A GAMBIT FOR GRID 2035

A SYSTEMIC LOOK INTO THE DISRUPTIVE DYNAMICS UNDERWAY

April 2021

FOREWORD

The Pacific Energy Institute (PEI) was founded to address the need for independent, informed, and balanced perspectives on the complex issues related to a more distributed electric system. We seek to change the conversation by drawing upon leading insights from across the globe to inform decision makers in the transformation of electric networks.

The challenge of navigating a path to 2035 led a series of collaborative discussions within the Pacific Energy Institute and others across the globe regarding the future of the electricity systems in developed countries based on insights from Australia, United States and Europe. PEI recognizes a systemic shift is underway in many of the world's electricity systems. In developed nations, this is from the legacy 100-year-old power system paradigm toward a more customer-driven ecosystem, and the related physical and market architectures needed for the 21st century.

These discussions and associated research led to the development of two initial white papers. This paper, *A Gambit for Grid 2035*, discusses the "why & what" of these systemic changes and related considerations. This paper is intentionally not prescriptive, but rather reframes the issues to consider what is needed moving forward.

A second paper, *Institutional Transformation* focuses on "how" to manage the scope and scale of changes underway. Together, these papers provide insights that are intended to help the many industry constituents better understand and address the opportunities and mitigate the potential challenges inherent in this chaotic systemic shift.

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The views and opinions of the authors expressed herein do not necessarily state or reflect those of the Pacific Energy Institute's Fellows and Advisory Board, or their respective organizations.

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"There is only one boss. The customer. And he can fire everybody in the company from the chairman on down simply by spending his money somewhere else." – Sam Walton

CONFLICTING CUSTOMER VIEWPOINTS

The essential structure of the electric industry is over 125 years-old and has reached its performance limits in terms of its capital and operating efficiency. The electric grid as the "largest and most complex machine ever built by man" and "one of the greatest 20th century achievements" is increasingly at risk. 21st century needs are requiring both higher levels of performance and entirely new capabilities to address environmental and cyber threats, integrate distributed resources, and utilize clean electricity as a substitute for fossil fuels. The existing system, including regulation, was not designed for this century – it was designed for a world dominated by largely predictable and generally passive 'consumers' with limited alternatives for sourcing electricity. This system was primarily viewed through the lens of the regulated supply-chain with a focus on meeting universal customer service obligations. The power system in this old paradigm stopped at the meter – customers were referred to as "loads" and identified by "rate or tariff classes."Rule-makers and suppliers largely decided the services and quality that customers would receive, albeit with some feedback through satisfaction surveys. Restructuring in the late 1990s attempted to improve the capital and operating efficiency as well as customer service options. However, restructuring mostly involved changing the players in the existing value chain and introducing contestable markets to incrementally advance the industry's performance for customers. While the industry, including regulation, has increasingly sought to focus on customers – changes have largely continued to be through the lens of a supply-chain orientation.

Over the past decade, an emergent set of customer options have become increasingly effective at meeting or supplementing customer needs. Distributed technologies and services for homes and businesses have allowed customers to manage energy dynamically through convenient automation, self-produce electricity, and store energy to use and sell. The range of businesses and services offered on the customer side of the meter have proliferated over the past two decades including the emerging convergence of the transportation sector and electric sector. These emergent businesses do not sell products or services unless customers make the choice to do so. This is a very direct means of satisfying customer's expressed needs and identifying latent needs that customers cannot yet articulate themselves. This is a new orientation based on customer needs and expectations.This emergent "behind the meter" business activity is increasingly encroaching the grid side of the meter. At first, the old industry paradigm labeled this as a minor distraction. Today, however, many in the industry are realizing that a tipping point for customer adoption of distributed resources and electric vehicles is approaching. A challenge for the electric industry evolution is that the traditional supply-chain oriented view and the emerging customer-oriented demand-side view have characteristics that inherently conflict.

The trajectory of the global electricity transformation is toward an increasingly customer driven future. This change is likely to result in a hybrid system comprised of large- and small-scale solutions to meet 21st century needs for resilient, clean electricity. In some parts of the world, such as Hawaii and South Australia, we are already there. This hybridized system necessitates systemic structural changes in grid architecture, market designs, business ecosystem and regulation.

INDUSTRY TRANSITIONS

The electric industry is following a familiar customer driven revolutionary pathway (enabled by technology and business innovation) experienced by other service industries. In response, the industry has been adapting through incremental responses (e.g. integrated grid planning, FERC 2222, IEEE 1547-2018, smart grid, etc.). This has created a false sense of control (through central planning and regulation) in the traditional electric industry's ability to manage these trends because emergent technologies and business innovations have not yet reached their tipping point. However, we are nearing the tipping point in the proliferation of large scale and distributed renewables and storage, in increasing customer participation in the marketplace, and in the growth of transportation electrification within this decade. The industry has already entered this transitional period involving structural transformation. The industry has "crossed the Rubicon."

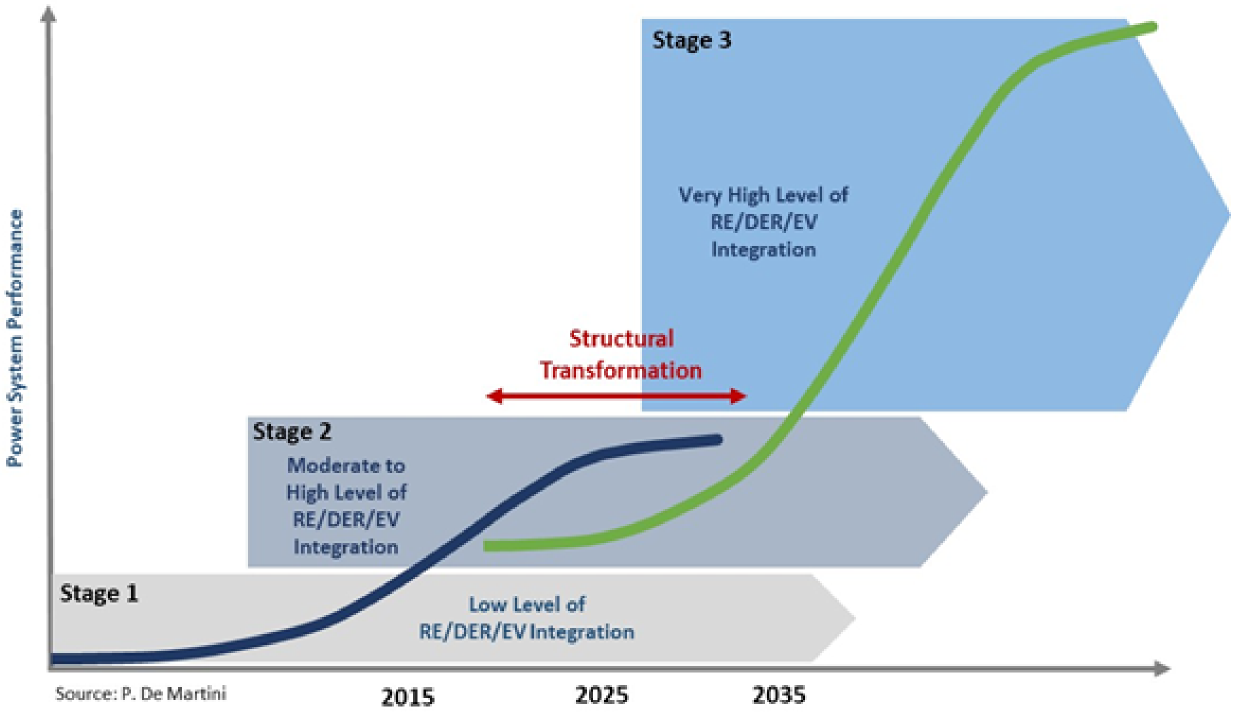


Figure 1: Electric Industry Structural Evolution

This phenomenon is illustrated by technology S-curves in Figure 1 above. The current and emergent industry structures are represented by maturity curves illustrating their respective evolution in terms of performance over time. As these S-curves show, each industry structure involves an initial breakthrough and incremental performance increases until it reaches its limits of what is possible within its structural paradigm. Each of these curves also represent a state of relative equilibrium in which incremental changes advance the effectiveness (maturity) of that structure.

However, near the final stage of maturity, a technology or service model is vulnerable to becoming substituted for a new technology or service model S-curve. When the existing structure progressively becomes less able to address evolving customer needs and expectations, a step change to a new industry structure that enables emergent businesses will organically emerge. For a time both old and new structures will co-exist. Ultimately, however, the old structure will give way to a new industry structural paradigm. One example of this type of discontinuous industry structural change involved the transition from feature phones to smartphones 10 years-ago.

Structural transformations involve a discontinuous step change to a new industry structural paradigm.

1. This figure is an update on earlier versions developed by P. De Martini depicting a single evolutionary curve. This figure represents a closer view of the industry structural transformation dynamic discussed in this paper.

NOKIA

ThIn 2016, Nokia was acquired by Microsoft. At the press conference, CEO Stephan Elop shared, *“we didn’t do anything wrong, but somehow, we lost.”* Nokia was 150 years-old and had been one of the largest corporations in the world. How did the systemic shift from feature phones from market leaders like Nokia and Motorola to smartphones from Apple and Samsung/Google happen? The simple answer is that a dynamic, evolving marketplace outpaced Nokia’s capabilities for change – more suited for incremental advancements in a different industry paradigm.

While feature phones addressed many expressed customer needs, smart phones not only delivered better performance on these but also addressed customers' latent needs, particularly a need for convenience. Smartphones incorporated greater functionality, flexibility through applications, and performance into a single device and customer experience. This technology was the result of customer empathy – “a deep understanding of the problems and realities of the people you are designing for" (2). Customer adoption of smartphone technology drove a restructuring of the mobile industry structure. Nokia and other feature phone providers that had been making incremental improvements could not keep pace and got left behind. This is illustrated *Figure 2* below. At the beginning of 2007, Nokia had 50% global market share of mobile phones. Five-years later, Nokia had 6.4% of market share and smartphones had 65%!

(2) IDEO, Human-Centered Design Toolkit

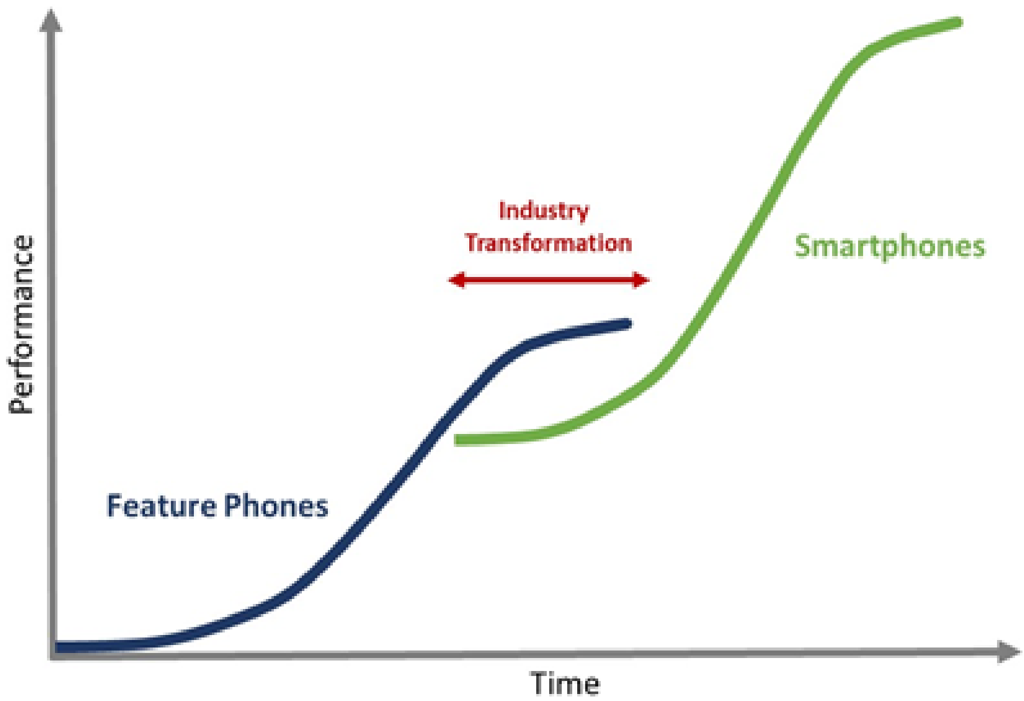
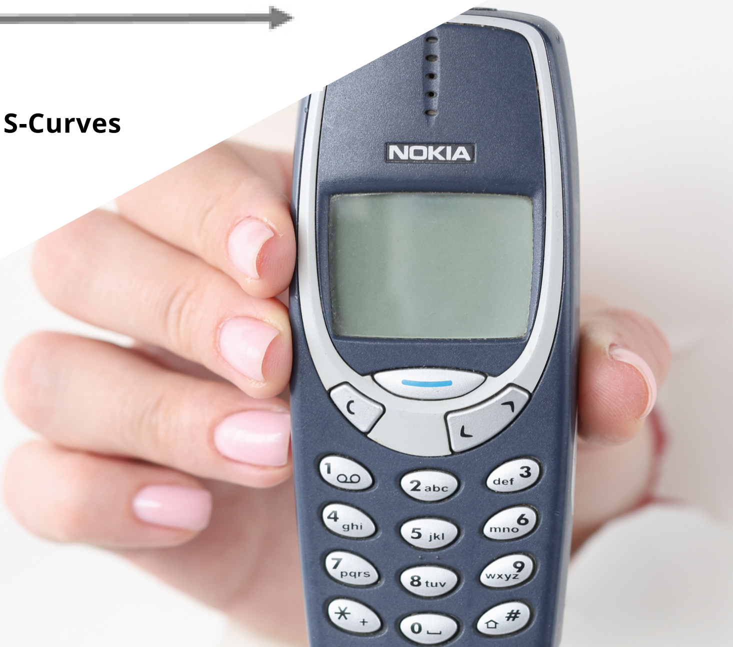


Figure 2: Feature Phone vs Smartphone S-Curves



The point for the electric industry is that we are reaching the performance limits of this 125-year-old industry structure and there are clear signposts that a new industry structure or "S-curve" is beginning to develop through technological and business innovation. Given the critical importance of electricity to modern society, understanding the nature of industry structural transformation and implications for the electric industry are paramount. This requires the ability of all organizations in this ecosystem to have a deeper understanding of how the entities within the ecosystem interact with one another. This understanding includes the internal decision-making processes related to inherent rate of change, and internal and external constraints as well as approaches to facilitating and enabling industry structural transformations.

This paper explores these issues through an application of business ecosystem research and control system theory to develop unique insights. Additionally, these insights are examined in the context of industry transformation. This approach, with a view to 2035 and beyond, provides a model to better understand and navigate the industry transformation underway. This is particularly, important when legislators and regulators consider large scale policy initiatives that have the potential to, knowingly or unknowingly, create winners and losers at the expense customer choice. It is through this lens that this paper seeks to facilitate a discussion of the structural transformation of the electric industry.

This paper is intended to enable readers to ask different questions to prepare for the future.

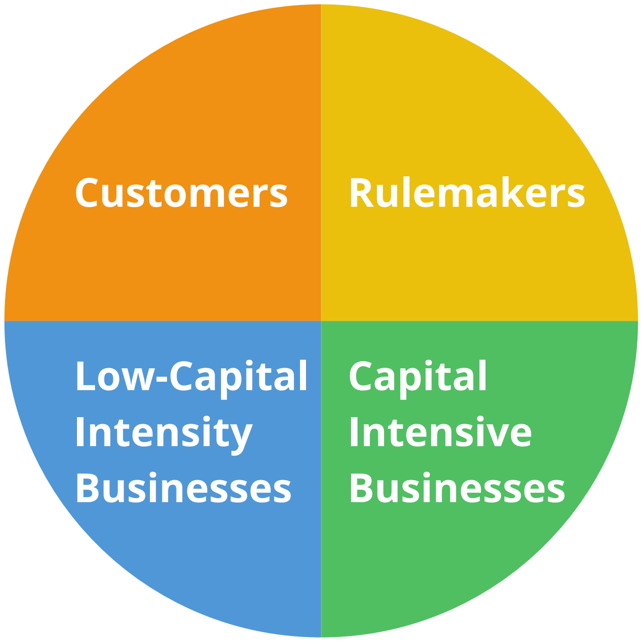
ELECTRIC INDUSTRY ECOSYSTEM

Industry structural changes can be understood through an examination of the underlying business ecosystems including roles and responsibilities, interactions, respective decision making and capacity for change. Business ecosystems are intentional communities of economic actors whose activities share in some large measure the fate of the whole community. *(3)* The structure of a business ecosystem is shaped by customer needs, flow of capital and resources, and innovation. Within this ecosystem, each entity affects and is affected by the others, creating a constantly evolving relationship in which each entity must be flexible and adaptable to survive, as in a biological ecosystem. Business ecosystems, unlike biological communities of co-evolving organisms, are social systems. And social systems are made up of real people who make decisions; the larger patterns are maintained by a complex network of choices and behaviours. *(4)*

KEY ECOSYSTEM ACTORS

The electric industry is an ecosystem principally comprised of customers, services providers that are capital intensive and those with low capital intensity, and legislative and regulatory rule makers. This ecosystem is organized through organic and regulatory created structures to provide electricity and related products and services through both competition and cooperation.

Each of these entities has a unique set of interests and behaviors that shape the evolution of the industry, but also constrain the ecosystem's functions and ability to transform. The following is a description of the key actors within the electric industry ecosystem.



Customers

Customers' needs and satisfaction have increasingly played a central role in the electric industry.Customer dissatisfaction spurs pursuit of alternatives to current services and/or providers that new technologies, business models and policy may enable. The expansion of customer service alternatives in the electric industry parallels similar dynamics in other sectors with customer purchasing behavior becoming a prime factor driving economic activity. Customers' experience with service providers in other sectors have reshaped customers' expectations in the electric industry over the past decade.
As such, customers are also increasing their expectations for a higher level of service based on their daily activities with other non-energy service providers.

(3) J. F. Moore, Ecosystems and the View From the Firm, Antitrust Bulletin, Fall 2005
(4) J. F. Moore, Predators and Prey: A New Ecology of Competition, HBR, 1993
https://hbr.org/1993/05/predators-and-prey-a-new-ecology-of-competition

What do customers say they want from electric services? A decade of business and consumer surveys, including a recent Ernst & Young (E&Y) survey of 1500 consumers and 100 global corporations *(5)* identified three key needs in order:

1. Resilience & Reliability
2. Affordability
3. Climate Change/Environmentalism

This survey's results are consistent with similar surveys over the past decade. It is not surprising that reliable electric service is of primary interest to customers as electricity has become an essential lifeblood for our modern society.

Often technology and/or policy are identified as the core drivers of industry change, but these are a function of changes in customer needs and dissatisfaction with the status quo that manifest in a willingness to adopt technology or political views that shape policy. Adoption of alternative reliability services and capabilities is happening outside the traditional industry ecosystem structure, yet it has a profound impact on various policies and business plans within the regulated grid side aspects of this sector. These customer driven changes are anticipated to continue to accelerate toward 2035. These changes will likely involve additional business and technology innovation cycles.

Customer Resilience

Recent major weather events in the U.S. have highlighted the value of reliable electric service to customers, communities, and local economies. As a result, residential and commercial customers are adopting onsite back-up generation at a compound average annual growth rate of 7% since 2010 according to Generac, the U.S. market leader. U.S. household adoption of back-up generation has reached 20% and back-up storage is growing quickly

(5) Ernst & Young, Fuels of the future — what is powering the US energy transition?, 2019
https://assets.ey.com/content/dam/ey-sites/ey-com/en_us/topics/power-and-utilities/ey-fuels-of-the-future-v21.pdf

Service Providers

The electric industry has two general types of businesses providing services to customers, a) capital intensive businesses (e.g., owners of generation, storage, or T&D assets) and b) businesses with low capital intensity (e.g., software as a service, operations as a service such as a virtual power plant, and project finance). The term capital intensive refers to businesses that require large amounts of investment to produce a service and thus have a high percentage of fixed assets. Low capital intensity is opposite in that the company is spendingless on assets and more on labor cost to generate comparable revenue.

There is a tendency to just focus on utilities as the primary capital-intensive business in the industry. However, 20 years of restructuring has led to many non-utility businesses with significant capital investment in generation and increasingly battery storage systems. Both utilities and independent resource owners have long-lived assets of 20 years or more. Further, capital investments by these firms can take 5-10 years to develop from when the need was identified. This creates a long cycle (or slow clock speed *(6)*) for decision making, new technology adoption and asset replacement. In contrast, low capital-intensive firms generally have shorter product development lifecycles as well as shorter product generation lifespans. This creates a shorter cycle time for decision-making (or fast clock speed), new technology adoption and product/service replacement. However, in the electric industry, firms with a faster clock speed are often dependent upon the products, services, or purchase decisions of the capital-intensive businesses and therefore the interrelationship of the respective clock speeds effects the rate of change for the entire industry ecosystem. This rate of change is also shaped by external factors related to consumer preferences, technology, policy, and market conditions as described earlier. The challenge for regulators and service providers is to keep pace with the disruption and changing customer expectations.

(6) C. Fine, Clockspeed: Winning industry control in the age of temporary knowledge, Perseus Books, 1998

Rule Makers

Rule makers include those federal, state, and local governmental entities that set policy and provide regulation of the electric industry. No single government body sets government policy for the electricity sector, which like businesses, means that the disparate, diffuse, and asynchronous rulemaking creates a very complex governance structure. A key aspect of rulemaking involves adequate and effective regulation to ensure supply reliability, continuous investments, reasonable pricing and efficient markets, and proper market behavior. This is often expressed through a regulatory compact which is essentially an agreement between shareholders on behalf of customers and regulated entities who provide and maintain long-life assets to serve expected customer outcomes.

Traditionally, the regulator's role was to primarily act as a proxy for competition, so customers received a standard of service at reasonable prices while balancing the monopoly utility's economic interests. This core responsibility still shapes much of electric regulation today. Regulation often involves public engagement through formal hearing processes. This is particularly true of adjudicated proceedings that address expenditures, customer programs and rates, and market design. These, and other processes used in rulemaking have relatively long-cycles from need to rule implementation as well as very long lifecycles for the resulting rules themselves. The governance structure for the electric industry also has a significant bearing on the pace of change as regulations create constraints for businesses and the resulting products and services available to customers. These regulatory structures directly shape the institutional structures of regulated entities and exist to ensure the expectations of stakeholders and shareholders are delivered consistently.

ECOSYSTEM DECISION STRUCTURE

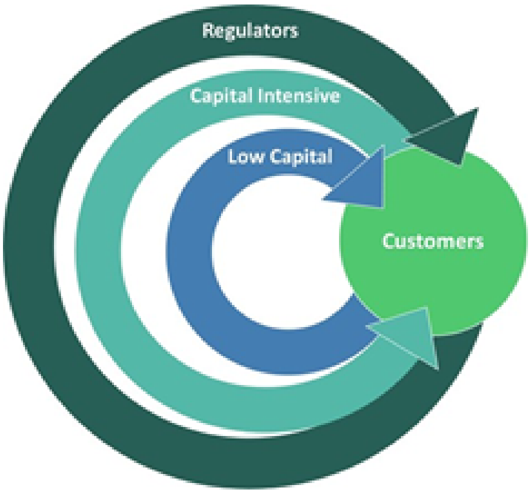
The electricity ecosystem includes a complex decision structure that has evolved so that nonlinearity and dynamics have a significant impact on the industry transformation process. The focus here is not on individual decision mechanisms. It is on the multi-scale structure of multiple interrelated decision processes and the consequent dynamics and flow of constraints affecting how the industry changes. Understanding the structural issues of electricity ecosystem decision making is a significant aid to understanding the transformation process.

REGULATED INDUSTRY SUPPLY-CHAIN VIEW

The capital-intensive businesses, the low capital intensity businesses, and regulators view decision-making in a manner that derives from the historical regulated monopoly and capital-intensive origins of the electricity industry. In this view, regulation, investment certainty, and supply and grid engineering-economics are the driving influence

This heavily regulated industry view of the decision-making process structure has four fundamental nested loops. They are (from outermost to innermost):

·Regulator decision loop
·Capital intensive business decision loop
·Low capital intensity business decision loop
·Customer decision loop



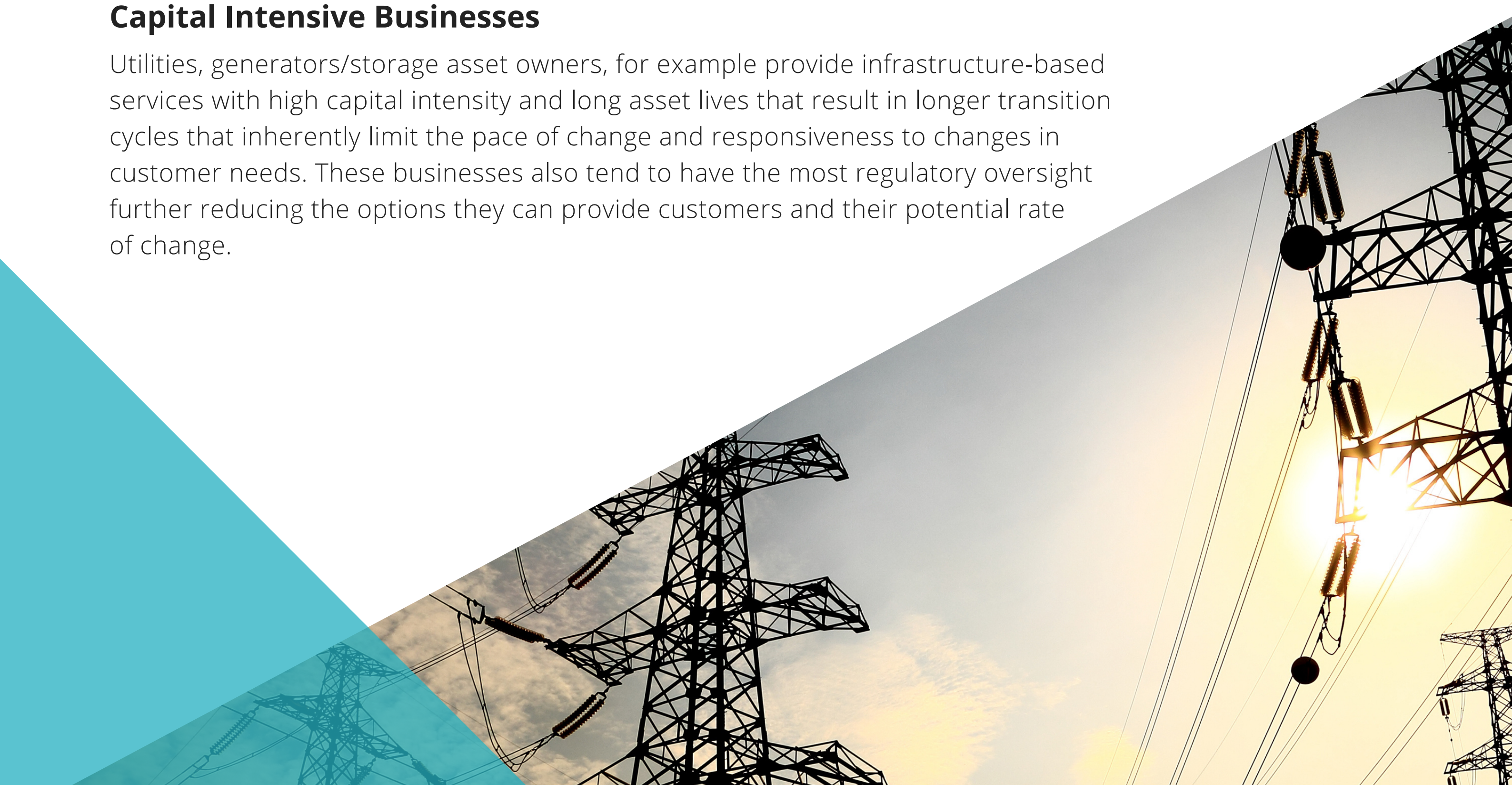
The interrelationships and behaviors of each loop are summarized below.

Regulation

Legislation and regulation inherently constrain the options for customers either through specific pricing (e.g., rates/tariffs) and programs available as well as rules regarding industry structure, services, and scope of business activity allowed.

Capital Intensive Businesses

Utilities, generators/storage asset owners, for example provide infrastructure-based services with high capital intensity and long asset lives that result in longer transition cycles that inherently limit the pace of change and responsiveness to changes in customer needs. These businesses also tend to have the most regulatory oversight further reducing the options they can provide customers and their potential rate of change.



Low Capital Intensity Businesses

Services businesses with low capital intensity, such as aggregators, energy commodity retailers, energy consumer products firms, and DER project developers have inherently faster rates of change to respond to customer needs and often much lower regulatory oversight that may otherwise constrain their service offerings. Nonetheless, regulation does play a role in the design and pricing of services to customers in relations to reference tariffs, market and grid services opportunities, and standards such as interconnections and consumer protections.

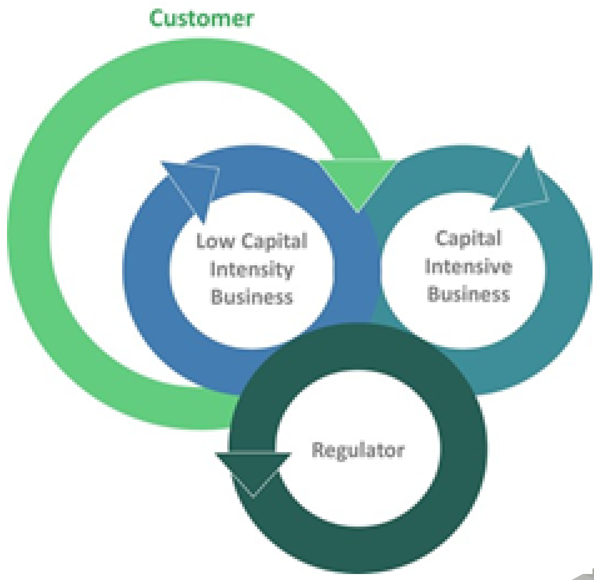
Customer

Customer options are constrained by industry structure and regulation and viewed from a supply side orientation often in generic terms as load to be managed for the benefit of the upstream system economics and profits.

CUSTOMER DRIVEN VIEW

In contrast to the regulated supply-chain viewpoint, the customer driven perspective is informed by direct customer interaction through product and services sales experience. This is the case in virtually every other service industry and in the expanding behind-the-meter market of alternatives to grid provided services. In these contexts, the customer is the driving influence, which leads to a rather different decision loop structure.

While the structure for the regulatory, capital intensive business, and service business loops are the same, the customer loop is now positioned outside of that nested loop structure to act as the driving input to the other three loops. Customers' needs and expectations drive the ecosystem decision cycles and process as direct inputs to the decision-making process of the other three levels of the decision structure.



Customer

Customer needs drive service offerings from businesses and the resulting industry structure without undue regulatory constraints.

Low Capital Intensity Businesses

Services businesses, with low capital needs, have greater flexibility to adapt to meet evolving customer needs and expectations and create beneficial partnerships that both reshape industry structures and satisfy customer needs.

Capital Intensive Businesses

Asset owners have greater flexibility to leverage their asset and organizational capabilities directly for customers and in partnerships with other services providers to meet customer needs.

Regulation

Legislation and regulation focus on market oversight and on identifying ways to reduce structural, regulatory impediments to innovation for the benefit of customers and the services business that serve customers.

Resilience Example

Resilience solution investments provide a good example of the difference in perspectives between a regulated industry supply-oriented view and a customer demand-oriented view. Grid side resilience solutions are typically focused on serving many customers' needs. The cost effectiveness of these solutions is assessed, in part, in relation to economies of scale. A larger solution serving more customers' needs can have a lower marginal cost than several more granular solutions that could result in uneconomic investments in resilience. However, these larger solutions may not meet the specific needs of individual customers. Also, these grid solutions are usually paid by all customers through rates and so may not meet regulatory criteria for an additional investment. For example, regulators may perceive that system average reliability is good enough, or that there are other investment priorities within the limits of acceptable average rate increases. This can result in certain customers' needs being unmet. This is an example of supply-oriented perspective.

Conversely, customers see the ecosystem through the lens of their own experiences and personal outcomes rather than explicit ecosystem measurement processes (e.g., reliability metrics such as CAIDI). Which is why many customers (approx. 20% of US homes) have spent $1,000 to $15,000 for back-up power options. The same disconnect with customers' needs and expectations has been true for customer adoption of distributed generation options.Customers' decision making is rationally focused on their needs – which typically ignores the industry supply-oriented engineering-economic paradigm.

DECISION STRUCTURE DYNAMICS

REGULATED INDUSTRY SUPPLY-ORIENTED STRUCTURAL ANALYSIS

As described above, the regulated industry decision-making process structure has four nested decision-making/implementation loops, in order:

- **Regulator**
- **Capital intensive businesses**
- **Low capital intensive ("Services") businesses**
- **Customer**

Each loop is operated based on its own objectives (not explicitly depicted in the diagram), subject to general ecosystem, political and social considerations, and are modified by the constraints imposed on it. Constraints in the current electric industry largely originate from legislation and regulation (regulator loop). These regulatory decisions and actions create decision constraints that feed into each of the three inner loops. Constraints also cascade from outer loops to inner loops and aggregate along the way. The customer loop is inside the other three loops, and this structure has the effect of pushing grid and electricity ecosystem constraints onto the consumers at the innermost loop in the form of limited product and service choices as well as limiting potential product and service providers. A more detailed illustration of this structure is provided in Figure 3.

Specifically, decisions made at the capital-intensive business level are often shaped by regulatory orders. This in turn creates a flow of constraints down to the service business and customer levels and likewise decisions at the service business level cause a flow of constraints to the customer level. In the case of DER programs, for example, this can affect program eligibility, pricing of services, and interconnection and participation requirements, and limits the number of potential service providers

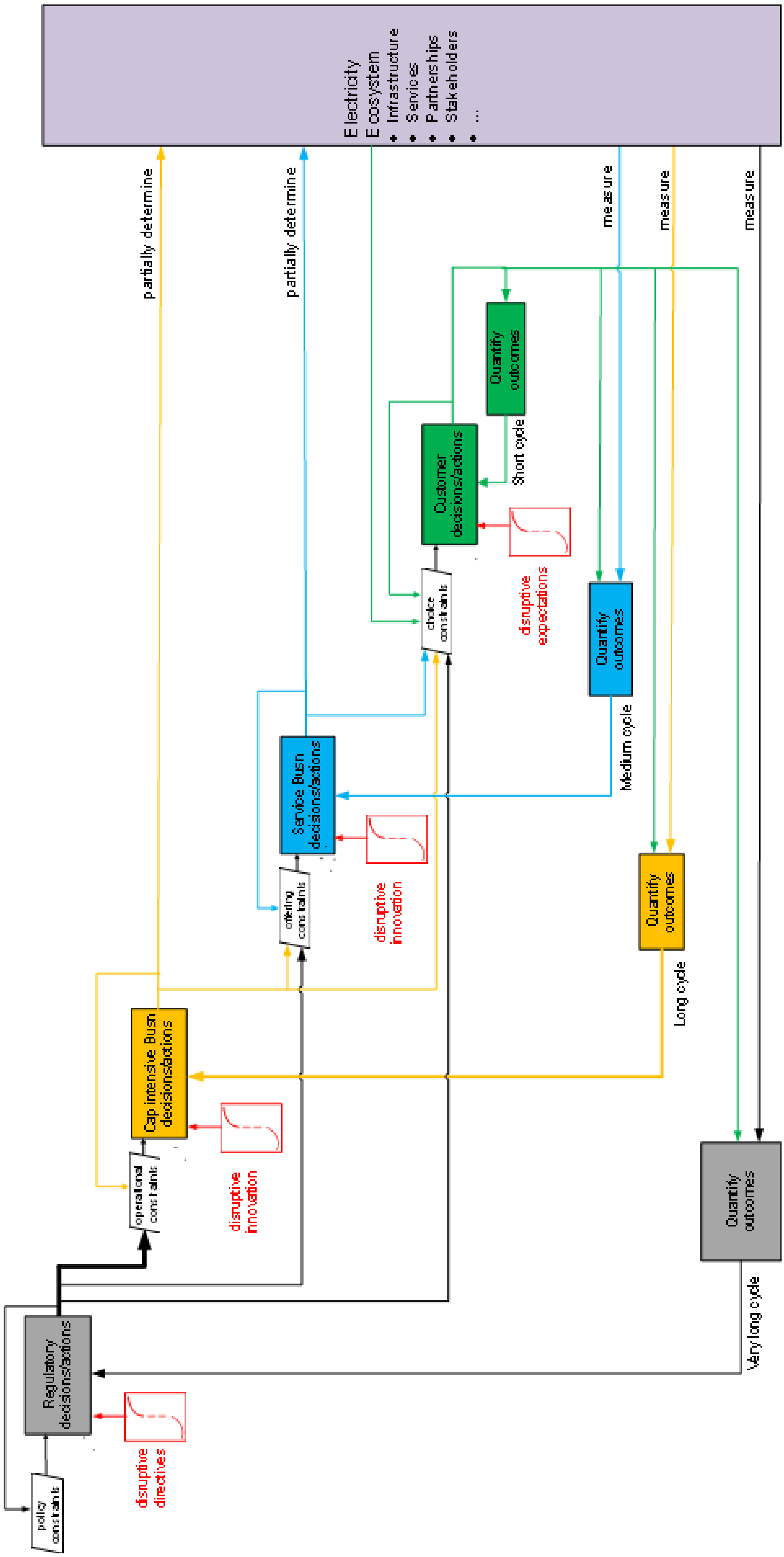


Figure 3 Regulated Industry Supply-Oriented Decision Structure

Ultimately, as illustrated, the entire set of decisions in all three outer loops result in a cascade of decision constraints onto the customer level. In a sense, this means that the consumers are being controlled (in terms of choices and behaviors) by the outer decision loops as well as limiting the choices provided by the ecosystem in general.

This industry structure does include customer feedback to attempt to align to customer needs, but it is relatively weak. Regulators and businesses measure their own operational performance based on separately selected elements in the ecosystem. They also make attempts to obtain feedback from the customers by sampling customer satisfaction and measuring changes in consumption as indicated by the green feedback arrows in the diagram. This results in an abstracted view that is often disconnected from the realities of customers' experience and needs. Research shows that between 65-85% of customers who switched brands were satisfied or fully satisfied with the brand they left. *(7)*

"Customer satisfaction tells us almost nothing about what our customers will do in the future."
Philip Kotler

(7) F. Reichheld, Loyalty-Based Management, Harvard Business Review, March–April 1993

Dynamics of the Regulated Industry View

Generally outer loop cycle times are longer than inner loop cycle times at each level, but cycle times are not necessarily constant nor are they necessarily uniform across all members of a particular group (i.e., the set of services businesses or the set of state regulators). At each loop level, some types of decisions may be made on different cycle times than others. Finally, measurements made for outcome quantification purposes may be taken on different cycle times than those on which the decision loops operate (for example, sampling customer satisfaction may happen on a slower cycle than measuring ecosystem effects).

Consequently, this decision system is a multi-loop arrangement with complex inter-loop interactions, operating on multiple variable time scales. The slower outer loops present inertia with respect to the potentially faster dynamics of the inner loops. Given that in this model, the customers (who generally have the fastest loop dynamics) are limited by the outer loops that always lag the customer in decision making. This is a consequence of the fact that in this model, the outer decision loops are operating on feedback. The lag effect is especially noticeable when disruptive step changes occur in the inner loops.

The lag effect is especially noticeable when disruptive step changes occur in the inner loops.

The customer loop, being innermost, acts as a source of volatility inside the larger decision structure, which is dampened by the outer loops, potentially resulting in dissatisfaction on the part of the customers. To be clear, it is not that the utilities do not want to be responsive to customers, in fact they certainly do, as seen by the many ways they have made electricity easy to use over the course of the 20th Century. It is the ability to move to new operational models and offerings that is dampened by the dynamics of this decision loop structure.

These systems tend toward a steady state equilibrium in a manner that depends on the dynamics of each loop and the nature of the loop interactions. This dynamic equilibrium is a state of balance among several ongoing processes involving the operation of the power system as well as the respective business models of the various capital intensive and low intensity services businesses. A dynamic equilibrium or steady state may be disrupted by influences such as new technologies, radical changes in customer expectations, and new legislative, judicial, or executive directives.

The issue is twofold: the dynamics of the industry's supply-centric decision loop structure inherently creates a lag effect, and the cascade of decision constraints from outer to inner loops limits what businesses can do. This is particularly problematic for most regulated businesses. The lag effect was not as much of an issue in the 20th Century, but as customer expectations change due to technological and business innovation, this constraint flow hampers the ability of the industry to react in a timely fashion with appropriate responses. As such, this industry structure is very prone to customer dissatisfaction. Unfortunately, this traditional structure may also result in more heavily regulated businesses not being able to transition successfully.

This structure is very prone to creating customer dissatisfaction.

CUSTOMER DEMAND-ORIENTATION VIEWPOINT

As described earlier, the customer demand-side viewpoint is informed by direct customer interaction through product and services sales experience. Figure 4 shows this significantly different placement of the customer decision loop in greater detail. While the structure for the regulatory, capital intensive business and service business loops is the same, the customer loop is now positioned outside of that nested loop structure to act as the driving input to the other three loops. Customers' needs and expectations drive the ecosystem decision cycles and process as direct inputs to the decision-making process of the other three levels of the decision structure. These three (now) inner loops still make measurements on aspects of the ecosystem, but now they receive input from the customers as feedforward, rather than as lagging feedback. The c ustomer is now the reference input to the dynamic system represented by the inner triple decision loop and the electricity ecosystem, thus driving the ecosystem to meet the customer needs, just as the customers have come to expect from other services industries.

The customer directly drives the decision structure to create better alignment of business decision making and less need for regulatory intervention which can overly constrain customer choice.

Figure 4 is a classic example of a combined feedforward plus feedback control system that can significantly improve performance over a simple feedback control system, such as the traditional regulated system in Figure 3. In a combined feedforward plus feedback industry structure, whenever customers' needs and expectations change, it is identified at the point of interaction with the businesses. As such, it can be addressed directly by the businesses in terms of revised products and services. In contrast, traditional regulated model relies only on relatively weak feedback after constrained business decisions are made creating substantial lag and higher likelihood of not meeting customers' needs. Under accelerating changes in customer expectations, such a "feedback only" system will not be able to keep pace.

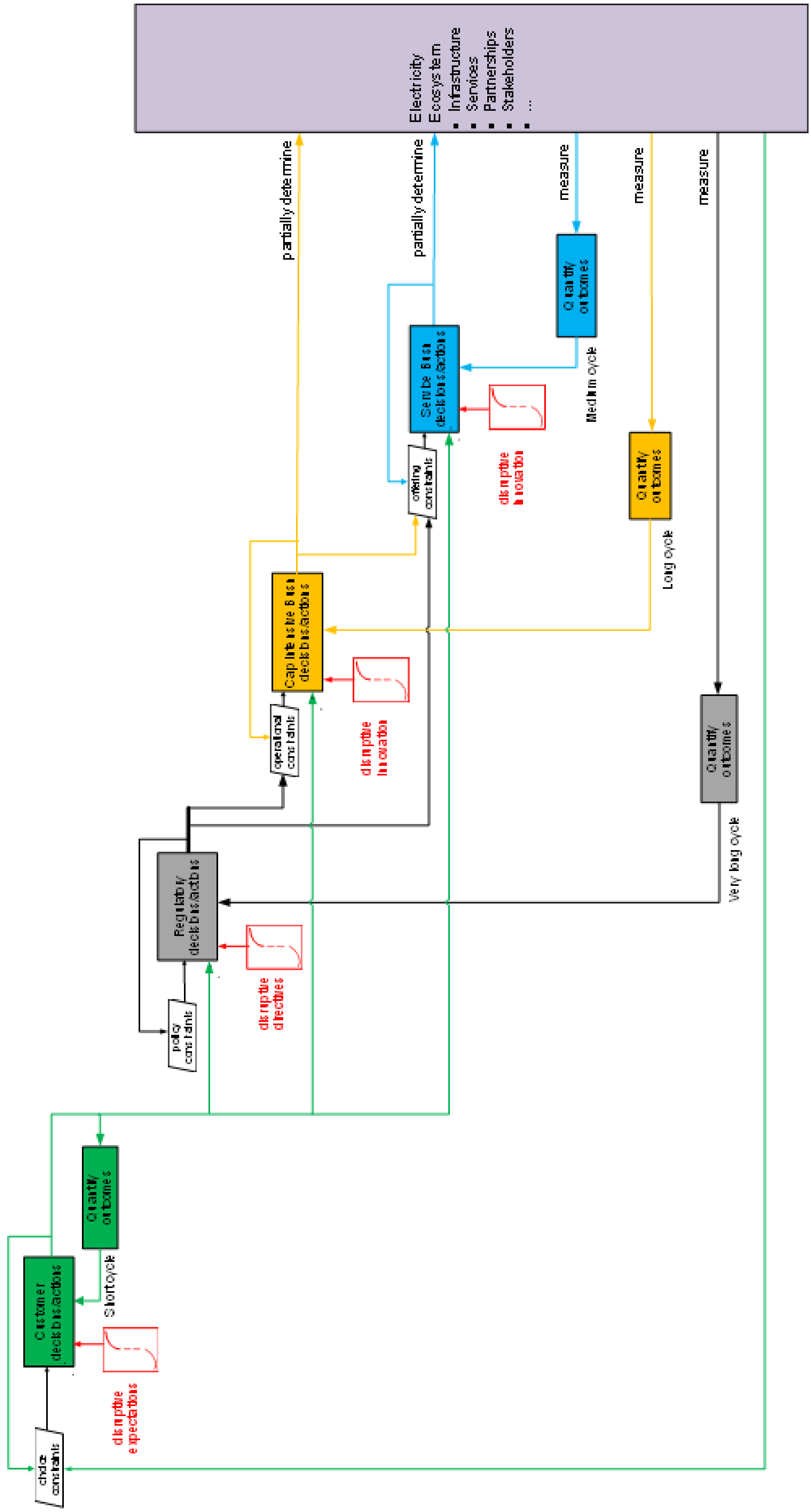


Figure 4 Customer-Centric View of Decision Structure

Dynamics of the Customer View

This structural change removes the dynamics of the customer loop from inside the three other loops and turns it into a reference input. The customer loop no longer embedded in the dynamics of the regulation/capital intensive business/service business decision subsystem. That is, the customer is no longer wholly captive to the electric industries decision cycles and constraints. The dynamics of the three-loop subsystem are also less complex than before since the customer loop is not connected into the others via internal feedback. This change effectively decouples customer expectation trends from industry ecosystem dynamics.

Use of reference input feedforward is a standard method for improving closed loop system performance in terms of tracking (responding to) a dynamic signal and makes it easier to predict or forecast customer trends, since they are not mixed in with other decision loop dynamics. The remaining three-loop subsystem (regulatory, capital intensive businesses and services businesses) can be more responsive to the customer given the more direct input. Additionally, the directness also avoids the problems of the traditional supply orientation that involves weak customer feedback loops and overly constrained business decision making. The three-loop subsystem effectively integrates customer preferences in a more manageable fashion than with the traditional regulated structure.

A source of increasing tension is the difference in mindset between traditional industry entities with a scarcity mindset versus customers and new business entities with an abundance mindset.

This customer view model is based on the premise that there is an increasingly wider range of options available to the customer based on accelerating technology and business innovation. Many of these options do not come from the traditional supply-oriented industry. This reorientation is exactly what has happened in terms of customer options to address their bill management, reliability, and environmental objectives over the past decade and will increasingly occur over the next 15 years. This is a key difference between the two decision loop structure models: the traditional industry entities' scarcity mindset versus the customers' and new business entities' abundance mindset. This difference is a source of increasing tension.

INDUSTRY TRANSFORMATION

INDUSTRY ECOSYSTEM EVOLUTION

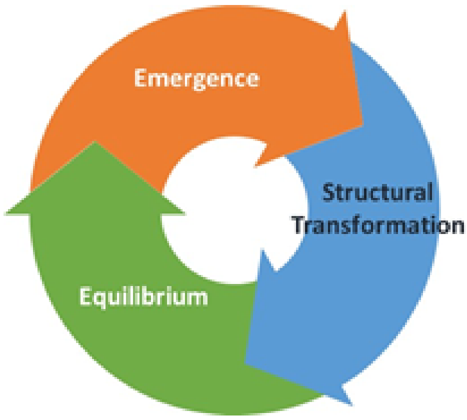
All industries are constantly changing in both the boundaries of the industries as well as within the industry. The changes are often caused by disruptive changes as is the case today. The electric industry is going through a major transformation within the industry, and the boundaries of the industry are currently being re-drawn (e.g., transportation electrification).

The dynamism in this ecosystem arises both from the constant interaction of all the various entities and from the changes and innovations that occur within each. Any change in one of the entities will produce a reaction to the change, as an accommodation to it or as an incentive for innovation and evolution. As such, the architecture of the electric industry ecosystem continuously changes because of evolutionary dynamics. In simple terms, there are three phases of industry evolution:

Emergence - Material changes in customer expectations enabled by technology & business innovation and/or new policy.

Structural Transformation - Responsive systemic change, as an accommodation to emergent factors or as an incentive for innovation and evolution.

Equilibrium - Resulting industry structure post-transformation, recognizing inherent increasing temporal fluidity.



Emergent factors drive structural changes both internally to an entity and externally among entities. These changes, for example, may involve entities changing their business processes and models in addition to products and services to address customer and policy needs. This change can encompass redefining the scope of services including expansion into new adjacent offerings to meet customer needs. The new customer service offerings, business models, and industry ecosystem structure result in a new "equilibrium". This equilibrium represents a state of the ecosystem the exhibits linear, reasonably predictable behavior for a period of time. This equilibrium is represented by an S-curve in our model. Within this period of "equilibrium," there will be continuous cycles of small changes that improve the overall performance of the system.

However, ultimately an emergent factor reaches a tipping point that creates a large structural shift to a new hybridized structure. This is represented as a second-generation S-curve in Figure 1: Electric Industry Structural Evolution. Several signposts suggest such a transformation will likely occur over the next 15 years. The electric industry, not unlike other customer dominate industries, remains highly susceptible to accelerating technological and business innovation.

STRUCTURAL TRANSFORMATION

Industry Rate of Change

Structural transformation of today's electric industry is significantly more complex than the wholesale and retail electricity restructuring of the 1990's. The reason is that there are many more entities involved in providing electricity and related services to customers today as well as options for customers to become a provider of electricity and services. As a result, the rate of change for individual entities and the electric ecosystem becomes critically important. There are three essential parameters of clock speed to consider *(8)*:

Product technology – capital equipment or product/service lifecycles and frequency of new product introduction or intervals between product generations.

Process – streamlining of new product development process or new capital investment planning and required approvals.

Organizational - rate of change in organizational restructuring.

These three parameters shape the overall decision making and related implementation process for each entity that are discussed further below. The challenge for all entities is to address existing external and internal constraints to decision making and related decision cycle times that may impede the ability to satisfy customer needs.

Structural changes involve more profound modifications such as introducing new entities or new relationships, for example. In most cases, this will mean new interfaces and new or changed definitions of functions, roles, or responsibilities. Structural changes are more complex and typically occur on long time scales involving significant costs and time to implement.

(8) C. Fine, Clockspeed.

Structural Traverses

It is important to consider these clock speed factors in the context of the systemic industry structural change underway, particularly as business entities are making changes to the products and services they provide to customers. This may also involve changes to business models, including profit models. As seen in other industries, businesses may seek to evolve into adjacent services to expand or change their offerings to meet customer expectations. For example, utilities such as Green Mountain Power are offering customers reliability enhancement solutions such as back-up generators/battery storage. This non-traditional service offering requires the utility to evolve its traditional business model, including its products, business processes and organization structure. This type of change in business models is called a "structural traverse" - moving across and into new functions.

These structural traverses are inherent in the type of structural transformation underway in the electric industry for all business entities to successfully transition to the new ecosystem "equilibrium" structure. The need to meet customer needs and expectations will drive business decision making toward these traverses. In turn, this dynamic will challenge the traditional view of monopoly and competition and the shape of regulation.

It is essential, therefore, that this evolutionary process has effective governance mechanisms that allow sufficient freedom for making business decisions so that the ecosystem may structurally transform to ensure resilient, affordable electric service for all customers. This is necessarily driven by a customer view as opposed to a regulated industry view with less top-down deterministic rulemaking.

As seen in the telecom industry responding to similar structural changes in the 1990s and 2000s, regulatory frameworks that enable entities to pursue business models that traverse traditional boundaries have proven to be more successful when the industry is transforming from supply orientation to demand orientation. The anticipated growth of electrification and abundant, low/no marginal cost renewable energy and storage by 2035 will accelerate this shift to customer-centric economics already well underway.

This structural traverse (or transition) from one structural generation to another requires an ability to develop a second or parallel business and regulatory operating systems. That is, ecosystem organizations need to create new capabilities (products, technologies, and organizational changes) at the same time as managing the legacy business. The traditional structures remain necessary for managing near-term day-to-day operations but are insufficient for successful transition. The shift to a hybridized based industry structure will allow greater economic and resilience performance from customers' perspective. As noted in the first curve, the system performance will decline as a hybrid system more fully develops. This is expected as the current power systems were not designed for this future and have inherent structural limitations. The current system structure has reached its performance peak and increasingly the limitations are being exposed with greater variable and distributed resource, particularly in the face of severe weather events. The incremental, linear improvements in markets, grid modernization, and regulation currently underway will not resolve these limitations. This is illustrated by the transition stage in Figure 5 below.

There is a need to ensure regulatory protection where long-life monopoly services endure but encourage service innovation where it can occur.

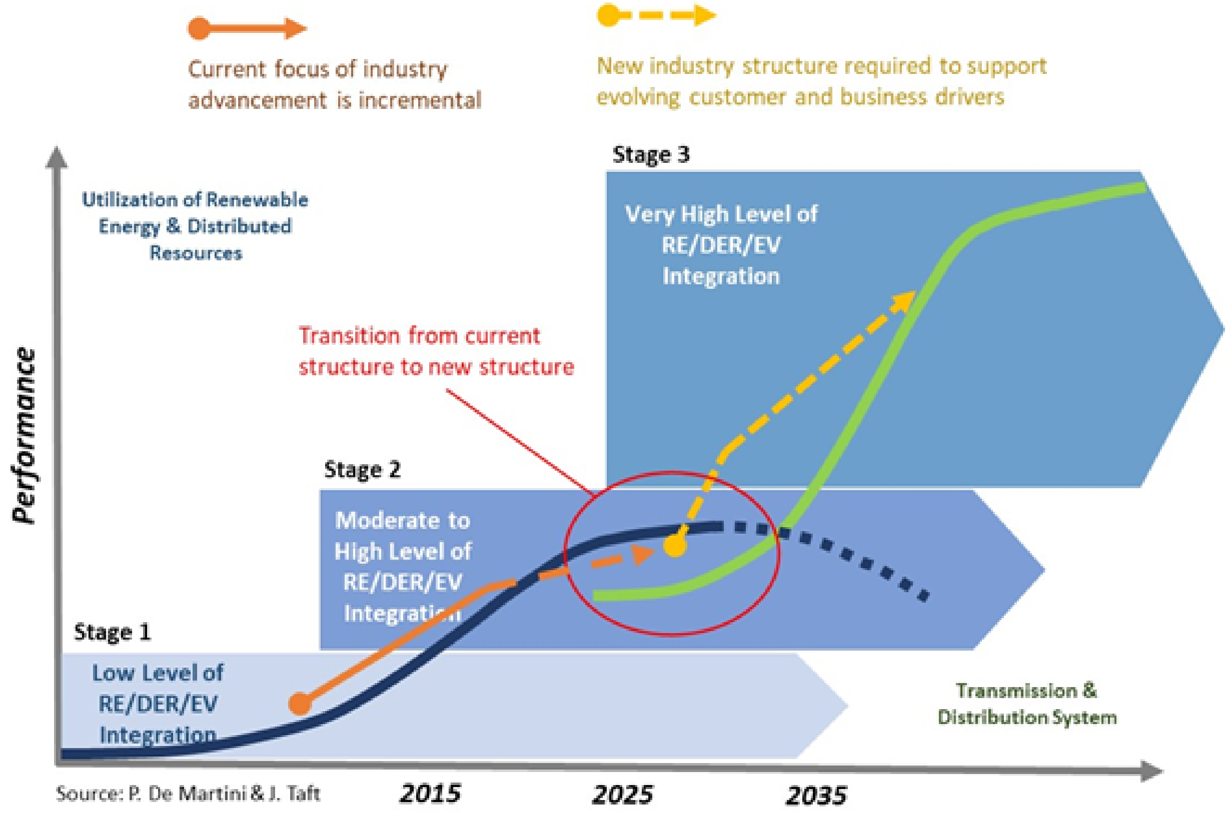


Figure 5: Parallel Operating System During Structural Transition

The current regulatory environment is fundamentally oriented toward 20th century monopoly electric service. It will be challenging to avoid constraining business models that would be optimal for this emerging and significantly more complex industry structure. Instead, effective regulatory structure can provide the constraints that provide effective oversight, but also de-constrain both high and low intensity businesses to effectively respond to disruptive changes. This will also require regulators to consider alternative process and oversight for legacy ecosystem and the emergent structure that will be materially different in many aspects. The recent National Academies report on the future of the US electric industry identified this urgent need in their recommendations, albeit they did not necessarily identify the step change that would be required to address the systemic shift to deep decarbonization *(9)*.

(9) National Academies of Sciences, The Future of Electric Power in the United States, 2021. Recommendation 3.9: Industry and regulatory groups and government agencies (e.g., NARUC, NASEO, EEI, APPA, NRECA, LPPC, DOE, and others) should collaborate on work to collect and share information on best practices and lessons learned from efforts across the country to promote change and regulatory innovation at the distribution level.

CONSTRAINTS THAT DE-CONSTRAIN

Ecosystem survival is based on diversity; diversity in species, in organisms, in interdependency, in ‘cooperation,’ and in information. By allowing greater flexibility and adaptability, the existence of diversity can be seen as a long-term survival strategy of ecosystems as a consequence of permanently changing environmental conditions *(10).* As described, successful services providers will necessarily need to pursue various traverses across regulated and unregulated electric subsector value chains/networks through evolving roles, partnering, outsourcing, and technology platforms to succeed *(11).* A simple example is the opportunity emerging through battery storage which simultaneously allows regulated entities to provide what is considered a regulated service (such as network capacity) while also providing unregulated services (such as generation). As we look ahead, this distinction may become irrelevant as we identify an intrinsic architectural need for the shock absorber function that storage provides all other commodities and networks. That is, we shift storage from an optional application to a core functional grid requirement no different than poles and wires *(12).*

A key factor in the ability to evolve business models are the “constraints that de-constrain”. This is a concept that shows how properly chosen constraints can free up downstream decisions. That is, selecting the minimal constraints that determine what a business entity can and cannot do regarding new products and services, technology adoption, business processes, and organization changes. All of these are currently constrained to a degree in the current industry ecosystem dominated by the regulated view of the electric industry.

Note that while it is common to focus on what is not allowed, it is the ability of well-chosen constraints to enable new and abundant capabilities and functions that matters in enabling transformative change of the electric industry to address evolving customer expectations for electric services. This shift in orientation is what occurred in the telecom industry that previously viewed voice, data, and video as three uniquely different silos and ecosystems with related regulatory constraints. As customer expectations changed and were enabled by technology and business innovations, the boundaries of the silos began to blur and by the 2010s these boundaries collapsed into a converged ecosystem.Google, Amazon, and Apple, for example, are now providers of data/information, video content, telecommunications, and consumer products among other services. Telecommunications services, which were once provided by asset intensive monopolies, are now provided by agile data-intensive competitive providers with a range of telecommunications services and customer choice.

This type of structural business evolution is impacting every service industry in the 21st century. The electricity industry is not immune. It will be necessary for regulators to reconsider the appropriate level of oversight as the traditional electric industry ecosystem evolves to meet the challenges and opportunities of the next decade and beyond.

(10) J. Korhonen, Four ecosystem principles for an industrial ecosystem, University of Joensuu, Finland 2000 http://www.dartmouth.edu/~cushman/courses/engs171/IndustrialEcosystem.pdf
(11) A. Andreoni, Industrial ecosystems and policy for innovative industrial renewal: A new framework and emerging trends in Europe, SOAS University of London, Department of Economics https://tem.fi/documents/1410877/4430406/Antonio_Andreoni.pdf/8a499465-50e2-4bcb-959b-59c5202663f7/Antonio_Andreoni.pdf.pdf
(12) R. O'Neil, A. Becker-Dippmann, and J. Taft, The Use of Embedded Electric Grid Storage for Resilience, Operational Flexibility, and Cyber-Security, PNNL, 2019 https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-29414.pdf

Twenty years ago, David Wirick of NRRI discussed themes common to the evolutionary forces within regulated industry ecosystems that underwent structural changes and the considerations of the appropriate regulatory constraints *(13)*.

"By applying systems thinking, regulatory mechanisms and the utility service delivery network can, more fruitfully, be viewed as processes: as open, non-linear systems tied inextricably to the environments that gave them birth, subject to the fluctuations of that environment and the resources flowing through them. The activities of these systems or processes provide feedback to one another and are attracted to certain patterns of complex but repetitive behavior, referred to in the literature of chaos as "attractors." If the system is knocked out of equilibrium, it will be attracted to return to these patterns of behavior fairly quickly."

However, Wirick also noted that, changes in technology and business innovation can permanently shift the entire model in new directions when a tipping point has been reached. These observations of patterns in other industry sectors from 20 years ago have been repeated since. This dynamic is helpful to consider regarding the role of regulatory oversight and related constraints. He observed that the variables that drive a complex ecosystem's behavior are not "either/or" propositions (e.g., competition versus cooperation, consumer protection versus profit maximization) but are complexly interwoven with intrinsic limits due to self-correcting feedback. This is especially true of a customer demand-oriented model that is more closely aligned to customer driven outcomes.

Regulatory systems should not be designed with the goal of producing order by reducing system behavior to linear predictable patterns. Applying linear structures to nonlinear processes is an exercise in frustration.

D. Wirick, NRRI

Wirick states that regulatory systems should not

"be designed with the goal of producing order by reducing system behavior to linear predictable patterns. Applying linear structures to nonlinear processes is an exercise in frustration. There are limits on the behavior of all systems, and as limits are approached, systems self-govern themselves by pushing behaviors back towards the tolerable levels. Self-governance has, in fact, always characterized the behavior of regulatory systems."

The transition from the existing linear models (e.g., cost of service, integrated resource planning, current market designs, etc.) will need to adapt to new models given the increasingly non-linear characteristics of the electric industry. This transition will require an ability to operate in parallel institutional modes during the transition phase. *(14)*

(130 D. Wirick, The Creation of Dynamic Regulatory Institutions, National Regulatory Research Institute, 2001
https://pubs.naruc.org/pub/FA85AAF3-E3C7-18DD-FC88-A60D0666D523
M. Paterson, M. McDonnell, and J. Phillpotts, "Institutional Transformation: Navigating a decade of accelerating change en route to Grid 2035", July 2021.

STRATEGIC FORESIGHT IS NEEDED

The challenge is knowing the moves to make a successful transition given the high degree of uncertainty facing this industry. The most complex situation is where the future is truly ambiguous, seemingly unknowable, not unlike how the next 15-20 years may look. However, it is possible *“to identify patterns indicating possible ways the market may evolve by studying how analogous markets developed in other ambiguous situations, determining the key attributes of the winners and losers in those situations and identifying the strategies they employed. Early market indicators and analogies from similar markets will help sort out whether such beliefs are realistic or not." (15)* This is what strategic foresight based on decision making under uncertainty draws upon. As such, although it will be impossible to quantify the risks and returns of different strategies, managers should be able to identify what information they would have to believe about the future to justify the investments they are considering.

This is how chess grandmasters develop their strategy for a given match. It is based on opponents’ past performances and their own strengths/weaknesses. They start each game using a prepared set of moves, an “opening theory” (e.g., based on historical data and current trends), to set up themselves up for the mid-game. The mid game is where these grandmasters, in the moment, analyze how well their opening strategy worked and then make mid-course adjustments (navigating the uncertainty) to achieve a winnable endgame. A chess grandmaster cannot tell you exactly how the game will be won (i.e., what the exact board will look like in the end or how the game will exactly progress). But they can know what conditions and considerations they will need for the opening theory and mid-game adjustments to navigate toward winning. In other words, strategic agility is critical for surviving and thriving in an operating context that is both transforming and ‘emergent’.

The ability of the electric industry to transition effectively to a future structure is highly dependent upon such an opening theory (i.e., ecosystem dynamics and grid architectural principles) and specific conditions (e.g., constraints that de-constrain). Lessons from other analogous industries, such as telecommunications, may provide insights regarding how to enable successful structural transformations. Businesses and regulators’ strategies for 2035 will depend upon decisions that will necessarily sacrifice a near-term gain/move for strategic outcomes in the next generation industry structure. This is the “Innovators Dilemma" *(16)*, but a necessary gambit for the grid 2035.

These considerations are explored in more detail in our companion paper, “Institutional Transformation: Navigating a decade of accelerating change en route to Grid 2035". *(17)*

(15) H. Courtney, J. Kirkland, and P. Viguerie, Strategy Under Uncertainty, Harvard Business Review, Nov.– Dec. 1997
(16) Clayton Christensen, Harvard Business School
(17) M. Paterson, M. McDonnell, and J. Phillpotts, “Institutional Transformation: Navigating a decade of accelerating change en route to Grid 2035", July 2021