LEADING-EDGE TECHNOLOGY EVOLUTION AND THE NEXT GENERATION UTILITY

DynamicEnergy™

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1. EXECUTIVE SUMMARY

The electric utility market is in a state of transformation, driven by the development and growth of a new class of distributed energy technologies — rooftop solar PV to start, but eventually behind-the-meter batteries, smart and flexible load controls, and grid-integrated electric vehicles, which are also on the rise. And there is no guarantee that today's electric utilities will maintain their position as arbiters of how this growth takes place — or that they'll profit from the transition.

Unlike almost every other major development in the electric industry over the past 100 years, today's changes are not coming from the top down, but rather from the bottom up — or, perhaps, from the edges in. For the electric grid, the edge consists of customers — the residential, commercial and industrial "accounts," "loads," or "ratepayers," — who now have the opportunity to reduce costs and meet sustainability goals, participate in power markets, and create more transparent and customizable relationships with their energy providers.

And those energy providers do not necessarily have to be their traditional distribution utility, opening the threat of "disintermediation" by players such as retail energy providers in competitive markets, enablers of direct access or community choice structures in reformed vertically integrated markets, and the aggregators of the PV, batteries, EVs and smart loads that are making this transformation possible.

This transformation is creating both threats to and opportunities for change in the traditional way of doing business. Utilities and other energy companies have to address this challenge head-on by developing new product lines, improving customer service, bolstering reliability, and reducing costs. Regulators are taking note of the benefits technology can offer to both customers and utilities and exploring new incentives and business models.

In this report, we delve into this dynamic set of developments and suggest a new way of looking at the future of the electricity system, a paradigm we call DynamicEnergy™. It's an energy environment in which two-way transactions become the new normal. In the DynamicEnergy™ model, load can follow supply as reliably as supply now follows load, with customer behaviors triggered by price and engineering conditions, and with the ever-shifting demands and supplies of the energy network controlled by intelligent and automated equipment.

Key elements that will be explored to provide a better understanding of this DynamicEnergy™ future include:

- Critical technologies that provide the capabilities needed
- Stakeholders and market context
- Applications and opportunities
- Threats to the traditional utility business model
- Effective strategies utility executives can employ for navigating this evolution.

Through this analysis, we will seek to illustrate how the Next Generation Utility (NGU) will leverage new technologies and incorporate them into a broader reimagining of the electricity market to set the stage for a DynamicEnergy™ future.

2. TECHNOLOGY EVOLUTION AND THE UTILITY PATH

As new technologies transform the electric industry, a host of opportunities and threats are emerging. Utilities are now better able to monitor and control grid operations at both the transmission and distribution level. Customer engagement has moved online, opening up many new possibilities. Customers themselves are adopting new technologies such as building management systems, learning thermostats and smart appliances, solar panels, electric vehicles, energy storage systems and backup generators.

These applications have achieved varying levels of maturity and cost-effectiveness. However, the technologies underpinning them are rapidly accelerating. The clearest example of this is the rapidly accelerating cost-to-performance improvements in solar PV, and to a lesser extent, battery energy storage, as the total cost of a commercial 2- to 4-hour lithium-ion energy storage system dropped from \$3,400/kilowatt-hour in 2010 to \$1,600/kWh in 2014 (GTM Research).[1]

The adoption of new technologies will in turn create new opportunities and expectations across an interdependent and increasingly complex energy value chain. It begins with customers, who are demanding a more transparent and customizable relationship with their energy providers to match the experience they're now getting from other business relationships.

In terms of distributed energy technologies, some are enabling customers to participate directly in grid operations, providing a new source of competition in what has long been the exclusive domain of utilities. An analogy can be drawn to the "sharing economy" enabled by companies such as Uber and Airbnb. Why should your plugged-in electric car, smart thermostat or Powerwall battery sit idle when they could be earning money by providing grid services such as frequency regulation or ramping reserve? What's more, there is no sign that this transformation will be slowing down. As technology becomes increasingly digitized, practically anything that consumes electricity can become part of the "internet of things."

On the utility side of the equation, distributed IT and ubiquitous connectivity can serve as a platform for improvements in traditional utility tasks, or as jumping-off points for new services. There are already numerous examples of utilities reporting improvements in service reliability of over 35%, enabled by the deployment of sophisticated analytical capabilities. The Electric Power Research Institute has found that smart grid technologies contribute to reducing energy losses equivalent to between 2 million and 16 million metric tons of CO_2. New technologies are increasingly being used to help meet sustainability goals and integrate renewables. The U.S. Energy Information Administration estimates that new energy technology has the potential to reduce global CO_2 emissions by more than 2 gigatons per year by 2050, an important contribution to the global goals outlined at the Paris climate conference that took place in December 2015.

Globally, regulation is adjusting, and in some cases driving the industry to adopt these technology opportunities. In the U.S., utility commissions across the country have active proceedings on distribution.

Competition in this field is intense. A vast array of electrical equipment manufacturers, information and communication technology specialists, construction companies, consumer product companies, and innovators are all vying for a share of the global utility technology market. GTM Research estimates this market will be worth \$400 billion by 2020 (*Global Smart Grid Technologies and Growth Markets, 2013-2020*).

1. North American Microgrids 2015: Advancing Beyond Local Energy Optimization, GTM Research, July 2015.

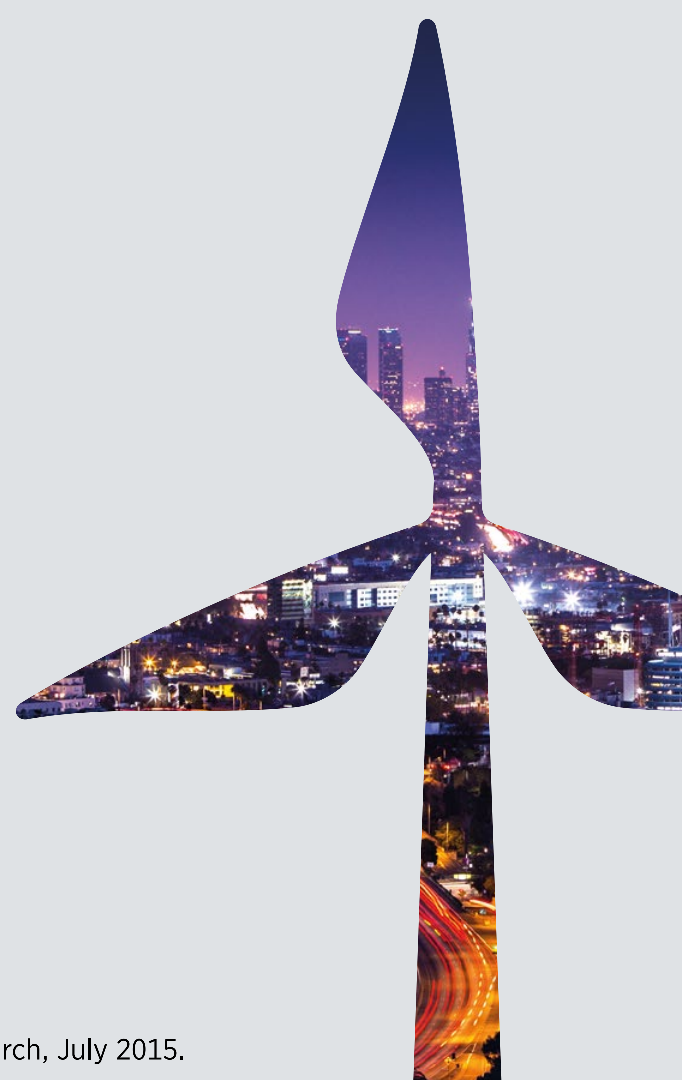
3. DynamicEnergy™

Defined: designing for the future.

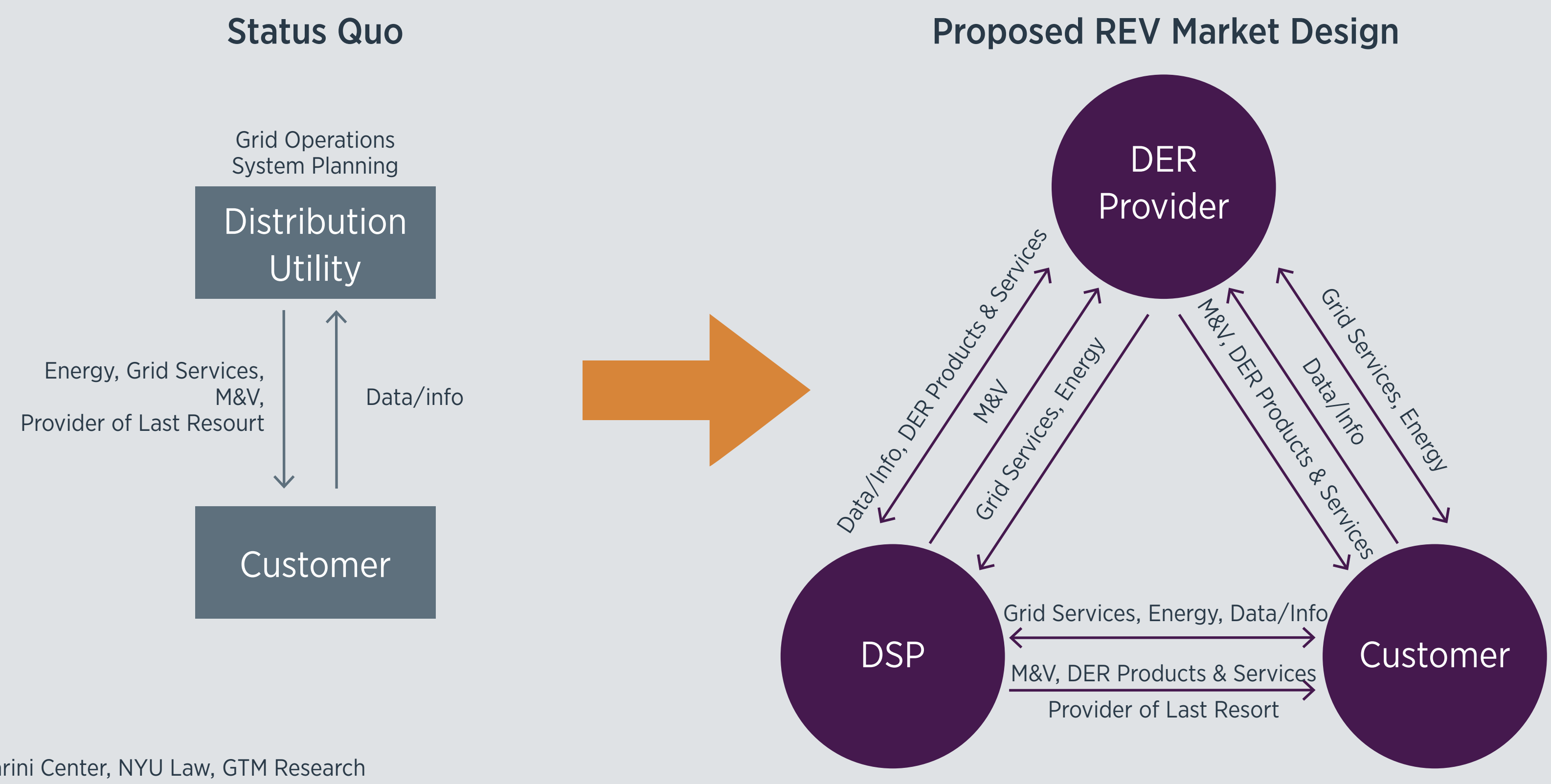
While these "utility of the future" concepts go by a number of names, we like to call the whole vision DynamicEnergy™. DynamicEnergy™ is a future state enabled by technology, in which the line between producer and consumer is blurred. In an ideal DynamicEnergy™ state, all parties in the electricity market are able to participate in two-way transactions, with responses triggered by price and engineering signals, and with full automation and machine learning to increase the transparency, efficiency, reliability and speed of grid operations.

The role of traditional players — market operators, transmission and distribution companies, and generators — is radically different in the world of DynamicEnergy™. In today's system, power flows one way, from generator to consumer, and the financial rewards largely flow in the opposite direction, with transmission and distribution systems built mainly to accommodate new growth and with little flexibility to incorporate energy-aware or generation-enabled customers. But in the future where "prosumers" (producers-consumers) are capable of generating and selling their own energy an integrated community or corporate microgrids can organize these edge players into larger groups. The utility's role could evolve into serving as a source of backup power and last-resort stability, rather than providing the sole source of energy.

In places like California, Texas, New York and other Northeast states, elements of this concept are being piloted and demonstrated today. According to GTM Research, microgrid capacity is expected to more than double by 2020, with the market for microgrid infrastructure — which includes project development, generation, and distribution enhancements — growing by 267% between 2016 and 2020.[2]



2. North American Microgrids 2015: Advancing Beyond Local Energy Optimization, GTM Research, July 2015.



Source: Guarini Center, NYU Law, GTM Research

For these distributed energy assets to function in the most cost-effective and system-supportive manner, they'll require a flexible and transparent virtual grid architecture that is open to both utilities and eligible third parties. In this architecture, central hubs will continue to facilitate and manage transactions at both the wholesale and retail levels, and set the standards by which third parties can participate. In some locales such as Australia and the U.K., a central operator already facilitates "the market in the middle," enabling transactions through auctions and other real-time mechanisms. Looking to the future, these centralized hubs or marketplaces will expand to fully embrace the provision of dynamic and diverse products and services across the energy value chain while maintaining economic and engineering constraints.

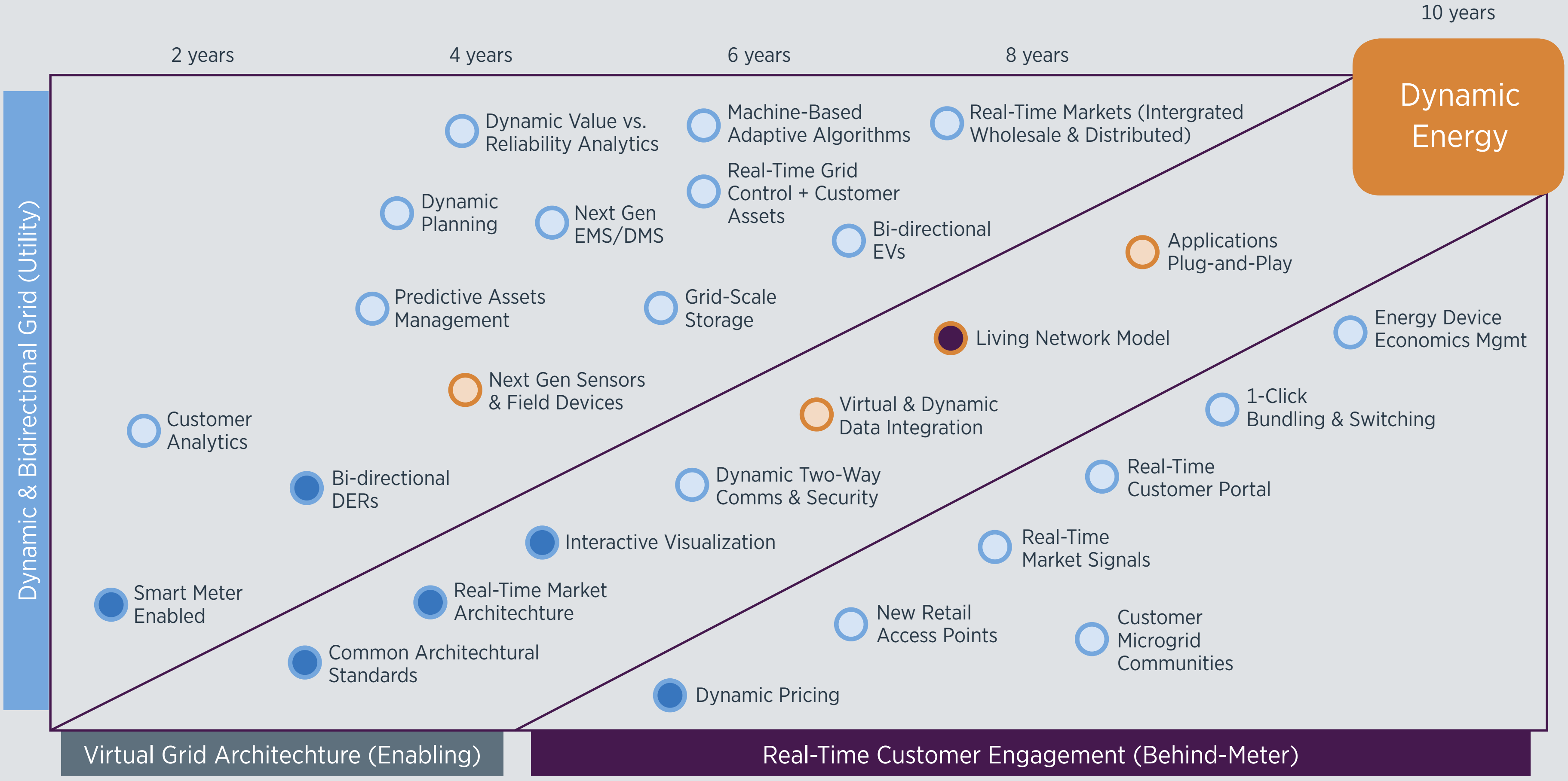
These concepts are used today at the wholesale level. Regional transmission operators around the developed world provide this "hub" service to allow competitive generators, energy retailers, and demand-response aggregators to participate in the system. But DynamicEnergy™ technologies would extend these concepts to the distribution level, enabling customers to act as market participants. While some larger, more knowledgeable customers already participate in wholesale markets, automated and distributed technologies will make it simpler for even savvy homeowners to join in.

In New York, the Public Service Commission has begun a proceeding, called Reforming the Energy Vision or REV, which seeks to reimagine the role of the distribution utility in a way that embodies many of the concepts of DynamicEnergy™, as illustrated in the figure above. While this may not point the way for all utilities, it demonstrates a strong willingness among regulators to evolve their market-design concepts at a pace commensurate with the changes taking place in the electricity ecosystem.

Imagine a system where stakeholders have a plug-and-play relationship with the electric system, similar to the relationships they have now with many different businesses and services via their smartphones.

The future could look like this:

- A building manager could sign up for demand response by going to an online hub, setting up an account and choosing a vendor, then downloading demand-response software to the building energy management system. This online hub may be utility-managed, or the responsibility may fall under the purview of third-party technology companies that are more customer-savvy and able to update and enhance online platforms more rapidly.
- A customer buys an electric vehicle, installs a home charger, then signs up to let an aggregator dispatch the plugged-in car for frequency and voltage regulation services. Similarly, every customer



home outlet and major electrical device may be enabled with remote-control capabilities, allowing participation in DynamicEnergy™ markets and resulting in compensation.

- A marketer servicing community microgrids or energy storage solutions is able to access customer data from the hub to tailor new offerings, track usage, and receive and make payments.

These are just a few examples of emerging and future use cases that will define much of what the Next Generation Utility will evolve into.

The first steps have already been taken, with deployment of smart meters, SCADA systems, and bidirectional distributed energy resources in a growing number of markets. Looking forward, while technology and data will be the most important enablers of this market, they will also be the biggest challenges for all stakeholders. Utilities have an opportunity to design for the future in terms of both strategy and deployments.

The diagram above illustrates the evolution from this base technology to a DynamicEnergy™ market across customer, grid and architectural domains. In coming years, customers will continue to deploy distributed energy resources (DERs) with ever-greater intelligence and market capabilities. Grid operators will benefit from improved situational awareness and control, thanks to nextgeneration sensors and controls. Grid architecture will become increasingly comprehensive, fluid and flexible, enabling a greater level of distributed innovation.

Common standards will be imperative in this framework, to allow many different vendors to create systems that are interoperable, and preferably “out of the box”. While there has been progress in this area, there are still competing architectures, technologies and standards bodies across the value chain whose differences and points of divergence must be resolved.

4. THE BUSINESS PLAY: APPLICATIONS AND OPPORTUNITIES

Utilities will have a wide choice of approaches to seek out new business opportunities in this DynamicEnergy™ vision — but so will many different non-traditional players. In simple terms, approaches can emerge as discrete business plays, in energy-only bundles, or with both energy and non-energy offerings combined. A current example on the customer side is Comcast's Triple Play package, which has long bundled television, internet and phone nationwide. Comcast is now offering electricity and gas in Pennsylvania, New Jersey and Illinois, working with partner Crius Energy to manage the actual delivery of these energy resources, while bundling the business terms of that service in its communications offering. Comcast's Xfinity Home service bundles home security and home automation features, with a smartphone app that can control devices from different vendors.

The opportunity for different parties to disintermediate the relationship between utilities and their energy-buying customers is expected to grow, as new devices and platforms become more central to customers. Perhaps the biggest set of players to keep an eye on are in Silicon Valley. In addition to dozens of startups, tech titans like Apple and Google are branching out, looking to put spare capital to work conquering other industries. They have cast their eyes on the biggest prizes, such as the electric utility industries. Additionally, in 2014 alone, there were more than 100 venture capital or private equity deals in the grid edge space, totaling approximately $1.3 billion (GTM Research, Grid Edge 100 Part 1, 2015).

Entrepreneur Elon Musk, with his interests in SolarCity, Tesla electric cars, and most recently Tesla batteries, represents an interesting example of how traditionally disparate business lines could support one another in this DynamicEnergy™ environment.

The idea of integrated solar, storage and electric vehicles is far from unique to him, and many other partnerships are following Musk's lead. With the strengthening economy, new impact investing trends, and sustained friendly federal and state incentives, financial institutions across the investment spectrum are more willing to partner in making bets on emerging cleantech or scaling up existing technologies.

Working against this transformation is the nature of the U.S. utility and energy industry, which historically has largely been regulated on a state-by-state basis. If anything slows down this transition, it will be regulators in certain states. The culture of regulation tends to be conservative, moving cautiously, even in deregulated states.

We believe that some leading states and companies, along with the pressure of technological progress and consumer demand, will force the issue. As the line between wholesale and retail becomes blurred, as producers and consumers merge into prosumers, and as external factors impact things in their regulatory purview, regulators — indeed, all stakeholders across the value chain — will be forced to adapt.

5. THE JOURNEY

The journey to a real-time DynamicEnergy™ environment will have very different ramifications for different market stakeholders. By planning and deploying with these stakeholder viewpoints and journeys in mind, utilities can reduce stranded assets and regulatory risks, while increasing customer engagement, grid resilience, and revenue streams. Prudent executives can establish a solid base for their next generation utility future.

Across these future stakeholder journeys, three main constructs emerge:

DynamicEnergy™ Opportunity: Predictive Analytics

Another important area of opportunity lies in the realm of data management. Millions of grid-enabled machines will be receiving and sending price and engineering signals that vary by time and location.

Predictive analytics are capable of improving reliability and managing intermittent loads, renewables, rapidly changing weather patterns and other grid conditions. These analytical tools represent the ultimate goal for utility technology capabilities. Indeed, the advancement of both Hadoop and in-memory storage and processing has changed the conversation from "What data should be stored?" to "What can we do with more data?"

This "big data" flow has attracted both pure-play vendors and new market entrants from the telecommunications and consumer electronics sectors, such as Amazon and Cisco, whose cloud-based servers are capable of rapid analysis. They are vying to generate, aggregate and analyze data to make it more actionable for third parties and customers alike. Driven by the growth of DynamicEnergy and distributed energy resources over the next decade, GTM Research predicts that U.S. utilities will invest significantly in customer analytics software, creating a market opportunity of more than $2 billion.

1. A Dynamic and Bidirectional Grid (Utility)

The nextgeneration grid will be technology-rich, enabling a host of technical capabilities and functionalities distributed across the network for all stakeholders. Utilities will see significant value from a combination of next generation smart sensors, switching systems, field analytic devices, network adapters, and access points. Those will be empowered by advanced real-time learning and adaptive analytic software engines, and next generation communication networks to manage and enable the new normal of two-way energy flow.

Reliability will be enhanced through machine learning and analytic-based grid automation, including real-time self-healing, load and voltage management, distributed energy resources, and demand response.

The structure of operations themselves may change into an integrated network of distributed microgrids (the virtual network).

2. Real-Time Customer Engagement (Behind the Meter)

DynamicEnergy™ will enable customers to interact with a real-time virtual hub that provides a "one-stop-shop" environment for all customer needs, including switching, billing, dynamic pricing and rate choice, supply choice, self-generation, bundling energy and non-energy services, broker involvement, DER connections, and community microgrids. According to GTM Research, there are fewer than 50 technology vendors across the software and applications ecosystem that have either partnered with utilities on demo projects or are exploring direct sales of these platforms to third-party players.

3. Virtual Grid Architecture (Enabling)

The overall grid architecture will be increasingly virtual, as it moves to the cloud, begins to feature plug-and-play ease and standardization, and enables virtual applications, data-sharing and communications. In the DynamicEnergy™ world, this grid architecture could be provided as a service to business, stakeholders and customers.

The grid architecture will have an infrastructure that underpins all stakeholder engagement in a way that is scalable in both functionality and volume, integrated with the dynamic and bidirectional grid and the customer hub, and connectable to all markets.

A core piece of this virtual architecture is the real-time network model. With GIS capabilities, real-time self-detecting updates, operations activity, and QA/QC from the field, it will serve as the new center of the enterprise for distribution utilities.

Each stakeholder group will engage with these constructs in a different way, as shown in the following tables.

Stakeholder Group	Key Use Cases	Vision
Customers Prosumers Brokers Retailers Energy Service Companies	• Energy Engagement Hub • Broker/Retailer Hub • Dynamic Rates and Pricing • Bundling Energy and Non Energy Services • 1-Click Bundling and Switching • Supply Choice/Self-Generation • DER Connections and Community Microgrids • Community Microgrid • Applications Everywhere • Economic Device Management • Real-Time Market Signals • Mobile Energy	From the view of the customer, this world is categorized by "anywhere" access to simple integrated applications and data that enables a full-service energy experience. Customers will be able to build a tailored application architecture that combines disparate economic, demand and social data. Access to both front-of-meter and behind-the-meter energy options will be central to this experience, as will be the ability for intermediaries (brokers, retailers) to enter and operate in the market without barriers. Prosumers will have the capability to become "customer network operators."

Stakeholder Group	Key Use Cases	Vision
Grid/Network Owners and Operators Transmission and Distribution Companies and Microgrid Owners	• Distributed Microgrid Management • Dynamic, Living Network Model • Next Gen Sensors and Field Devices • Machine-Based Self-Healing and Adaptive Algorithms • New Entrant Access Points (Incl. DSPs) • DER Location and Management Systems • Real-Time Situational Awareness, Two-Way Power Flow, Demand Response • DynamicEnergy Hub • Next Gen EMS/DMA/DA • Dynamic Control of Load and Voltage	The grid-operator view of the world is one of real-time automated management and control. Next generation intelligent, learning and algorithmic sensors and control devices dominate this network and feed the living-network model. Extensive sophisticated analytics and machine-learning technology dynamically manage and restore the network automatically with minimal human oversight. Real-time and distributed situational-awareness "control centers" will be a crucial component. The portfolio of distributed energy resources is vast, with standardized access protocols. Again, the consideration of economic inputs in grid management will be a central factor in this model.

Stakeholder Group	Key Use Cases	Vision
Generators and Independent Power Producers (IPPs)	• Dynamic Ramp-Up and Ramp-Down • Locational Analytics (DERs) • New Entrant Access Points • Economic vs. Risk-Based Portfolio Management • Machine-Based Asset Self-Healing and Adaptive Algorithms • DynamicEnergy™ Hub	For generators, whether incumbents or new entrants, this world will be dominated by participants with flexible generation portfolios and robust asset-management and market-interaction engines. Next generation situational visualization, analysis and planning applications are central to a generator's success. The balancing of economic and engineering needs, coupled with the ability to dynamically ramp up and down capacity, will be of paramount importance. Generators will also become brokers of independent capacity.

Stakeholder Group	Key Use Cases	Vision
irtual Architecture Providers, Owners and Operators	• Application Plug-and-Play, Bundling • Virtual and Dynamic Process and Data Integration/Provision • Applications/Data Everywhere/Data Sharing • Dynamic 2-Way Communications and Security • Interactive Visualization • Virtual Infrastructure Scaling and Performance • Real-Time Living Network Model With GIS, Self-Detecting Updates, Operations Activity and Field QA/QC • Connectable to All Markets	The world of the virtual architecture provider is a complex one where the intricate integration and provision of virtual "as-a-service" processes, applications, data, infrastructure and communications platforms enables the DynamicEnergy™ hub and links the interactions of markets and engineering, customers and producers, market-makers and grid operators. In the DynamicEnergy™ world, this virtual architecture could be provided as a service to all stakeholders. The living network model, the energy internet of things, and plug-and-play applications provide the operational backbone for the DynamicEnergy hub. Tariffs for architecture providers must be regulated such that there are no barriers to entry for market participants. The plug-and-play applications and the broad array of structured and unstructured data sources required in the marketplace will need to be seamlessly and rapidly provided to participants across the DynamicEnergy™ markets.

6. HOW TO THINK ABOUT THE DynamicEnergy™ FUTURE

This report describes a future utility system that is substantially different than the one that exists today. Many of its elements that are available on the market are quickly being adapted to serve utility functions, or are under development in national labs, universities and corporate skunk works. Some of the most successful companies in the world are scouting out ways to disrupt the industry and take market share from slow-moving incumbents.

But there's no guarantee that the factors leading to the disruptions we've discussed here will inevitably result in the realization of this vision. In order to design a scalable, "no-regrets" strategy for dealing with technology evolution, utility executives could start with the following principles:

- **Initiatives start and end in the business:** Although critical to positive outcomes, technology and data alone should not drive the evolution to DynamicEnergy™. Rather, principled business strategies and goals should remain at the forefront.
- **Put value first:** Start with what your customers will want and need, even if they don't know it yet. Think about long-term value, not this quarter's profits. As Steve Jobs said, "You have to start with the customer experience and work back toward the technology — not the other way around." The ability to offer value-added products and services customers want will increasingly become a utility differentiator in the future.
- **"Think big, start small, and iterate fast":** Speaking at the PA Culture of Innovation event in London, that's how Laurence Bret-Stern, senior marketing director at LinkedIn, succinctly described the company's strategy. This thinking has enabled LinkedIn, a 13-year-old company, to dominate professional social networking and gain a market cap of over $30 billion.
- **Allow R&D to hold its head:** Don't be afraid to prove or disprove technology-evolution hypotheses. Pilots or prototypes that are properly conceived, sponsored and managed, and which have a viable path to market scalability, should be encouraged.
- **Seek scalable solutions:** The journey is just beginning, but it will lead to large-scale change. Planning should account for infrastructure that can eventually manage hundreds of thousands of endpoint devices and the associated data across potentially virtual service territories.

- **Implement a clear data strategy:** Data must be handled holistically across business use cases. Combining and integrating data sources across new and existing systems will provide a powerful and intelligent resource for utilities to manage the grid, customers and operations.
- **Deploy initiative "scouts":** Once underway, initiatives can lead to the discovery of significant opportunities outside of their original scope. Project design should incorporate an overt scouting function and processes to capitalize on any significant findings.
- **Common industry protocols:** Infrastructure decisions should use open standards and industry best practices, and adapt over time to match the direction of market evolution. Establish repeatable processes, protocols and patterns across all market layers to enable a secure and simple path to engagement with the market and participants.
- **Interoperability:** Common and open standards will allow smart generation and transmission technology to be secure and both vendor- and platform-agnostic. Plug-and-play architectures should be used as much as possible to allow for the deployment of scalable and interoperable solutions.
- **Empower stakeholders:** Don't go it alone. Technology evolution comes from many directions, and many stakeholders can provide guidance on the journey. Listen to and respect customers and regulators, staff and vendors. Consider reorganizing along divisions between traditional and new business models. Given appropriate governance and direction, allow a new, dynamic culture, incentives, and risk management techniques to come from the bottom up. By being more open to innovation, utilities become more capable of reacting quickly to and even anticipating external technology developments.

7. EMBRACING THE PROMISE OF DynamicEnergy™

Imagine a world where energy is a ubiquitous commodity available bi-directional in all forms through a facilitated open marketplace deployed on customizable, "access-anywhere" platforms.

DynamicEnergy™ is the articulation of this vision. It is achieved through the architecting and blending of technology to meet the long-term expectations of utilities, customers, market-makers and regulators. Utilities that consider the potential roles and playbooks of all stakeholder groups alongside innovative technology evolution will ensure their success in a thriving, open and dynamic marketplace that balances the myriad engineering and economic forces at play.

Although there are still many constraints facing utilities, disruption is impacting the energy market in the same pervasive manner that it has other industries such as communications, banking and retail. This could be seen as a crisis, but in the culture of the next generation utility, it is more aptly regarded as a significant opportunity, and not something that can be avoided or managed in a piecemeal manner.

The time is at hand for aspiring Next Generation Utilities to embrace this disruption and the opportunities it offers via an adaptable and inclusive long-term DynamicEnergy™ strategy. For more information on the DynamicEnergy™ future, please contact us at energy@paconsulting.com.

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