is a good place to start. Even if early adoption is low, it puts in place the basic equipment required for the transactive energy model.

Utilities will also need to work on their customer relationships. When trust is low, it's difficult to get consumers to buy in to new programs and new ways of interacting with their utility.

Utilities will need to redefine their relationships with consumers. While the average consumer may not have much time to spend thinking about their energy usage, they are far more technology savvy than they were ten or twenty years ago. Smart phones and other devices can be leveraged to put information and control in the hands of the consumer. For the utility company of the future, customer engagement will be a vital part of corporate strategy.

In the end, perhaps the hardest adaptations will need to be made by the regulators. Elected to oversee the industry and imbued with the instinct to "do something," they are going to need to take a deep breath, step back, and let the markets work. The current regulatory model in which most fixed costs are recovered through volumetric rates charged on a per-kilowatt-hour basis won't support transactive energy," says Nicholson. "There are some interesting market models being proposed, but in the end, finding a solution will require that regulators, indeed the entire industry, be open to the discussion.

References

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[2]Consumer Trust in Utilities Lowest in Four Years, June 2013. http://newsroom.accenture.com/news/consumers-trust-in-utilities-lowest-in-four-years-new-accenture-research-shows.htm

[3]http://www.ferc.gov/industries/electric/indus-act/demand-response/dem-res-adv-metering.asp

[4]What's Transactive Energy? PNNL's Carl Imhoff fills in the blanks, Sustainable Business Oregon, May 23, 2013

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