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The Future of Electric Utilities

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The Future of Electric Utilities

The electricity generation sector is in flux. Demand is flat, cheap natural gas is shuffling the generation stack. NIMBY-ism and policy uncertainty make it difficult to build new transmission and generation capacity. At the same time, there are deep structural changes afflicting the sector: decentralization, decarbonization, and digitization are interacting to overturn existing market structures and change the way electricity is generated, distributed and consumed. The long-standing utility business model is under threat, but where there is change, there is opportunity. This report will summarize the upheaval in the electricity industry to help inform consumers and provide recommendations for TVA to facilitate evolution with the industry.

Introduction

The nation's electricity sector is undergoing remarkable change. The existing integrated utility model, in which electricity is generated, transported and distributed by a single company is under threat. Three forces are combining to pressure existing integrated utilities: *decarbonization, decentralization, and digitization*. These forces present a challenge for utilities, but also an opportunity. The way households buy and consume electricity is changing. TVA can take advantage of these changes to profit from the new paradigm. Utilities that cling to existing business models risk being eclipsed by external forces.

Low natural gas prices are shuffling the generation mix. After decades of uninterrupted growth, electricity demand has leveled off. The hydraulic fracturing (fracking) boom has led to a glut of natural gas, rearranging the mix of electricity generators. A growing "Not in My Backyard" (NIMBY) movement has made building new generation and transmission capacity more difficult than ever.

Decarbonization: Electricity generators are the largest single source of carbon emissions in the U.S. The future regulatory environment is unpredictable adding to the difficulty of planning future capacity. Current subsidies to renewable generation, along with growing consumer and business tastes for alternative fuels, are further altering the mix of generation capacity. Carbon capture technologies are promising, but unproven. TVA's carbon emissions are falling and it is well positioned for any future environmental regulation.

Decentralization: The business model of selling a bundled product: electricity generation and transmission, using a single price per kilowatt hour is changing. Individual consumers can generate electricity using renewable technologies and in many instances sell extra generation back to the grid. Utilities can reduce demand at peak times by remotely and instantly cycling down users' air conditioners and appliances.

The decentralization of the electricity market, facilitated by digitization and deregulation is the single biggest challenge facing integrated utilities today. Fuel prices have always been volatile and the industry has weathered several waves of environmental regulation. Decentralization has the potential to fundamentally change how electric utilities operate. TVA has begun to explore decentralization, but has much more to do.

Digitization: New information and communication technologies have been developed to make the generation, distribution and consumption of electricity more efficient. Smart meters record consumption minute-by-minute, generating huge volumes of data. Smart appliances can respond to signals from grid operators to ramp up or down. New software for modeling the flow of power allows for instantaneous re-optimization. Digitization has allowed new firms to enter the industry and compete with utilities on their own turf, but utilities are uniquely situated to take advantage of these technological advances as well.

TVA's regulatory structure discourages it from adopting some of these advances. This makes it difficult to dispatch the grid as efficiently as unregulated utilities.

This policy brief describes each of these issues in turn and presents some of the notable difficulties and opportunities for TVA. It closes with basic recommendations for TVA to take advantage of the changing electricity model and continue to provide clean and reliable electricity at low cost.

Section 1: Changing Markets

The electricity market has been hit by concurrent shocks. The impacts of *decarbonization, decentralization and digitization* are particularly difficult to predict because the electricity market is undergoing a period of rapid change. After decades of growth, demand is flat. At the same time, changes in fuel prices have made natural gas fired generation competitive as a source of baseload. Technological advances and regulatory incentives have led to an explosion of renewable generation capacity. Consumer and business tastes have changed as well, revealing an increased preference for alternative fuel sources. These market changes are roiling the grid.

For nearly a century electricity consumption and economic activity have grown together. Since the Great Recession of 2007, that relationship has broken down. While economic growth has returned to pre-recession levels, electricity demand has been flat. Consumption and economic activity seem to have become uncoupled.

Demand has been flat in Tennessee as well. Figure 1, below, shows from 2007-2016 electricity consumption fell by nearly 6%. While the Great Recession certainly played a role, it is clear from the figure that the post-recession environment has been altered dramatically. Holladay and Davis (2016) shows that sluggish demand in Tennessee is led by the industrial sector, down five percent across their study period. Residential demand was up only 0.2% during that time.

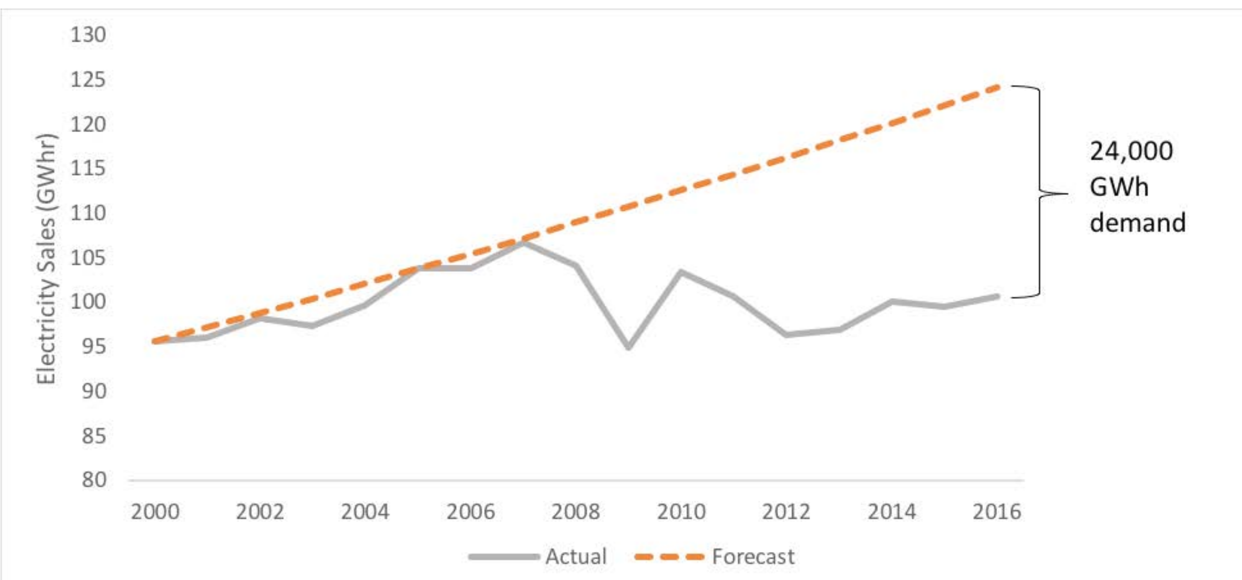

Figure 1: Electricity Demand in Tennessee: Actual and 2001-2007 Forecast

Note: Annual retail electricity sales in Tennessee as reported by EIA. Average annual growth rate of demand from 2000-2007 is 1.6% a year. Demand still has not returned to its pre-recession high. If demand had continued growing at its pre-recession pace it would be around 24,000 gigawatt hours (19%) greater than it is today. Source: EIA Electricity Detailed State Data.

Existing forecasts disagree on the path of future electricity demand. Some analysts suggest that we have entered a new period of energy efficiency that will keep demand flat or even falling. Others predict a return to steady demand growth just around the corner. While it is difficult to predict future demand, there are is no reason to expect a return to growth in the next few years.

All of this makes projecting future demand much harder than it used to be. When electricity demand grew in lock step with the economy, making long-run predictions for capacity planning was relatively straightforward. Now that growth and demand have come uncoupled, future projections are much more difficult. Forecasting a return to the usual growth in demand risks bringing on new generation and transmission capacity that will not be needed. On the other hand, utilities that plan for demand to be flat, or even falling, risk being caught short of capacity if demand resumes its historic climb.

Increasing demand was historically a cushion to the electric utility sector. In a world with two percent growth every year, utilities could shuffle their generating fleet, expand their transmissions capacity and overcome any bad bets on generation technologies or new power lines. When demand is flat, changing the fuel mix of the generation fleet requires retiring plants rather than simply adding new plants and allowing attrition to reshape the fleet. This is a more difficult decision financially and politically.

Cheap natural gas has upended the generation stack. Energy Information Administration (EIA) data reported in Figure 2, show the evolution of natural gas prices for electric power generation. The introduction of hydraulic fracturing and horizontal drilling have led to sustained historic lows in natural gas prices (Joskow 2013). Efficient combined-cycle natural gas generators now have operating costs below the average cost for existing coal plants, meaning that natural gas is displacing coal and serving baseload.

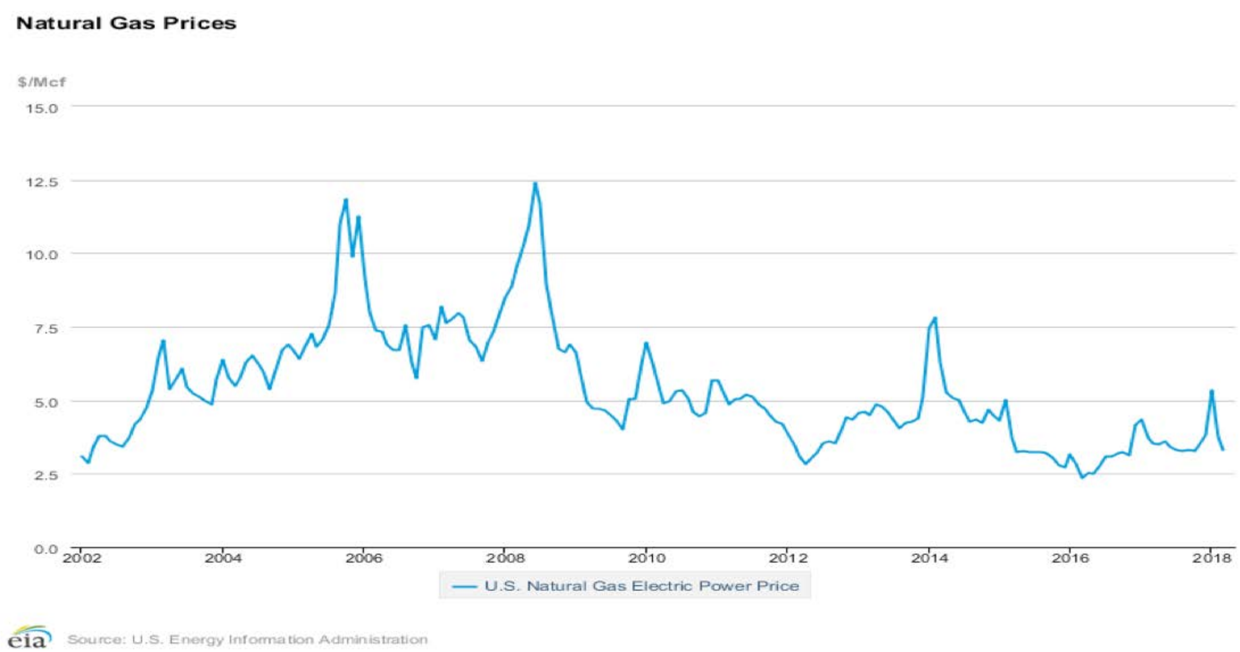

Figure 2: Natural gas prices

Note: Price of natural gas delivered to electric power producers in $/Mcf. The Great Recession ended nearly a decade of high natural gas prices. The introduction of fracking and horizontal drilling prevented prices from rebounding as the economy returned to growth.   Source: U.S. Energy Information Administration Electricity Data Browser.

The changes in fuel price have led to big changes in the installed capacity of the generation fleet. Coal and nuclear generators, the traditional sources of baseload, are retiring and being replaced by renewable and natural gas generating capacity. Figure 3 illustrates the shift in TVA's generation capacity by fuel type. Over the last ten years TVA has gone from having a majority coal-fueled fleet to being primarily nuclear. Over the next decade, the fuel mix is not projected to change significantly due to the stability of nuclear power generation.

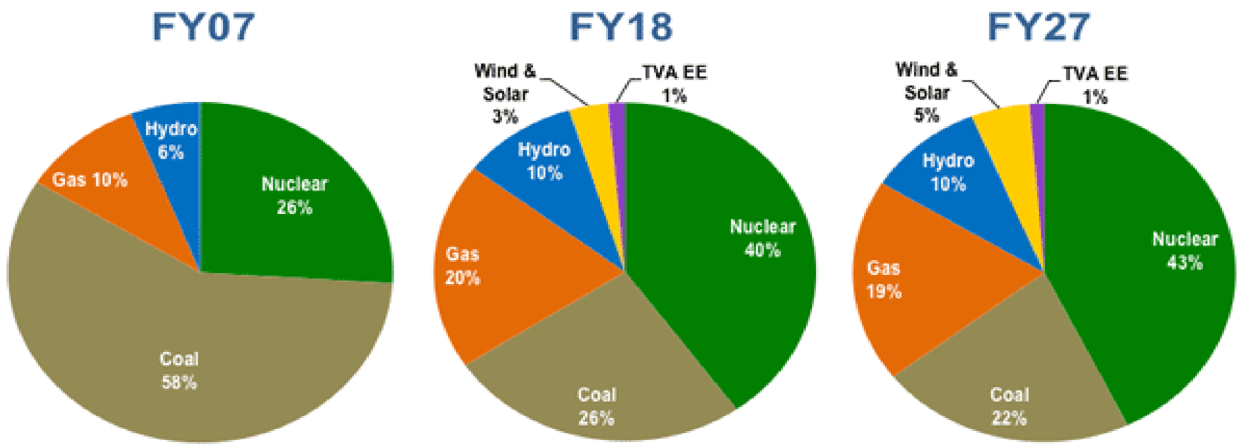

Figure 3: TVA's FY 2018 Budget.

Note: TVA has retired a number of coal plants and brought a new nuclear facility online over the last ten years. The next decade is expected to be fairly stable for the fuel-capacity mix of TVA's fleet. Source: FERC Energy Infrastructure Update, March 2018.

Natural gas prices are near long-term lows and there is little prospect for them to fall further. Dyson *et al.* (2018) find that renewable technologies, paired with bulk electricity storage, are approaching cost parity with fossil fueled plants. If their projections are correct, then future investments in generating capacity should carefully weigh the risks of lock-in to natural gas assets while renewable costs continue to fall.

Section 2: Decarbonization

The first of the three Ds' is decarbonization. Carbon emitters are under increasing regulatory pressure, as well as pressure from consumers and advocacy groups. In 2015 electricity generators accounted for the majority of U.S. carbon emissions.[1] Regulators have focused on carbon emissions from electricity generators because of the high level of emissions and the relatively small number of emitters compared to transportation and industry. The existing regulatory structure also makes it relatively easy to layer on carbon rules.

At the same time, emissions from the electricity sector have been falling rapidly, driven in large part by increases in natural gas generation. Figure 4 reports TVA's carbon dioxide (CO2) emissions from the electricity sector from 1995-2016. Emissions have been falling throughout that time period. They fell sharply during the Great Recession and have continued their downward trajectory ever since.

[1] According to E.I.A., electricity generation accounted for 29% of U.S. carbon emissions. Transportation accounted for 27% and industrial uses 21%.

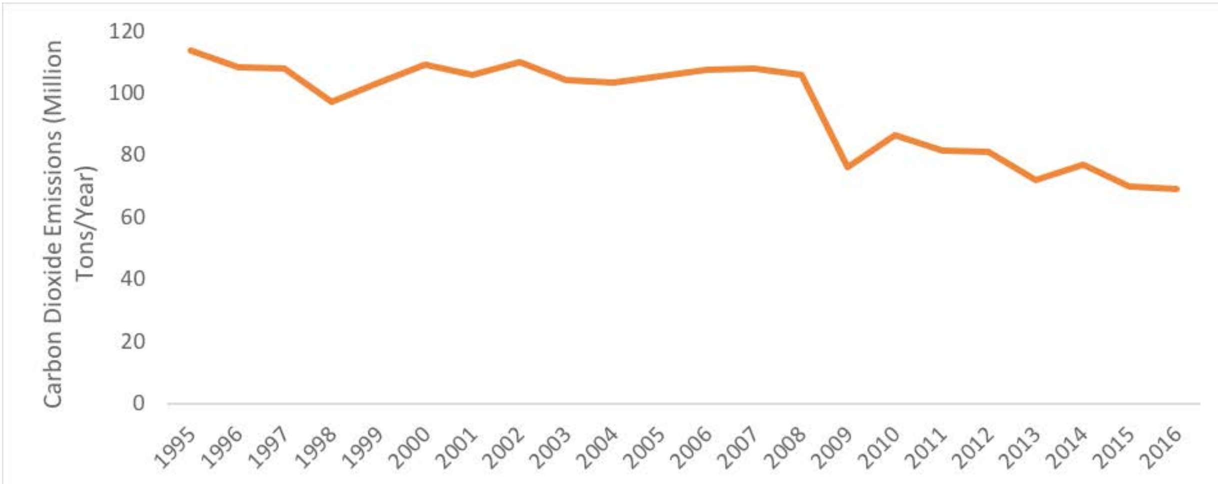

Figure 4: TVA's Carbon Emissions from Electricity Generation

Note: TVA's annual emissions have been trending down for more than twenty years. Emissions are down by more than one-third over this time period. Source: Data collected from TVA's Environmental Stewardship Report.

The regulatory environment for carbon emissions is uniquely uncertain. Regulating carbon emissions is a political hot potato. Congress considered and eventually rejected green-house house gas (GHG) regulations. EPA has proposed GHG regulations in the form of the Clean Power Plan, but they have been remanded in court. The Trump administration is working to roll back or eliminate these regulations. A change in presidential administration or control of Congress could quickly vault GHG regulation back on to the radar. Utilities are making investments with a forty-year lifespan, but the regulatory treatment of carbon emissions is hard to predict even a few years into the future.

Environmental groups have been strong advocates for emissions reductions. In response to their concerns, politicians have subsidized solar and wind generation as a politically feasible way to address the problem. The subsidies take a few forms. As of August 2017, twenty-nine states had adopted renewable portfolio standards, including North Carolina and Virginia. The standards require a certain percentage of generation to come from renewable sources. Households that install solar receive a thirty percent federal tax credit. Wind energy receives both federal investment and production tax credits.

These subsidies, and falling costs, have led to big increases in renewable penetration. Solar output has more than doubled over the past three years. Wind generation is up by over a third. In 2017 renewable generation accounted for 17% of electricity generation, just below nuclear at 20%.

Fossil fuel generators are aggressively exploring carbon capture technologies to mitigate the environmental impacts of burning coal. The potential of carbon capture is tantalizing. Low-cost technologies to scrub carbon from power plant emissions would radically alter the potential for fossil generators to comply with enhanced environmental regulation. These technologies could serve as a lifeline for coal.

Recognizing the potential of these technologies, Congress has extended the 45Q tax credit program for carbon capture research. The tax credit was part of the Trump Administration's budget and had bi-partisan support. A number of projects exploring the technology are in place around the country. Among the furthest along, is a NET Power natural gas plant in Texas designed to have zero carbon emissions.

While the potential is alluring, the technologies are unproven. Leung *et al.* (2014) provide a detailed summary of the technological and business hurdles to the development and adoption of carbon capture technologies. In a low natural gas price environment, the incentive to invest in these technologies to encourage the development of new coal-fired power plants is tenuous. While public and private research and development continues, the lack of a compelling business case for carbon capture limits the scope of investment and thus the rate of technological improvement. In the long run, the benefits of selling carbon credits must exceed the cost of installing the carbon capture technology. The future costs of carbon regulation are unknown and current costs of installing the technology are quite high, making it unattractive for wide-scale deployment.

TVA is well positioned to respond to the decarbonization of the electric power sector. Emissions have already been falling as TVA retires coal-fired power plants and replaces them with natural gas fired facilities. The large nuclear fleet would be a competitive advantage if carbon regulation emerges. The renewable fleet is small, driven in part by the relatively low renewable potential of the TVA footprint. TVA can further limit the impact of decarbonization by adding more renewable generation capacity both inside and beyond the TVA footprint (Murray *et al* 2014).

Section 3: Decentralization

The second of the three D's is decentralization. Perhaps the largest challenge to the legacy utility model is the increasing decentralization of the industry. Fuel prices have always been volatile. Environmental pressures have played a role in electricity markets for at least fifty years. Utilities have considerable experience dealing with these pressures. The increasing decentralization of the electricity market is different. It represents a fundamental break with how we have generated and distributed electricity. *Decentralization represents an existential risk and an opportunity for incumbent utilities.*

Electric utilities are the text book model of a vertically integrated industry, in which a single company owns every piece of the supply chain. In the text book model, utilities generate the electricity at company-owned power plants, transmit over company-owned power plants and distribute to consumers who pay the company a single price per kilowatt hour. The textbook model never fit every utility, but it is quickly becoming an anachronism.

The model of utilities generating electricity and users consuming as much as they want, whenever they want has changed. Public Utilities Commissions have forced utilities to spin off their transmission, generation or both. The grid was designed and optimized to facilitate large amounts of generation at specified locations and to move that electricity to widely-dispersed consumers. Responding to decentralization requires re-thinking this structure.

Sources of energy generation or demand reduction spread across the grid are known as Distributed Energy Resources, or DER. Incorporating DER's is arguably the largest challenge facing traditional utilities. DER's include rooftop solar, demand response and small-scale electricity storage and provide ancillary services like frequency regulation. Introducing these technologies onto the grid changes the need for generation, transmission and distribution. It also changes the flow of power and potentially the utility's ability to control what is happening on the grid.

Technological improvements in solar panels have lowered costs tremendously. Paired with large subsidies for installation in some places, roof-top solar capacity has exploded over the last decade.[2] As

[2] The TVA footprint has lagged the nation in adoption. As of 2016, Tennessee's adoption rate was 0.2%. Alabama and Mississippi had even lower rates. North Carolina was ninth in the nation with 3% penetration. California (14.1), Hawaii (8.8%) and Vermont (7.8%) led the nation.

consumers become producers, the traditional model flips. Distribution lines intended to move power to users may become overloaded when households start generating electricity and putting it onto the grid. Bollinger and Gillingham (2012) show that solar installations tend to be contagious, further stressing the local distribution network. Net metering programs (that account for a consumer's energy use as well as its supply of energy to the grid) and the bundled pricing model of legacy utilities (a single price per kilowatt hour) mean that solar households are often paid more than the cost of generating electricity for their solar.

Demand response is the ability to reliably reduce electricity demand from consumers. Households and companies can receive benefits in exchange for installing technology that allows their demand to be remotely controlled. For example, a household might install a new thermostat that allows the utility to cycle down their air conditioner in exchange for an upfront payment or reduced electricity rates. Employing demand response permits utilities to reduce demand when prices are high, or the system is stressed.

Small-scale energy storage is a relatively new phenomenon. Areas at risk of blackout have long installed backup generators, but batteries represent a cleaner and easier alternative. As small-scale storage spreads on the grid, the ability to control when that storage is charged and discharged becomes increasingly important. Software that allows owners to manage the operation of their storage in real-time has the potential to integrate with utility prices, renewable generation levels and forecasts to manage the grid.

Widespread adoption of DER's adds complexity for integrated utilities, but it also has benefits. Utilities are uniquely positioned with the data and technical expertise to maximize the value of DER's. The market for that management is huge and not surprisingly, several firms have developed products that compete to provide those services. These tend to be tech-savvy startups that can take advantage of advances in computing power to collect data, analyze it and participate in wholesale electricity markets. While some of these firms have developed strong products, there is no need for traditional utilities to cede the field. As owners of the grid and generation assets, they have the experience needed to take advantage of these opportunities.

TVA has introduced some DER, most notably the TVA-EnerNOC Demand Response Program. There is relatively little solar installed behind the meter in TVA due to relatively low solar potential and a lack of state-level incentives. TVA is behind the curve in preparing for decentralization. Its unique regulatory structure and current capacity mix give it time to prepare for and take advantage of the decentralization pressure facing other utilities.

Section 4: Digitization

The third of the three D's is digitization, the rapid increase in technology to manage the grid. Decentralization is facilitated by digitization. The advances described in the previous section are made possible by improvements in information, communication and technology. Utilities have the technology to charge consumers different prices throughout the day in response to conditions on the grid and users can reduce their demand in exchange for lower prices. Consumers can generate their own electricity, store any excess and disconnect from the grid entirely. None of this is possible without a bundle of technological developments that let market participants on all sides share data instantaneously across the grid.

Incumbent utilities have largely been behind the curve on the Internet revolution. Advances in consumer technology have led to changing relationships between producers and consumers in all sorts of industries, but utilities have seldom led the way. Utilities are justifiably reluctant to change, and the relatively low-tech business model has worked well for a long time. Additionally, regulations make it difficult for utilities to invest in new digital opportunities and ensure they earn a rate of return.

The installation of smart meters gives utilities unprecedented information about their customers' usage patterns. Access to this data has the potential to provide utilities with insight to better manage both generation and demand. The sheer volume of data requires technical and statistical capacity to conduct analysis and gain insight—capacity that is not likely present today.

As renewable penetration grows, wind and solar intermittency represent a risk to the stability of the grid. Emerging software and hardware solutions allow utilities to better predict second-to-second renewable energy generation. Integrated with flexible generation, storage or other DERs these solutions allow utilities to manage the intermittency. Managing intermittency requires technically sophisticated grid design, managing and responding to changes in real time. Ensuring the correct response entails analyzing reams of data and cooperation from generators, utilities load serving entities.

Demand response is a particularly attractive opportunity for digitization. Small firms and incumbent utilities are installing demand-response software and selling reductions in demand back to the grid. The combination of demand-response technology and open wholesale markets facilitate this opportunity. These firms can sell demand response capacity to the market when prices are highest and potentially reduce the need for costly investments in transmission and generating capacity.

New technologies have the potential to help utilities manage the grid more efficiently while still meeting consumer demands. New transformers can report their operating status back to the utility. This can be used to efficiently schedule maintenance and prevent failures that lead to outages. Network topology software allows utilities to control the impedance of their lines in real time to optimize power flow and reduce congestion.

Digitization presents the opportunity to manage the grid at lower cost. It also introduces two issues for utilities. The most pressing is cyber security. Managing the digital grid requires integrated technological systems. These systems work together to provide critical services for the grid. Managing data security is a serious national security matter. A second concern is that digitization of the grid is facilitating the breaking of the utility bundle and allowing nimble firms and even competitors to provide services that were once the sole responsibility of the utility.

TVA, and other regulated utilities, are permitted to include capital expenditures in their rate of return. In some cases, new technological solutions are considered operating rather than capital expenditures. These are not incorporated in the rate base and are more difficult to recover from electricity consumers using traditional rate-of-return models. This regulatory structure encourages utilities to solve all problems through increased capital expenditures. Many of the lowest-cost solutions for improving the efficiency of the electric grid are software solutions that regulated utilities are discouraged from incorporating. This puts TVA and other regulated utilities at a big disadvantage in responding to the digitization of the grid.

Section 5: Recommendations

This brief ends with a set of recommendations for TVA. The discussion above has described how decarbonization, decentralization, and digitization are modernizing the electric grid. The grid is changing and there is potential for cleaner energy to be delivered at lower cost with less underutilized infrastructure. The situation is fluid, and the market participants that act quickly have an opportunity to shape the future of the grid and benefit from those changes.

The changes described in this brief are creating more efficient energy dispatch and fewer stranded assets. The age of building new transmission and generating capacity to meet reserve requirements may be coming to an end. Fewer utilities can afford to carry generation capacity that is only used a few days a year, when other low-cost alternatives are emerging. TVA faces different incentives than most utilities, but it still must find ways to make dispatch more efficient or face increased pressure from regulators, policy makers and customers.

This report recommends that TVA:

1) *Continue to reduce the number of rate classes*. TVA has been moving in this direction, including its 2018 rate change proposal to create a single manufacturing rate schedule. They can and should go further. The cost of electricity does not vary by who uses it, neither should the price.

2) *Continue the move towards separating energy costs and non-energy costs*. Charge volumetric prices for energy and a fixed price for all policy costs. The 2018 Rate Change Proposal represents a first step in this process. TVA should continue working with its Board of Directors to align its pricing structure with costs. This approach requires careful monitoring for grid defection. Given current levels of renewable penetration and electric storage costs, grid defection is less of a concern than inefficient pricing.

3) *Move towards granular pricing*. The costs of generation, transmission and distribution vary across time and space, so does the value of DERs. Using a single price everywhere, all the time gives consumers an incentive to arbitrage inefficient pricing against TVA raising the price of electricity for everyone. TVA should take advantage of the flexibility and technology described in this report to begin moving towards charging prices that reflect the cost of electricity generation and paying external resources based on the value they provide.

The move towards granular pricing should happen gradually. For example, by moving from a single TVA-wide price to three or four regions. Similarly, TVA could introduce different prices for peak and off-peak electricity consumption. As distributors and consumers adjust, prices should be further disaggregated to match the true costs of generation in a time and place.

4) *Work with local distributors to promote the use of smart meters everywhere*. Smart meters provide utilities with the ability to price electricity over time. They also provide invaluable insight into customers' consumption patterns. TVA should encourage its distributors to invest in smart meters and aid in collecting, managing and analyzing the data those meters provide.

5) *Explore the potential of DER's to meet capacity requirements*. The TVA-EnerNOC Demand Response Program should be continued and expanded. At both the transmission and distribution level, demand response and other forms of DER should be solicited in places where transmissions constraints or reliability requirements affect dispatch choices. Those DER's should be flexible and linked so that TVA can call them as generation.

Using DER's, rather than capacity or transmission, to assess reliability concerns will require significant investments in TVA's technical infrastructure. The current regulatory approach incentivizes the use of capital expenditures to meet reliability requirements. TVA needs to begin to educate its Board and regulators on the expense of encouraging increased deployment of capital rather than more efficient dispatch. This is a difficult conversation, but as unregulated utilities shift their spending towards software solutions to capacity problems, TVA's efficiency will begin to suffer by comparison.

The largest risk to TVA is inaction. As other utilities adapt to the three D's of decarbonization, decentralization and digitization, TVA's unique regulatory status should insulate it. Over time, if other utilities can respond to these challenges and dispatch more efficiently, they will begin to enjoy costs advantages over TVA. TVA's low-cost structure provides a defense against one final D: *deregulation*. While TVA does not compete head-to-head against other utilities it must face rate setting commissions and convince them that it is being a wise steward for the electricity customers they serve. If TVA is proactive in responding to decarbonization, decentralization and digitization, they will be well positioned for the evolving future of model of utilities.

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