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# Planning for Change in the Electric Power Industry

## A Primer for Transactive Energy Scenario Development

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***Abstract*—The electric power industry and its associated infrastructures (a.k.a. "the grid") are evolving from centrally planned, organized, and operated networks of players, technologies, and resources to systems of systems that are increasingly digitized and distributed in their operation and innovative capacity. Subsequently, strategic planners and technology managers associated with the electric power industry are faced with a range of scenarios to evaluate, including one that considers the emergence of commercialized transactive energy systems in the coming ten-year time horizon. The crafting of a transactive energy scenario can help inform technology innovation and management efforts that benefit consumers, electricity providers, and society by providing planners with a tool to investigate key drivers of change and a range of desired attributes of future technologies that could be employed to address emerging customer needs, wants, and expectations. This paper introduces readers to key elements associated with the market emergence and adoption of transactive energy systems in order to encourage their inclusion in long-term scenario portfolios being utilized to inform electric power industry planning efforts.**

### I. Introduction

The electric power industry and its associated infrastructures (a.k.a. "the grid") are evolving from centrally planned, organized, and operated networks of players, technologies, and resources to systems of systems that are increasingly digitized and distributed in their operation and innovative capacity. While these changes have been unfolding, in some ways, for decades (e.g. digitization), the pace and volume of change has been steadily increasing in both velocity and the degree of long-term impact [1][2][3].

With change arriving simultaneously from almost every direction, electric power industry professionals and stakeholders are addressing the dual-challenge of meeting short-term needs while at the same time planning for the future. Subsequently, technology managers are addressing a range of issues associated with maintaining reliable legacy systems while at the same time planning for and implementing grid infrastructure upgrades with emerging technologies. For retail and wholesale electric utilities, in particular, the stakes are high. Grid infrastructure upgrades are expensive, often taking up to fifty years to acquire a full return on investment. Ill-informed choices today have a real risk of becoming tomorrow's underperforming or stranded assets—with cost impacts potentially reaching into the billions of dollars and diminishing organizational competitiveness for the long-term.

The following research findings have been gleaned from a larger effort associated with on ongoing effort to craft and explore a full range of long-term scenarios and their potential impacts upon the U.S. Pacific Northwest's electric power system. Of the many takeaways that have been unearthed from this exploration, one in particular calls out for immediate communication to other technology management professionals working in the electric power industry—the need to give more attention to the potential advancement of a shared energy economy. Specifically, technology managers and strategists that are responsible to support long-term planning efforts should consider expanding their scenario portfolios to include the emergence of functional, commercially competitive transactive energy systems within the coming ten-year time horizon.

This work is intended to serve as an introduction to various elements associated with the development of transactive energy systems and their adoption by industry stakeholders (both supply and demand), along with some discussion of the policies, markets, and technologies associated with their adoption by market players. What might the emergence of transactive energy system enabled electric grids mean for end-use consumers, electric utilities, and society at large? What elements are acting as drivers? What attributes might be valued by each category of stakeholder? What applications might we expect to emerge? And finally, what scenario indicators might foresight analysts monitor to confirm the ascending or descending nature of the scenario's emergence?

Organizations that own any stake in the future evolution of their local or regional electrical grid have a responsibility and a vested interest in planning for the future. It is not my intent to convince these stakeholders that we are *guaranteed* to witness the emergence of a shared energy economy in the next ten years. My goal is simply to get these stakeholders to open their minds to the *possibility* that this scenario could, in fact, come to pass. After all, if planners cannot open their minds to the possibility of this scenario beginning to play out over the next ten years, then the organizations that they represent are more likely to be caught flat-footed if they are wrong.

### II. Methodology

Many organizations utilize scenario planning to probe future uncertainties (for a range of time horizons), and there are a variety of approaches to develop scenario portfolios. This paper is not intended to provide an overview of scenario development methods; instead, my intent is to provide

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transparency as to the method used to create the scenario portfolio that was instrumental in highlighting the potential emergence of transactive energy systems in the Pacific Northwest in the coming ten-year time horizon.

A long-term scenario portfolio was developed and used as one of the upstream inputs to inform strategy development at the Bonneville Power Administration (BPA)—a power marketing administration housed within the U.S. Department of Energy. This portfolio was crafted over approximately two months using a modular scenario methodology and was designed to be used as the main input for a two-day workshop attended by the full executive team, mid-level managers, and subject matter experts (SMEs)—roughly sixty people in total.

Approximately two dozen SMEs, chosen by the agency's executive board, were tasked with supporting the creation and revision of the scenario portfolio. Due to the aggressive deadline (roughly two months from start to finish, with November and December holidays to consider), it was not possible to meet with SMEs as a single group due to calendar constraints. Instead, each SME was engaged directly by the project manager (me), using a mini-Delphi approach—that is, using a semi-structured interview process, where each SME was initially blind to what other SMEs had already offered as inputs for the scenario portfolio.

Each interview lasted approximately an hour and a half, and was launched with the following question: When you look out into the future, what is the most significant force of change that could affect BPA (and that is addressable, to some degree, through strategic planning)? Once each interviewee prioritized the most significant force of change (from their perspective, of course), follow-up questions were posed to help articulate a title, description, emergence date/date range, indicators, contra-indicators, and implications for BPA. In situations where an SME identified a force of change that had previously been articulated by another SME, they were encouraged to make adjustments to pre-existing content so that their input was reflected in the write-up of that force of change. (However, if they wanted to work with a clean slate, that was encouraged as well.) Prior to sharing the resulting portfolio with any executives, each SME was then given an opportunity to make any additional revisions to the forces of change that they helped craft. Once revisions were received by each SME on individual forces of change, they were integrated into the draft portfolio.

Interviews were completed over a seven-week period and resulted in a portfolio of twelve forces of change. This draft portfolio was presented to a nine-person executive steering committee and was subsequently prioritized to include nine of the twelve forces of change (for use in the approaching executive team scenario workshop). The revised portfolio was then released in its complete form to all of the SMEs for a second round of peer review, but one that invited them to comment on the entire package, not just the force of change that they helped write. Once all SME peer review revisions were addressed, the portfolio was released to the entire executive team as input for the scheduled two-day workshop engagement (with roughly a week's lead time before the workshop).

In the workshop, attendees were divided up into pre-selected subgroups of ten people each, with one or two scenario steering committee members acting as facilitators for their subgroup's overall production. Over the course of two days, each group then explored a series of scenarios where one or more forces of change emerged (and possibly converged). For the workshop, care was taken to frame each force of change as a jumping off point for strategic conversations, often framed as such: If X happens, how could/should the agency respond, strategically?

Ultimately, the scenario workshop was successful in engaging the executive team with meaningful forward-facing, strategic-level content. However, one lesson learned was the acknowledgement that the advancement of transactive energy systems should not be treated as a distinctly separate force of change from high distributed energy resource (DER) adoption (as we had done in preparation for the workshop). Based on real-time observations during the workshop and then some follow-up conversations, it became clear that for *some* electric power industry professionals (especially those whose entire careers have been shaped within a paradigm of central system planning and operations), transactive energy was interpreted as little more than science fiction. From their perspective, the advancement of transactive energy systems was so far off into the future, it seemed pointless for them to dedicate any time contemplating the potential implications. This disconnect may have been avoided (or diminished) if the advancement of transactive energy systems was, instead, embedded into the force of change focusing on high-DER adoption. This intellectual disconnect may have also been made worse by the use of the term "transactive energy," itself, particularly because many utility executives do not have engineering or technical backgrounds. Consequently, industry planners wishing to engage non-technical audiences on this topic should give serious consideration to the use of a more vernacular term such as "shared energy systems" or "shared energy economy" when introducing transactive energy content for consumption.

## III. Literature Review

Compared to past changes in the electric power industry, the current evolution of the electric grid and industry is being catalyzed largely by end-use consumer demand and enabled by the increasing availability of desired technology—which is itself steadily improving in performance and falling in cost [4][5][6]. Politicians and regulators in some states have embraced the opportunities offered by emerging market conditions and have designed policies that support DER-related economic development efforts that also provide environmental benefits. Policies to support the surging growth of solar PV (e.g. net energy metering, feed-in-tariffs, tax credits, etc.) have made it the tip of the spear to many of the changes beginning to unfold across the United States and beyond. Add to this an increase in state-level policies supporting the market growth of distributed storage technologies and parallel advances in the functional capabilities of building- and micro-grid-level energy management systems and it becomes less difficult to imagine a future where large electric utilities aren't counting DER systems in their service territories by the hundreds, but by the thousands or even millions in some places [6]. From an industry perspective, being able to reliably manage DERs at low penetration levels is not too difficult to imagine, but as the DER penetration on any distribution feeder increases, there are significant issues associated with voltage and real/reactive power that must be addressed to avoid outages [7].

The GridWise Architecture Council (GWAC) has taken note of the "mega-trends" associated with DERs (e.g. cost declines, performance improvements, consumer interest), played it forward, and has been working on establishing a common architecture that may satisfy the requirements of a transactive energy future that emerges on the heels of a high-DER penetration scenario [6]. GWAC defines transactive energy as "a system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter." The Transactive Energy Association expands on GWAC's definition slightly: "Transactive energy engages customers and suppliers as participants in decentralized markets for energy transactions that strive towards the three goals of economic efficiency, reliability, and environmental enhancement" [8]. Importantly, the latter definition is geared toward explaining transactive energy to a wider audience than GWAC's more industry-facing definition. Either way, both definitions are built around a core assumption that transactive energy includes both electricity producers and consumers in a value-driven exchange of electricity and data, capable of flowing bi-directionally between parties that may be scattered across both distribution and transmission systems.

The technical and academic literature published, to date, about transactive energy can be divided into two basic categories: one associated with hands-on learning associated with pilots and demonstration projects; the other associated with more traditional academic explorations of various elements associated with transactive energy as an emerging technology (or system of technologies).

There is a lot that can be learned by studying some key pilot and demonstration projects that have been undertaken in the past fifteen years. Three efforts, in particular, deserve some intentional review by technology managers and power industry strategists.

The earliest transactive energy project in the United States was the Pacific Northwest GridWise Testbed Demonstration Project, implemented on Washington's Olympic Peninsula between 2004 and 2007. Key parties involved in the project included local end-use customers and retail utilities, BPA, Pacific Northwest National Lab (PNNL), and IBM. The most significant findings from the experiment included the confirmation that end-use loads were capable of responding to price signals from grid managers and that grid-level coordination of demand response and distributed generation could help manage peaks and grid constraints [9].

Another important demonstration project was executed by American Electric Power Ohio, PNNL, the Electric Power Research Institute (EPRI), and others between 2010 and 2014. Like the Olympic Peninsula project, the AEP Ohio gridSMART Demonstration Project also exposed end-users to (near-real-time) market prices, using transactive signals to facilitate the management of end-use loads to address distribution-level grid needs [10].

A third project worth review is the Pacific Northwest Smart Grid Demonstration Project, implemented by PNNL (Batelle), BPA, regional utilities, and many other stakeholders between 2010 and 2015 across a five-state area. The project represents the largest smart grid demonstration carried out in the United States, to date, and made use of a revolving five-minute market signal communicated to end-use loads through 27 different pricing nodes spread across the region's transmission system. [11]

Some of the most common challenges associated with all three projects involved the interoperability of various technologies/products, the efficacy of differing communication pathways between equipment, and a range of issues associated with data ownership and data sharing privileges. But as a whole, all three projects demonstrated that end-use loads are, in fact, capable of responding to distribution and/or transmission operator signals. Importantly, though, each of these projects was concerned with advancing the capabilities associated with operating a transactive energy system from a distribution and/or transmission system management perspective.

Other research and demonstration efforts have recently been carried out that explore the efficacy of transactive energy systems from the perspective of end-users and non-utility parties. LO3 and Siemens, for example, have been working together to enable peer-to-peer transactions at the neighborhood level in Brooklyn, New York since 2016 [12]. Their approach, which utilizes blockchain technology to manage transaction accounting, has shown enough promise to begin replicating them in Texas and Japan [13].

Sonnen (acquired by Shell in 2019) launched a non-utility-based transactive system in Germany, Austria, and Australia in 2016 [14]. This program, called Sonnen Community, has enabled owners of Sonnen battery systems to trade power with other end-users with similar systems (that are registered members in their trading platform). Sonnen also recently began working with new home construction companies to design and build solar-plus-storage enabled *communities* in Arizona and Florida [15][16]. Sonnen's goals are to enable the neighborhoods to be mostly self-sustaining, relying on access to grid-supplied power primarily during early morning, off-peak hours to charge up the neighborhoods' batteries with low-cost energy.

While some planners could be inclined to disassociate these latter efforts from the flavors of transactive energy presently being explored by the national labs and utilities, we should all be taking note of the continually evolving structure, variety, and performance of the fullest range of emerging end-user-oriented systems being tested and commercialized. There is a lot of innovation being driven by these kinds of projects, and while it is presently unclear how they might continue to mature, they are indeed continuing to mature.

As pointed out above, perhaps the most significant driver catalyzing research into the development and operation of transactive energy systems is the trend toward increased commercial adoption of DERs. In 2015, EPRI published a benefit-cost framework that examined some of the key implications of DER proliferation. [17] Unfortunately, while offering significant insights into some important issues associated with DERs, EPRI's "integrated grid" framework failed to consider the concurrent advancement of transactive energy systems. Fortunately, other scholars and industry practitioners have offered high-level perspectives that can supplement EPRI's work.

Farrokh Rahimi, Ali Ipakchi, and Fred Fletcher crafted a high-level description of the changes occurring in the electric power industry, providing readers context to help understand the development of transactive energy systems [18]. Ron Ambrosio offered an additional interpretive summary of the big picture, while also warning about the risks associated with failing to proactively manage DERs in a high-adoption scenario [19]. Similarly, David Holmberg, David Hardin, Ronald Cunning, Ronald Melton, and Steve Widergren provided a high-level overview of the transactive energy "application landscape," while also articulating use-case applications and scenarios for consideration [20]. Readers should also review L. Kristov, Paul Demartini, and J.D. Taft's work that clearly laid out two different visions of transactive energy systems that have been advanced by GWAC members [21]. And, for an additional perspective on various field research efforts that have taken place in the United States and Europe, readers would benefit from reviewing a summary and analysis offered by Koen Kok and Steve Widergren [22].

Academic researchers have also been contributing to the advancement of transactive energy systems. As might be expected, a considerable amount of work carried out within academia has involved different modelling approaches designed to explore particular areas of focus. Work by M. Nazif Faqiry and Sanjoy Das [23] and by Jianming Lian et al. [24] evaluated the performance of dual-auction transactive energy systems. Research carried out by Muhammad Babar et al. [25] and P. Hasanpor Divishali et al. [26] used modeling approaches to explore the effectiveness and implications associated with transacting energy in systems populated by multiple agents distributed across systems.

Other modeling efforts have similarly explored issues associated with coordination and control of multiple assets (i.e. aggregation). Junjie Hu, Guangya Yang, and Yusheng Xue utilized nodal pricing to explore costs and benefits accruing to different actors in a system [27]. And other studies, like the one undertaken by M. Salman Nazir and Ian Hiskens explored operational impacts stemming from the convergence of multiple factors (e.g. load synchronization, system oscillations, and price volatility) [28].

Some scholars have focused their efforts on microgrid-level studies. Fernando Lezama et al. utilized modeling simulations to help determine the efficacy of using microgrids to help integrate renewables and support energy trading [29]. Yang Chen and Mengqui Hu investigated how interactions between microgrids (within microgrid clusters) can optimize power management and add value to all collaborating parties by leaning on each other's systems [30]. And Mousa Marzband et al. simulated collaborations among residential parties to optimize revenues through coalition-based behavior [31].

Additional studies have been carried out with goals of identifying ways to optimize revenues for individual end-users (instead of looking at system optimization), including research done by Jiayong Li et al. [32] And still more efforts have focused on understanding the potential values offered by transactive systems, more generally. In particular, Jenjie Hu et al. conducted a valuation study of a network-constrained transactive energy system [33], and Qiuhua Huang et al. have developed a valuation simulator that can be used to compare the value of various transactive energy system frameworks [34].

The ongoing evolution of microgrid systems has also provided scholars with an area of focus for transactive energy research. In this space, some research teams, such as Nahida Akter et al. [35] and M.E. Khodayar et al. [36], have investigated and proposed different analytical and system frameworks for consideration. Other research teams, such as Samantho Janko et al. [37] and Weijia Liu et al., [38] have focused their efforts on various collaboration and coordination issues associated with the operation of multiple microgrids.

And finally, some scholars have focused their research on the exploration of system coordination issues that could arise between distribution and transmission systems. Farrokh Rahimi and Ali Ipakchi explored how microgrids can maximize revenues by providing services to legacy systems (retail and wholesale) [39]. Junjie Hu et al. also explored some likely coordination challenges, proposing a framework for how to aggregate DERs to provide services to transmission systems in ways that avoid negatively effecting system reliability at the distribution level. [40]

## IV. Market And Policy Drivers

The commercial adoption of transactive energy systems is (to a great degree) dependent upon the adoption of enabling technologies—most importantly DERs, which have, by and large, been supported by local, state, and federal policies [6][[41][42][43]. At a minimum, attention to the following cluster areas, in particular, should be integrated by planners into organizational foresight efforts:

- Renewables: Renewable portfolio standards, net energy metering, and state/federal incentives
- Battery storage: Self-supply, demand response/load management, demand charge avoidance, dynamic rates, state mandates, and co-installation/operation with renewables
- Electric vehicles: Emissions reduction targets, electrification efforts, and incentives
- Microgrids: Resiliency strategies, programs, and projects

Consumer eagerness to import and export electricity from non-utility parties is, to no surprise, directly related to both the retail price of electricity and to the rate of utility compensation for customer-generated exports.

Net energy metering (NEM) programs are a key contributor to the development of viable state-level distributed generation markets (especially for solar PV). They have typically been launched with compensation rates set at retail rates, which both reflect and reinforce consumer expectations in regard to policy fairness.

As utilities lower (or threaten to lower) NEM compensation rates, or when rates are lowered due to any other reason, consumer interest to buy and sell electricity from non-utility players will likely increase. Essentially, any significant differential between any utility's retail rate and their compensation rate for consumer-generated power will create an economic environment for a peer-to-peer market to develop once transactive energy platforms are commercialized [41].

Having access to a reliable transactive energy platform promises to offer value for consumers of all sectors, distribution utilities, and bulk-grid operators [44].

Consumers can benefit from achieving various degrees of energy independence, lower utility bills, access to clean energy, and improved resiliency [45].

Distribution utilities can benefit from the advance of transactive energy through the application of distribution-level trading platforms to help maintain reliability and potentially increase revenues through the offering of DER-related sales and services [46].

Bulk-grid operators can benefit from the enablement of demand-side grid assets that can be utilized to avoid and/or alleviate transmission system congestion and to provide increased flexibility in regard to management of power generation (e.g. increased flexibility with hydropower generation to accommodate non-power requirements like fish passage) [47].

That said, regulatory reform is necessary to commercialize transactive energy platforms and enable a shared energy economy. When utility retail rates are undercut by increasingly cost-effective substitutions, utility revenue will suffer (especially at those utilities whose business models are still based on the volumetric sale of electricity). This will, in turn, increase pressure on utilities to recover their costs from a shrinking pool of customers, potentially saddling them with a disproportional burden of distribution grid operation and maintenance costs [48]. Regulators must balance the needs to open competition, expand market participation, modify utility business models, and protect non-participating electricity customers [44][49] [50].

## V. Technology Landscape Exploration

Transactive energy concepts are still relatively new, and they are being developed under the shade of more than a century of centralized systems thinking, one-way power flows, and captive/dependent end-use consumers. With the above descriptions of transactive energy in mind, even a cursory exploration of consumer, utility, and societal-level perspectives and plausible experiences can inform our maturing dialogue on this new, certain-to-be-disruptive direction that the electrical grid *could* begin to transform into over the coming decade. Technologies have played a significant role in the story afoot so far. No doubt they will continue to do so over the coming decade. But what technology attributes/functions and applications might we expect to be developed and commercialized as part of the larger network of grid points that is, itself, the foundation for a network of transactive energy platforms?

### End-Use Customers, Utilities, and Society

Beginning with end-use consumers, since they have been understandably credited by many as being the key driver to the changes occurring behind-the-meter, what are we seeing [51][52]? What can we expect to witness as time marches on? Already, we are observing strong interest in solar PV, for which markets are expanding and prices are falling. Early adoption consumer interest in rooftop solar has been driven in large part by consumer desires for intangibles like freedom, security, and control. State-level NEM policies and enticing entry-level financing products have, at least for now, satisfied consumers' needs for a cost-effective energy independence solution. Not only can consumers use existing incentives and policies to their advantage, but they can often do so with little or no money down. In the process, they have the potential to secure their home against blackouts (if their inverter is appropriately enabled), reduce their dependency on their electric company, enable themselves to fuel their own home and transportation needs with sunlight rather than fossil fuels, and even increase the value of their home by 10 to 15 percent. [53]

For all the advantages that a cost-effective solar PV system has to offer consumers, utilities have been typically pretty cold toward the continued market adoption of this technology. After all, as solar PV penetrates their territories, it reduces their load-serving obligations to each customer that "goes solar," ultimately eroding revenues at the same time additional investment is needed to upgrade their infrastructure. Utilities have responded, on the whole, by aggressively pursuing changes to state-level NEM laws (which direct utilities to financially compensate end-users for any power they export into the grid). In the past several years, for example, utilities have fought to reduce compensation rates from retail levels down to wholesale levels.

Over time, we can expect that utility/rate-based compensation levels for end-use-customers' exported power will likely fall—either from modified NEM rules or because of higher PV penetration (as more PV is added to the system, the output from each becomes worth less to markets—especially during periods of oversupply). Solar companies have already been preparing for this contingency, however, and have responded by partnering with battery installers in order to offer solar + storage systems that enable a strong self-supply value proposition. As it turns out, consumers are being greeted with battery trends running similar to, if not roughly 6 to 8 years behind, solar PV. Batteries are quickly falling in price at the same time that their performance continues to improve. Ironically, that means that even if or when utilities "win" the policy fight over net metering, they will likely drive their customers to embrace solar + storage systems, reducing utility load-serving requirements *even more* than would have happened from stand-alone solar PV systems tied to NEM programs. And in the process, some utilities could even actually alienate those same customers.

So far, this seems to shape up a future where consumers that can afford to invest into solar PV or solar + storage will be doing so with self-supply in mind. For transactive energy to really take off, one more function, at a minimum, must be satisfied (at the consumer level): automated energy management. Very few people are likely to want to spend any part of their day actively monitoring energy use, forecasting power needs, evaluating market prices and opportunities, and actively engaging in nano/facility-scale energy trading. For the vast majority of people, transactive energy won't satisfy their needs and expectations unless it is fully automated—ideally with a self-learning agent that can make decisions in the best interest of consumers with a minimal number of pre-determined preferences.

Imagine a future consumer looking to export power to the grid in a policy environment where net metering compensation rates have been lowered to wholesale prices, say $0.04/kWh, if they were to export power to their utility. If the utility requires them to purchase power at $0.10/kWh, they will likely be interested in having their agent explore and exploit any opportunities to sell power to anyone who will pay more than $0.04/kWh. Without an automated agent doing it for them, they would likely not see the value; however, if they didn't have to think about it and it was automated, many people would be enticed to do it. The sense of unfairness engendered by changes in utility compensation (for right or wrong) will likely even become a driver for some consumers to engage in a transactive energy system as an alternative to utility-supplied power. But, so too might the generation mix of utilities. If customers can't get clean power from their utilities and they *really want it*, they will get it from somewhere else if they have access to a viable substitution. Once the technologies are available, and the customer desire is made clear to regulators, we are bound to see movement, first, in more future-leaning states with a robust adoption of distributed generation and storage (e.g. New York, California, Hawaii). Soon after, other states will follow suit—maybe not everywhere, but in a lot of wheres.

Beyond the development and acceptance of automated energy trading (at the end-user level), we can also expect to see some technology-enabled energy banking services, a range of mobility services, and the use of products that offer real-time observation and control. Energy banking could offer value by helping to integrate variable energy resources and could potentially support the lowering of electricity costs. Twenty-four-hour products might work just fine for solar generators in year-round sunny climes. Every day they could deposit their excess daytime production into their account and then withdraw it for nighttime needs. Others might need deposit/withdraw accounts that cover one, two, three or more weeks if they live in areas that get regular batches of multi-day cloud cover.

Utilities (and the people who work for them) are in a tough place. The first wave of change (DER adoption) is setting off metaphorical fires in regard to utility obligations to maintain reliability and subsequently threatening to increase costs at the same time that revenues are being eroded. Making matters worse, utilities often rely on deterministic planning models that only account for past actions in regard to resource additions and policy. That means that many planning models use data from the year prior and then make out-year projections based only on *existing* policy. Over reliance on these kinds of models can create a false sense of security because they fail to estimate the impacts from significant changes to the status quo. Risk can be mitigated if the models are run frequently; unfortunately, large model runs used for power or transmission/distribution planning are often only run once per year, and they will always misrepresent industry activity taking place during rapid or high-impact periods of change to the industry. All this to say that by the time that many utilities wake up to the reality of what is happening around them, it might be too late for them to remain solvent without a rapid change to their business model. Their survival might just rely on how well they can pivot their business models to earn revenue from selling DER-related products and services that a portion of their customers are eager to utilize. And if they don't, someone else probably will.

For those utilities that proactively embrace the role of being a distribution services provider, the use of some form of distributed energy resources management system (DERMS) will likely be a necessity. In fact, it is difficult to imagine any medium-sized or larger utility being able maintain reliability without the use of a DERMS in a high-DER adoption scenario. Not only will they need it to alleviate certain reliability contingencies (e.g. peak management, balancing, oversupply), but they will also need it to maintain visibility and control of end-users wishing to participate in wholesale market and bulk-grid programs. Additionally, strategically minded utilities will want to limit their investment risk by utilizing customer investments into DERs in as optimal a fashion as possible. By aggregating DERs, retail utilities can lean on local resources and right size their grid modernization investments in distribution-level infrastructure. Not only will this help avoid a considerable amount of redundant spending, but it will reduce the utilities' risk of investing into underperforming or even stranded assets.

The most ambitious utilities and bulk-grid operators may also want to host or co-host transactive energy trading platforms. These platforms will provide their customers with a mechanism to engage in peer-to-peer energy trading or in aggregation programs that trade on their behalf with the resources made available to the platform host. For utilities, subscription and wheeling revenue can help address the diminished revenue streams associated with their shrinking volumetric sales. Of course, bulk-grid operators could potentially do the same—along with new entrants. This area of business may become a hotspot for competition, with first-mover benefits driving action by aggressive players in the industry.

Even if this transition is difficult for utilities, a shared energy economy could offer significant value to society as a whole. Community resilience in the face of natural disaster will be enhanced. Economic development activity will provide needed jobs and revenue to states and communities, with the advancement of peer-to-peer trading keeping dollars circulating in the local economies longer than if they were paid to the utility (particularly in regard to investor-owned utilities). The establishment of regional-level peer-to-peer transactions could even provide a much-needed boost to rural economies, where people who can build oversized systems can sell surplus output into both urban and some rural markets (where opportunities for on-site generation are more limited). Much like the local foods movement, we could see some positive relationships develop at a time when the rural-urban divide has been defined, in part, by the *lack* of relationships—especially *positive* ones. And, beyond all this, renewable DERs can help society accomplish at least a portion of the emissions reductions required to stave off the worst impacts of global climate change. But, for all of it to work, the technologies associated with the shared energy economy will require a high degree of interoperability. If trading platforms are established with closed system, proprietary technologies and communication protocols, instead of a shared energy economy, there will likely be a more balkanized set of transactive energy platforms that may or may not allow for trades between distribution systems.

## VI. Potential Indicators & Contra-Indicators

As pointed out above, conditions are beginning to align that now indicate the *potential* birth of commercialized transactive energy systems within ten years in the Pacific Northwest (faster in high-DER adoption areas). For planners that consider this scenario as a plausible possibility, it will be necessary to integrate some type of monitoring function into whatever form of foresight program or function that their business has for such needs. Here, indicators and contra-indicators can be very useful—providing a discreet list of trend points or milestones to regularly evaluate. If a planner starts checking off indicators as having taken place, they can raise an alarm for proactive action. Conversely, if the contra-indicators start getting confirmed, then they can document the diminishing likelihood that the scenario will emerge into reality. Below are examples of potential indicators and contra-indicators that can be used by planners in the Pacific Northwest to monitor the emergence of a shared energy economy scenario over the coming decade. This list has yet to be confirmed and/or revised by electric power industry-related experts, and it is included below to provide a starting point for planners rather than as anything final.

**Indicators**

1. Net energy metering compensation is reduced from retail level to something closer to the wholesale level.
2. Smart meters reach 25 percent penetration in PNW.
3. Smart appliances become widely available.
4. Battery storage becomes cost-effective in the PNW (either independently or as a renewable-plus-storage hybrid project).
5. Distributed generation penetration reaches 5 percent in Oregon and Washington.
6. Blockchain-based transactive energy pilots prove successful (establishing a viable, auditable accounting tool).
7. Peer-to-peer (P2P) trading attracts the attention of regulators in California, Oregon, or Washington.
8. California launches a P2P pilot.
9. Major industry technology/software providers offer transactive energy platform subscriptions/services (e.g. OATI, Siemens, ABB, IBM, etc.).
10. Transactive energy systems/platforms become operational (beyond pilots and demonstration projects) in any of the following countries: Australia, United Kingdom, Germany, China, Japan, Denmark, or Norway; domestically in Hawaii, California, or New York.

**Contra-indicators**

1. Cybersecurity vulnerabilities are exploited, with drastic consequences, causing a chill in further commercial adoption of transactive energy systems.
2. Battery storage proves to be a false promise (low costs never materialize, performance/safety is sub-par).
3. Smart appliances do not penetrate markets.
4. Statutory/regulatory hurdles prove to be too high, with failures in policy advancement in multiple states.
5. The lack of confidence in existing financial accounting and settlement mechanisms limits consumer and investor trust and acceptance of P2P transaction platforms and business models.
6. Regulators and/or utilities establish conditions that make switching costs for end-use customers sufficiently high enough that they reject non-utility offers for power service substitution.

## VII. Conclusion

While the market trends associated with DER adoption seem unstoppable, today, the future is still far from certain. Countervailing forces such as global conflict (e.g. hot wars, trade wars) and/or severe economic depression could still change things in unpredictable ways. That said, outside of a *major* disruption to the mega-trends already underway, many industry analysts (myself included) expect to see continued DER adoption by consumers—even if federal intervention causes the trend to slow in the short term. Utility staff are thus faced with a choice: either disrupt their own business models, proactively, in a way that embraces DERs and turns them from a revenue threat into a revenue opportunity; or continue their business-as-usual mode until new entrants disrupt their business models for them. As with other industry-wide digital transformations, the threat of utility insolvency is not likely to bring the ongoing changes to a halt. The trend toward transactive energy will likely continue gaining steam even in the face of the fatal disruption of some laggard utilities.

Finally, it is important to remember that the current evolution of the grid is not being driven by utilities; it is being driven by consumers and the increasing availability of cost-effective alternatives to electric utility-provided products and services. The insolvency of slow-moving utilities will ultimately be footnotes to the bigger story, becoming talking points in a larger conversation—much like Kodak and Blockbuster are often referred to today. Players will change, but the industry will survive. Phone companies did not disappear when telecommunications shifted to distributed, digital technologies and business models. Banks did not disappear with the advent of online banking. TV, radio, and movies did not cease offering new programing with the advent of online streaming and download services. As much as change is certain, any sustainable transformation in the transaction of energy services will still need to satisfy consumer demands for safe, reliable, convenient electric power provision. Odds are good that even if transactive energy emerges to take its place in the sharing economy of the 21st Century, it will not obviate all the artifacts of the current centralized electric power system. The poles and lines will still be there. Many of the centralized power plants will survive. The majority of utilities will likely survive (once they modify their business models). And, consumers will still want electricity. The infrastructure utilized to meet consumer wants and needs will be more automated and distributed, but even with all of the changes, it is likely to continue to maintain a quazi-invisible status. After all, most people only become aware of the electric grid and its many parts when it is not working correctly or is unavailable for some reason.

Transactive energy systems will not enable a one-to-one replacement of the current electric power infrastructure—even if utility business models are forced to change. That is not to say that the onset of a shared energy economy would not be disruptive. It will most assuredly be that. But, hopefully, the development and use of scenarios that include the commercial adoption of transactive energy systems will help power industry planners and technology managers proactively prepare for this potential future.

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