Decision-Maker's Transactive Energy Checklist

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The GridWise Architecture Council

December 2016

Final Version

The GridWise Architecture Council was formed by the U.S. Department of Energy to promote and enable interoperability among the many entities that interact with the electric power system. This balanced team of industry representatives proposes principles for the development of interoperability concepts and standards. The Council provides industry guidance and tools that make it an available resource for smart grid implementations. In the spirit of advancing interoperability of an ecosystem of smart grid devices and systems, this document presents a Decision-Maker's Transactive Energy Checklist to provide the context for identifying and discussing suitable applications for these systems. Please see the www.gridwiseac.org website for more products of the Council that may be of interest.

PNNL-25658

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1 INTRODUCTION

1.1 ABOUT THIS CHECKLIST?

Transactive Energy Systems are a way for various energy related parties to "interact" and "interoperate" in a way that supports a more resilient, reliable, and stable energy system. The concept of Transactive Energy Systems (TES) can help electric grid owners, regulators, and consumers/users manage the growth of Distributed Energy Resources (DER). Technology is emerging that enables customers to generate power locally at prices competitive to central generation. Furthermore, public policy in the United States and other countries is encouraging and accelerating these developments.

DER is fundamentally changing the landscape of the grid. Consequently regulators, utilities, and other stakeholders are increasingly discussing transactive energy as an essential component of the future electric power system especially with regards to, but not limited to, supporting the expanding numbers of DER.

Some customers are seeking a business structure to become a prosumer and sell excess power to the grid operator and to specific buyers. Market pressures from suppliers of renewable energy and storage, and customer demand for these products have the capability to disrupt a century of electricity business that has flourished in a stable operating environment. The GridWise Architecture Council (GWAC) has created a framework for transactive energy systems with a combination of economic and control perspectives to assist energy service providers, equipment suppliers, regulators, and complex/sophisticated users in adjusting to this emerging reality while maintaining grid performance and stability.

In addition to supporting DER and new energy markets, transactive energy systems are also relevant for the supporting the management of distribution systems. Transactive energy systems are not ends unto themselves, but rather a means for harnessing flexibility as a way to adapt to variability and for enabling value-based relationships in the electric power system. The purpose of this document is to provide industry decision-makers with background information and key questions to consider. These are presented with the goal to aid in understanding, evaluating, and eventually implementing components of transactive energy systems.

Decision-makers can use the checklist to review whether the principles and attributes of transactive energy are incorporated in electricity-related policy or asset investment proposals including:

- The purchase of new distribution and transmission equipment
- The design of a new demand response or distributed generation program
- The implementation of grid automation and control
- The cost recovery of micro-grid investments and their operation
- The adoption of new energy end-use devices
- The design and deployment of system software
- The adoption of new market structures.

1.2 The Audience For This Checklist

The Decision-Maker's Transactive Energy Checklist is a tool to help decision-makers evaluate options such as capital asset investments and new information technology opportunities to determine whether they conform to the principles and attributes of transactive energy. Conformance to these tenets will ensure a level playing field for prosumers, utilities, services providers, market operators, and investors, in a framework based on end-to-end interoperability, operational reliability, and economic efficiency. This is a tool that will help embody and assess the best long-term value for all parties.

This document is addressed to the following key decision makers:

- **Regulators** that are:
    - Considering policy decisions relating to energy assets, energy production, distribution, and consumption where a transactive approach may offer benefits through implementing best practices and offering enhanced value for all parties.
    - Wrestling with how to both encourage DER yet manage the variability that they may introduce.
    - Looking to encourage new ways to address resilience without significant additional infrastructure investments.
- **Utilities** that:
    - Need new tools to help them work with customers, ISOs, and partners to develop a value based approach to energy supply that can provide all parties with a fair mechanism to realize value based on time of use and costs.
    - Are looking for ways to evolve a more flexible distribution system that is not driven by design for peak load.
- **Transactive Platform providers** who:
    - Are responsible for the integrity of the grid both at transmission/bulk power and distribution vis-a-vis economic exchanges among various stakeholders and who must provide advisory information to stakeholders.
    - Require the ability to take action in real-time operation, issue warnings and if needed deny transactions that endanger operational integrity of the grid.
- **Service providers** that:
    - Work with customers to provide a consistent value proposition for their offerings and can use a transactive approach to ensure the highest quality/cost value for their contracts.
    - Can take advantage of emerging business models to develop innovative customer offerings.
- **Consumers/Prosumers** who:
    - Are engaged with energy providers to deliver demand response, load shedding, or similar programs based upon value based programs, incentives, and partnerships.
    - Are looking for approaches to help understand the precepts that could help to support actions to provide a bottom up approach to local coordination.

Regulators	Utilities	Transactive Platform Providers	Service Providers	Consumers/Prosumers
•Developing policy decisions •Relating to energy assets, energy production, distribution, and consumption •Where a transactive approach may offer significant program benefits •Implementing best practices and improved value for all parties.	•Connecting with customers, ISOs, and partners •Developing a value based approach to energy delivery •Where a transactive approach can provide all parties with a fair mechanism to assess value based on time of use and costs.	•Providing transmission services •Providing distribution services •Acting as an interface •Providing uniform market access to customers •Modifying base load •Modifying peak load	•Partnering with customers to provide value propositions for their offerings •Using a transactive approach to ensure the highest quality/cost value for their contracts.	•Engaging with energy providers and service organizations •Delivering demand response, load shedding or similar program benefits •Based upon transactive value programs, incentives, and partnerships.

Figure 1 – Target Audience for the Decision-Maker's Transactive Energy Checklist

While this list of key decision makers is the primary audience, others parties such as technology developers, system integrators, and system engineers will find foundational information in the concepts and approaches discussed here as they examine ways in which transactive approaches can be applied to broader challenges including the use of transactive energy systems as an alternative to new investments in traditional infrastructure.

1.3 How To Use This Document

This document has two sections in addition to this **Introduction**.

2 **Section 2** provides guidance about appropriate uses of this Checklist. Guidance is based upon framing the business/operational challenges and goals facing decision-makers and it contains a number of questions. These questions are to challenge the decision-maker in order to validate that the challenge for which the transactive energy approach is being considered is well understood. In terms of a potential transactive energy solution this section is aimed at helping the decision-maker identify ***what*** the challenge is.

3 **Section 3** provides questions that seek to validate the transactive energy approach for the challenges facing decision-makers in a number of areas. These areas are more fully described in the GWAC Transactive Energy Framework and the questions in this section build on the ***what*** from the first section and are intended to develop the decision-maker's thinking along the lines of understanding implementation topics that relate more to ***how*** the proposed system would work, focusing on topics like transaction details and exchanges of value.

The remainder of this Introduction provides some additional background about transactive energy systems and the GridWise Architecture Council.

1.4 Understanding Transactive Energy Systems

Transactive energy systems represent a model in which distributed generation, storage, loads, and grid-edge devices enabled by intelligent communications capabilities and relevant, reliable, and repeatable information create the ability for customers and utilities to buy and sell commodities (including energy) and services based on mutual economic benefits (usually an agreed price). Transactive energy systems go far beyond the simple hardware or software systems that can be bought and installed. They are interactive systems that provide **value** and **transparency**.

Transactive energy concepts emerge from the fusion of the electricity grid with the Internet of Things. Smart grids are cyber-physical systems. That is they are an integrated combination of two networks:

- **Physical** electric grids to move electricity and
- **Cyber** communications networks to monitor and/or control the electric grid domains[1].

The cyber network enables machine-to-machine (M2M) communications among grid elements and operating status sensors. Transactive energy applies this M2M and Internet of Things communications to the challenge of integrating DER.

Some systems will be transactive and some will not. This document was designed to help decision-makers ask questions about proposed initiatives to determine whether they could be transactive energy systems or not; and more pointedly, whether transactive energy systems offer a good solution for the challenges that they face.

The GridWise Architecture Council's Transactive Energy Framework 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 Framework further enumerates eleven attributes and six high level requirements (principles) that can be used to characterize transactive energy systems. Together they form a set of general requirements to align participants' incentives and values with grid operational reliability objectives, avoiding free riders, and unintended adverse impacts on non-transactive users of the grid. These attributes and principles should be taken into consideration as the possible application of a transactive energy system is considered:

[1] NIST Framework and Roadmap for Smart Grid Interoperability Standards (2014) Release 3.0 Draft, May

Attributes[2]	Principles[3]
• Architecture • Extent • Transacting parties • Transaction • Transacted Commodities • Temporal variability • Interoperability • Value discovery mechanism • Assignment of value • Alignment of objectives • Assuring stability	• Implement some form of highly coordinated self-optimization • Maintain system reliability and control while enabling optimal integration of renewable and distributed energy resource • Provide non-discriminatory participation by qualified participants • Be scalable, adaptable, and extensible across a number of devices, participants, and geographic size • Be observable and auditable at interfaces, i.e. the points of interactions between participants/agents • Be designed so that transacting parties are accountable for standards of performance

One key attribute worth mentioning in more detail is ***interoperability***, if only because it is often misunderstood. In general terms interoperability provides a measurable mechanism for disparate devices, subsystems, and systems to work together. GWAC defines interoperability as the capability of two or more networks, systems, devices, applications, or components to exchange information between them and use the information so exchanged. It is not simply about systems being able to exchange information, but being able to *use it effectively* to enable them to operate effectively together.

An example of existing uses of transactive energy systems is the manner in which a regional transmission organization dispatches energy based on the price per megawatt offered. Transactive energy systems have the potential to extend this type of approach by enabling customers and utilities both to generate and purchase energy plus offer services (e.g., voltage control, storage) based on economic, reliability, resiliency, and other benefits to all parties.

Transactive energy, however, is not an end unto itself. Rather, it is a means to enable the future utility to customer to device interactions in which an increasing number of customers will self-generate and independently decide when to buy and sell power. The motivation for transactive energy systems may not be driven by the economics of providing power outside of the customer, and organizations with campus facilities or large buildings may want to utilize these techniques to focus on the elements that are of most value to them whether they are cost, reliability, power quality, or other criteria. Customers may also wish to buy and sell energy among themselves, independent of the utility and regulatory communities.

This requires an environment that:

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[2] GridWise Transactive Energy Framework Version 1.0, PNNL-22946, January 2015 (http://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf)
[3] Described more in Section 3.1

- Empowers all customers to optimize their total energy bill according to their own varying priorities. Customer control, comfort, and cost are all important. Systems that can self-optimize that, for example, might reduce usage of more expensive energy later in the day by pre-cooling their residence or charging electric vehicles when there is abundant, lower cost wind energy earlier in the day. These new services will be enabled by automation and enhanced customer control.
- Values distributed energy resources appropriately with transparent time, location, and reliability based markets.
- Benefits and protects customers without distributed energy resources such as renters and those with low income.
- Stimulates innovative services and products with clear time and location-based economic value that can be contracted for future periods.
- Enables programs, services, and policies that benefit all parties in a transparent, equal access participation model.
- Provides locational economic signals for investments in distributed energy resources and intelligent grid-edge devices.

This emerging technological capability poses challenges to regulators and utilities.

- Utilities are accustomed to dealing with fluctuations in generation, customer demand, cost factors, and changing customer expectations. The challenge is to find new ways to adapt to an increasing rate of change that reduces the need for investment in new infrastructure assets yet increases the flexibility of the existing assets.
- Regulators must develop a new mind set in which customers will be both consumers and producers of electricity, demand management capabilities, and services that will be purchased by the traditional utility and/or other parties. This capability will require a redesign of the regulatory model beyond time of use rates and cost of service regulation.

1.5 Relevancy

In considering the relevancy of transactive energy systems to a changing energy ecosystem it helps to consider a range of possible future power grid composition scenarios. Today those scenarios are very different than they were just 10 years ago. The following scenarios seem to be shaping the future of the power grid:

1) Vast amounts of new distributed energy resources coming on line and potentially creating a situation that may be a destabilizing issue for grid operators, more from a grid operations perspective than a revenue model perspective.
2) Customers becoming more concerned about their energy reliability, source of their energy, and the variable costs. These concerns are driving more local microgrid implementations that may use the grid as a battery.
3) Power distribution issues such as line loss, power quality, and phase loading.
4) Customers looking to take advantage of smart building systems that interact in real-time with the power grid to optimize consumption based on costs and usage patterns and potentially get paid for providing grid services.

5) Aging nuclear facilities nearing end of life are driving requirements for alternate electricity sources in certain geographic location (San Onofre, California for example) and the strain it can put on grid operators, utilities, and regulators coupled with public opinion and decommissioning costs.
6) Per capita increases in both energy use and supply (rooftop solar, distributed storage) as society embraces technical and social changes such as electric vehicles, smart homes, computers, entertainment, and increased reliance on high-speed, always on (reliable) internet service. These may tend to largely cancel each other out from a system net load perspective[4] but it creates scenarios for power flows and energy/value exchanges that need to be facilitated and new issues such a phase imbalance, increased neutral currents, etc. that will have to be taken into account.
7) Demand management, frequency regulation, other services can not only create flexibility for grid operators but can also provide value to multiple parties so establishing the value to the respective parties and system as a whole can and must be considered within the TES analysis

The above scenarios illustrate some of the ways in which the industry is undergoing a fundamental shift from a "load following" paradigm, from where central generation adjusts to varying demand, to a "supply following" paradigm, where responsive distributed energy resources absorb variable generation such as solar and wind. During the transition, the industry can't afford to design purely for either extreme. That means we need an electric system that is flexible. *Transactive energy is a model that integrates that flexibility to more efficiently address system objectives and provide mutually beneficial choreography between supply and demand flexibility*.

Under the transactive paradigm price-discovery, or more generally, negotiation based on **value** could be balanced with generation and load requirements. Distributed control signals may then be based on a combination of value and imbalance requirements. This is an important point because it recognizes that control has an inherent value.

It is this flexibility and the ability to integrate distributed intelligent devices on both the supply and demand sides that makes transactive energy systems an attractive proposition. Transactive energy enables people and systems on both sides of the supply and demand equation (within a facility, locally, or regionally) to interact with each other and to make decisions based on individual values. *It creates the foundation for a distributed decision making approach that can harness the flexibility of both generation and loads to offset variability introduced by each other.* Transactive energy systems offer solutions that are innovative and interoperable so multiple parties can work together.

1.6 Problem Definition and Solution Approach

When developing a transactive energy system one must consider what problems the system will address and how the outcomes will be measured. Measuring the outcomes is important especially if one needs to demonstrate optimization benefits, reliability improvements, funding effectiveness etc. and in order to do that the requirements and objectives of the system must be well understood and documented. This section summarizes an overall approach to considering a transactive energy system that provides context for the questions in the following sections.

[4] Energy Information Agency (EIA)2014 Annual Energy Outlook

Transactive energy systems are being driven by economic, technological, and customer preference opportunities that were just emerging five years ago. Renewable energy sources are no longer experimental because of enhanced performance and declining costs. However, distribution systems were not designed for large scale, frequent insertion of energy from customers, which create power flows in multiple directions. Ad hoc arrangements have worked so far. But as the combined effects of changes – often outside of regulatory and utility observation and control – become significant, a more robust response to maintaining and enhancing safety, reliability, and resilience of distribution energy systems and markets is required. Any response should strive to create an increasingly flexible network at all levels of the electricity deliverability system.

Transactive energy systems are a means of achieving specific business and/or operational objectives related to the coordinated integration of multiple grid-edge devices such as customer equipment and distributed energy resources. A key feature of transactive systems is the ability to engage many loads and users that offer flexibility to offset variability introduced by renewable energy resources. A key starting point in considering designing and implementing a transactive system is to identify the specific operational and/or business objectives (top of Figure 2).

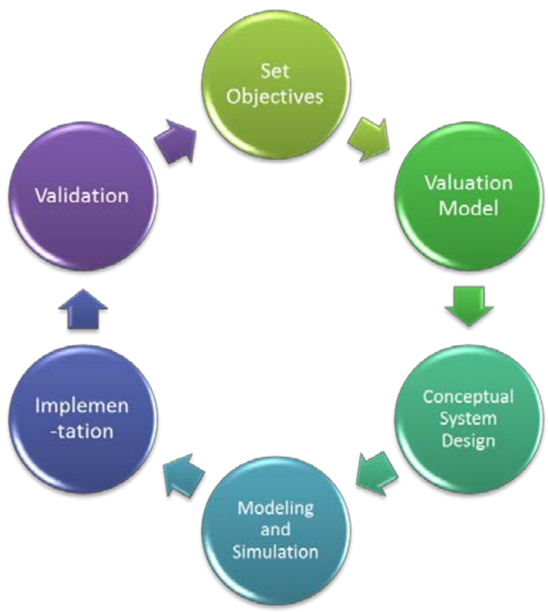


Figure 2 – Developing a Transactive Energy System

Having identified one or more such objectives one must consider whether or not they are dynamic and how they might be monetized (valued). One can then begin to develop a conceptual design of a transactive system intended to address those objectives. Modeling and simulation can begin to flesh out the conceptual design in support of detailed design. Additional modeling and simulation of the detailed design will verify that the system meets the operational objectives and can support the business case for the transactive system. Finally one can implement and deploy the system, gathering performance data during and after deployment to validate its effectiveness.

The steps summarized above represent a potential lifecycle for a transactive energy system project. In practice there will usually be design iterations and other elements typical of a modern software project

– but this simple summary illustrates the key elements of such a project that motivate many of the questions in this checklist.

Additionally, policy-makers and regulators must consider how to change the regulatory model to reflect customer and service provider opportunities arising from technological changes. The following discussion may help to frame the questions that should be posed to regulators, utilities, transactive platform providers, service providers and customers/prosumers.

It is important to note that the regulatory model and enabling legislation must recognize customer resources and grid service provision capabilities today and tomorrow. In other words, *the new regulatory model must be as flexible as the resources being added to the grid*. The model must also recognize that not all customers will participate in a transactive energy system and that those customer's interests must also be protected. Among many factors, the new regulatory model must:

- Identify and enable monetization opportunities for customers, utilities, and third parties
- Maintain fiscal and operational health of the utility
- Ensure transaction and pricing transparency
- Ensure service reliability and affordability
- Develop new forms of dispute resolution procedures that recognize customer-to-customer, customer-to-utility, and customer-to-third party transactions.

Regulations can influence the pace at which transactive energy systems develop, but customer capabilities and increasingly affordable generation, storage, ancillary service capabilities, demand management, and communications technologies will ultimately drive the increase, the development, validation, and deployment of transactive energy systems.

1.7 Example Transactive Energy Systems

1. A solar integrator provides industrial and commercial customers with a lower cost alternative to utility power by installing solar farms potentially shared by multiple customers. Acting as a microgrid, the solar company sees an opportunity to manage their solar production as an option to utility provided power and develops a method to optimize power generation and demand through customer incentive programs on their system. They want to engage with the utility to help manage peak loads using the solar resource and also work with their customers to limit demand when prices spike or to increase demand when there is excess solar power for example. The objectives are to sell power to customers and the utility, and also to consume solar power rather than reduce generation in situations where they cannot sell to the utility. They want to base the decision model on value based transactions between the three parties.
2. A retail mall customer with a million square feet of conditioned building space is considering adding in their own DER and sharing the cost (and value created) with their lease holders. Each store is retrofitted with a real-time energy sub-meter (non-utility owned) for owner-to-lease holder billing. Each retail customer has the ability to manage their space for lighting, HVAC, and other energy levels (freezers, grills, etc.). The mall owner wants to engage in a transactive based system to help their lease holders and the utility mange load based on real-time pricing and demand based on individual lease holder preferences. The mall

implements an advanced building automation system that can adjust individual space energy requirements per “contracts” with lease holders and can enable the DER based on weather, energy cost, and other relevant parameters. A transactive system enables all parties to set their level of benefit/risk based upon their own sets of values.

2 The Decision-Maker’s Challenge

This section provides guidance about appropriate and effective uses of this Checklist. Guidance is based upon framing the business/operational challenges and goals that are facing decision-makers along with a number of questions. These questions are to challenge the decision-maker in order to validate that the challenge for which the transactive energy approach is being considered is well understood. In terms of a potential transactive energy solution this section is aimed at helping the decision-maker identify **what** the challenge is.

2.1 What is the Operational Objective or Challenge for which a Transactive Energy System is Being Considered?

One of the principles of transactive energy systems is that they enable programs, services, and policies that benefit all qualifying parties in a transparent, equal access participation model. In order for a decision-maker to make decisions related to mutual economic benefit it is necessary to understand the scope of the challenge being addressed. The first step is to make sure that the operational or business challenge for which a transactive energy solution is being considered is satisfactorily understood.

Equally if transactive energy is being considered as a possible solution, it is important to be familiar with the business, technical, or policy drivers that make a transactive energy system an attractive solution proposition, or to understand where they need to be changed to create the opportunity.

To begin to address these questions the decision-maker must be able to identify their business, operational, and control objectives. If these objective are unclear, then transactive energy may not be the solution they are seeking. To go one step further, GWAC would question whether proceeding with any implementation is prudent if the underling drivers are not well understood and documented. If the decision-maker can state with reasonable confidence what the value drivers are for their challenge (or a proposed solution for their challenge) and they can identify the stakeholders involved, then the operational and control objectives may be able to be determined separately.

2.2 Is There More than One Objective or Problem Being Addressed and if so How are They Related?

Transactive energy solutions are a good fit for resolving multi-stakeholder / multi-objective challenges. These multiple goals pose the type of multi-objective control and optimization challenge that transactive energy systems were intended to address.

For decision-makers faced with trying to satisfy multiple objectives, instead of being a potential roadblock to a solution, this type of challenge is in fact a good indication that a transactive energy system could provide a viable solution.

Transactive energy embraces both the economics and engineering of the power system. A key principle in the broad application transactive energy systems is the continuous alignment of multiple objectives to achieve optimum results as the system operates. This alignment enhances the economic and engineering impacts of the dynamic balance(s) achieved by transactive energy systems. Note that optimal relates to balancing the entire transactive energy system, and to achieving an optimum balance necessary to optimize objectives, variables, and constraints. It is important to understand that optimization does not simply add intelligence to existing business processes, it changes business practices.

2.3 Who can Participate and How?

Understanding who will benefit from and who can participate in a transactive energy system is very important. Fundamentally, transactive energy involves transacting parties. Because a transactive energy system will provide services to various parties, its success in delivering these services will depend in part on the expectations and needs of each group and in part on the qualities of the delivered service. One of the principles of TE systems is that they should provide for non-discriminatory participation by qualified participants.

2.4 Is There Adequate Stakeholder Representation?

Transactive energy systems represent a convergence of economics and control. Combined with the fact that they are suited to addressing multi-stakeholder / multi-objective challenges this means that many interests must be considered, thus a diverse team is needed to support the evaluation of deploying such an approach.

The project team should include representatives from engineering, operations, planning, markets, customer service, IT, and cyber security.

If not, the team initiating the effort should begin to inform themselves about the related areas outside of their expertise and reach out to others to join the effort as it proceeds but early engagement is important. Energy costs and the increasing prevalence of renewable DERs and demand management capabilities in many markets is driving change as the grid evolves to accommodate them. Soon, more specialized markets will develop at the distribution level and in markets supporting but outside the utility wires. There are many challenges to address and multidisciplinary teams will be needed to resolve them or the risk is that a proliferation of specialized systems will appear that can selfishly optimize their own values but cannot adequately coordinate their actions and play nicely together, to the overall detriment of the grid.

2.5 How Will the Value Associated With The Objectives be Quantified and Monetized?

Another consideration for implementing a transactive energy system is the relationship between the value from an operational perspective and a long-term planning perspective. A transactive energy system that provides flexibility today will ideally be able to provide some capabilities to continue to create value as the grid evolves. The changes happening to the electricity grid are challenging the ability of traditional centralized systems. Transactive energy systems offer the potential for flexibility over time as well; *but quantifying that value and monetizing that value requires that the impacts of potential future changes can be assessed*.

As we move to a more distributed future, the reality is that we are already creating a hybrid system that combines central generation with distributed generation, ancillary services, and demand management. In most cases central coordination is able to bend far enough that the grid does not break; but it can only bend so far. We have to find ways to make it bend further with enhanced flexibility as renewables and intermittency increase daily and challenge the limited flexibility of today's grid on an increasing basis. Understanding how a proposed system addresses change is an important factor.

When attempting to quantify and monetize the value from a proposed transactive energy system it is helpful to consider the views of all stakeholders and a multi-disciplinary team will help with this. It is also important to consider how the value of DER, demand management, and ancillary services will vary within a day and over time thus analysis of potential solutions must be capable of recognizing these shifting values over time.

Things to consider include:

- How the system could be designed to be meaningful to utilities, DSOs, regulators, RTOs/ISOs, consumer advocates, and other stakeholders.
- What is the nature of the time-varying properties of the challenge.
- How to efficiently maintain the balance between supply and demand while delivering value to participants and also maintaining system reliability.

2.6 How will Success be Measured?

Defining and agreeing on the success metrics and a validation plan for a transactive energy project is crucial to ensuring an effective design and an implementation success. For example, if the operational / business objective for applying a transactive energy system is to manage loads in order to avoid building new infrastructure, the success metrics could include both whether the cost of engaging load flexibility is less than the cost of new infrastructure and whether the constraint or other reason for managing loads is also being met.

It is important to understand the success metrics for a transactive energy system and how they are related to objectives for multiple stakeholders. Additionally, the success metrics should be SMART i.e., Specific, Measurable, Attainable, Relevant and Time-based.

In a broader context, it is prudent for the decision-maker to understand the expectations for how the use of a transactive energy system helps to achieve multi-stakeholder objectives that can be measured over various areas including but certainly not limited to:

- Financial bottom line
- Company reputation and good will
- Environmental sustainability
- Quality of work environment

2.7 Does the Regulatory Environment Support the Proposed System?

The traditional utility model is predicated on load growth, but energy efficiency has severed the link between population/economic growth and energy growth. This change plus the shorter time scales for adding DERs when compared to traditional generation sources, and the increasing technical capabilities to facilitate cooperation and coordination between DERs, users, and devices creates a need to re-evaluate our cost of service regulation model.

New regulations are beginning to evolve as distributed energy resources and new technologies influence how energy is generated and consumed.

An important consideration is thus whether the regulatory environment or environments for the proposed TES supports the necessary enablers for transactive energy systems.

And if not, is another solution more viable or should the decision maker be working with regulatory staff to help pave the way for regulatory changes to support it?

2.8 Do the Existing Regulations Support the Plans?

The increasing diversity of resources has implications for the existing economic- and market-based elements of the power system. Markets have historically operated in a manner mostly decoupled from short-term grid operations, but in the future they might integrate with grid control on shorter timescales more appropriate for the new grid functions. This requires simplified mechanisms for integration of markets, advanced grid controls, non-utility grid-connected energy assets (DER), third-party energy services organizations, and responsive loads.

Some states are actively looking at ways to change regulations to support the changing energy ecosystem.

2.9 Are the Alternatives to Current Plans Well Understood?

Understanding whether a transactive energy system is the only way to provide a solution to the decision-maker's challenge requires a good understanding of the drivers of the underlying challenge. A good starting point is to list the key functional requirements and determine for each requirement whether a transactive or traditional approach would provide a solution. Quantifying the differences in benefit will help to decide which approach to take.

For many challenges a transactive energy system may not be the only solution, but it may provide a more flexible solution than a non- transactive approach. Transactive energy also provides a method for offering choices to participants in a market-like environment.

What makes a transactive approach more attractive than non transactive solutions is the flexibility they can offer but that can be difficult to quantify. Scalability and the ability for the system to evolve are other desirable traits. If control is more important than choice or if there are limited numbers of stakeholders there may be other viable solutions. A valid question, as with any solution, is whether this is a challenge that needs to be solved or whether this is an opportunity to apply a solution that is looking for a problem to fix?

3 UNDERSTANDING IMPLEMENTATION TOPICS

This section provides questions that seek to validate the transactive energy approach for the challenges facing decision-makers in a number of areas. These areas are more fully described in the GWAC Transactive Energy Framework and the questions in this section build on the ***what*** from the first section and are intended to develop the decision-maker's thinking along the lines of understanding implementation topics that relate more to **how** the proposed system would work, focusing on topics like transaction details and exchanges of value.

3.1 HOW DOES THE PROPOSED SYSTEM ADDRESS THE TRANSACTIVE ENERGY SYSTEM PRINCIPLES?

The Transactive Energy Principles described by GWAC are, in effect, statements of high-level requirements for transactive energy systems. As such these principles are intended to be foundational elements of any transactive energy system. Therefore *it is important to ask how any proposed transactive energy system addresses these principles*. These principles were listed briefly in the Introduction to this document but since they are foundational in nature they provide an excellent set of checks and balances for a decision-maker to apply to a proposed transactive energy system to verify that these principles are addressed in the proposed solution.

1) **The first principle states that a transactive energy system should implement some form of highly coordinated self-optimization.** This means that transactive energy systems are composed of many distributed entities that work together. These interactions need to be highly coordinated; otherwise the system as a whole will not be optimized. If individual devices can take unilateral actions without feedback or consequences then the system cannot be optimized effectively or reliably. Individual devices may make decisions based on selfish goals but the system as a whole must optimize these goals by coordinating actions among participating devices.
2) **The second principle states that a transactive energy system should maintain system reliability and control while enabling optimal integration of renewable and distributed energy resources.** There are two important points here. One is that a transactive energy system is a component of overall system control and ensuring reliability is a key component of every transactive energy system. The second point relates to distributed energy resources. A key driver of change in the electricity delivery system is the introduction of distributed energy resources and a significant benefit of transactive energy system is the flexibility they provide. While not every transactive energy system will interact with DERs, it is important that the integration of DER could be accommodated by a transactive energy system where this interaction is feasible in order to provide increased flexibility for the system as a whole.
3) **The third principle states that a transactive energy system should provide for non-discriminatory participation by qualified participants.** This is self-explanatory. If the transactive energy system is open to participation (and not a closed system within, e.g., a facility) then there should be criteria that make the qualifications for participation clear and unambiguous so that any qualified participant is accommodated. There may be limits on the number of participants based on constraints that may be transactive energy system dependent. However, if the system can accommodate additional participants there should be no preference for one participant over another.

4) **The fourth principle states that transactive energy system should be scalable, adaptable, and extensible across a number of devices, participants, and geographic extent.** This reflects the fact that GWAC sees transactive energy systems as an effective option for challenges caused by the changing nature of the grid. Not only should a solution be adaptable for its intended purpose when it is implemented but the grid will continue to evolve and transactive energy systems will offer far more valuable flexibility and adaptability if they are able to provide a viable option for a continuing solution as the extent, number of participants and devices change over time.
5) **The fifth principle states that a transactive energy system should be observable and auditable at its interfaces.** This is particularly important not only to the two transacting parties, but also to the regulatory and policy-making communities so that they are comfortable that consumer protections are in place. This is more than just transparency, especially of pricing options, but also for conflict resolution and equality of treatment. It is important to note, that while the technological capabilities for transactive energy systems become more available, the regulatory approvals may be lagging. Public policy-maker and regulatory approvals will largely be based on ensuring that consumer interests, both for those participating in a transactive energy system and those who wish to remain in a more traditional relationship with their utility, are protected.
6) **The sixth principle states that a transactive energy system should be designed so that transacting parties are accountable for standards of performance.** Transparency of transactions, costs, benefits, and responsibilities of all interacting parties will be of paramount importance in securing the political and regulatory support necessary for businesses to proceed. It is equally important to note that legitimate utility and other energy and energy service providers will hesitate to enter the marketplace without understanding their potential liabilities. Confidence among consumers, energy service providers, regulators, and other stakeholders that performance requirements exist and that actual performance can be measured will be key to securing widespread participation and support for transactive energy systems. The basis of this principle has to do with the discussions of "firmness" of response. If a participant bids into a market how are they held accountable to deliver the actions/services that they bid? There needs to be some definition of how and when market participants will be held accountable for standards of performance in order for the system to work properly. Early adopters and participants will prove the concept, the value of interoperability and technological interfaces, and assure the regulatory, consumer, and industry sectors that mass participation is appropriate with monetary opportunities for all, but only if accountability exists.

3.2 How Well Are Potential Vendors Aligned with Transactive Requirements?

Engaging the assistance of vendors will be an important part of developing and implementing the system. Vendor solutions should comply with the principles of TE described in GWAC's Transactive Energy Framework including but not limited to:

- Interoperable with other stakeholder systems
- Open (non-proprietary access by multiple competing parties (no vendor system "Lock In")
- Transparent access to system information deemed relevant by all transacting parties
- Provide a compliant level of cyber security to accommodate all parties requirements

- System/solution compliance certification and ongoing validation, especially through service upgrades, etc.

This question was introduced early in this section so that decision-makers can dwell on this discussion as they review the other material and look for ways to engage potential vendors.

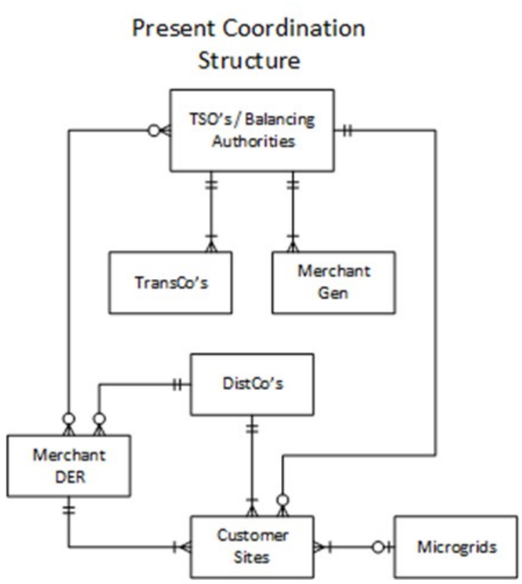
Some factors to consider as decision-makers look for ways that vendors can contribute based on other questions in this section, it is good to consider the following:

- Can they do what they claim?
- Is there a basis to assess whether the vendor can do what they claim?
- Have they simply added a "transactive" label to an existing solution?
- Are they familiar with the Transactive Energy Framework?
- Do their claims align with the attributes and principles of transactive energy systems?
- Can the vendor offer ways to improve stakeholder engagement?
- Will the vendor's proposal offer value to participating and non-participating parties?

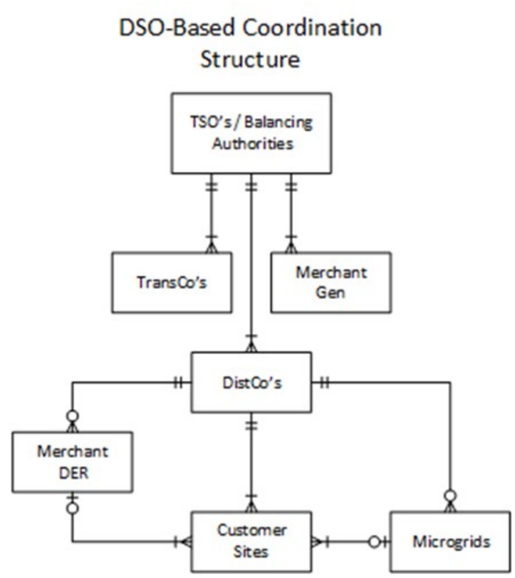
3.3 How is Value Aligned Within the System?

Assignment of value is fundamental to value discovery. A value discovery mechanism is a means of establishing the economic or engineering value (such as profit or performance) that is associated with a transaction. Fundamentally, a value discovery mechanism is the process by which transacting parties come to an agreement on value. For many transactions value may naturally be expressed in cost. However, in some transactions monetary costs may not adequately convey value.

Examples of non-monetary benefits are environmental quality, comfort, convenience, and health. Thus, value may be expressed monetarily or by a comparison of alternatives relative to a baseline.



Present Coordination Structure



DSO-Based Coordination Structure

Figure 3 - Current and Future Coordination Structures[5]

A key consideration is clear alignment of value and action in both the proposed architecture. Recent work on Distribution System Operator (DSO) constructs (Figure 3, above) illustrates this point.

- On the left of Figure 3 the present coordination structure illustrates that there are unaligned value chains. This is caused by the path directly from the Transmission Service Operator's (TSO) / Balancing Authorities to the Customer Sites. This path bypasses the distribution company thus limiting/removing the distribution company's ability to influence the customer site action.
- On the left of Figure 3 the DSO-based coordination structure illustrates the opportunity for value alignment. Action in response to TSO / Balancing Authority needs flows through the distribution company and therefore provides the opportunity for the needs of the distribution company to moderate action at the customer sites.
- Note that the relationship to Merchant DER is also affected by considering alignment.

Please note these paths are *information exchange paths*. The structure on the right should not be interpreted so as to prevent a prosumer, micro-grid operator, or any other Transactive participant with distributed assets, demand management capabilities, or other ancillary service values to deal directly with the Bulk Power system/market operator, but rather it ensures that the transacting parties share with, and get approval of, the distribution grid operator for such transactions. In so doing there is no need to disclose transaction details such as price to the distribution company (but they may voluntarily do so).

3.4 How Will the Objectives be Monetized?

The buck stops here. In general monetization will be the quantification that is used to express the objectives in a manner that some form of transaction can take place. This may be through expressing the objective(s) based on cost (or price), enabling the change over time to incentivize behavior or providing the information required to take market positions in a purely market based system (also refer to Section 2.6). Thus monetization will provide the basis for overall system optimization.

The impacts of this are self-evident. It means that all operational and/or business objectives need a way to be monetized. From a commercial perspective this is less of a challenge than monetizing subjective values, especially for customers who will in all likelihood need a way to convert subjective personal values into a way to provide objective criteria for decision making.

Once monetized, individual objectives can be optimized for overall system benefit. This may in turn cause some participants to reassess their values and so the system will continue to operate and iterate over time to maintain an optimal balance of goals and constraints while providing value to its participants. At the system level the monetization will need to balance all options for utility, service provider, and customer interests.

[5] Figure reproduced from: Grid Architecture and the Interactions of Power Systems, Markets, and Grid Control Systems, Jeff Taft, PNNL-SA-111777, http://gridarchitecture.pnnl.gov/library.aspx

3.5 WHAT AUTOMATION IS REQUIRED/AVAILABLE TO SUPPORT PARTICIPANTS?

Fundamentally, transactive energy systems involve transacting parties. In most cases these will be automated systems, possibly acting as surrogates for human parties. In some cases humans may be in the loop, but as emerging trends develop operations will increasingly shift to less human-in-the-loop control and more automated control with human supervision. Features to support transactive energy systems might be embedded in consumer products or in an Energy Management Agent[6] so that transactions occur automatically according to parameters set by the customer. Automation of responses will also enable participating parties to more efficiently respond to rapidly changing price signals for energy, demand management, or ancillary (or other) services.

Transactive energy systems will generally operate continuously. One of the drivers for many transactive energy systems will be to coordinate the flexibility from DERs. This will be driven by the need to offset the variability of customer equipment and other assets, requiring the transactive energy system to be capable of responding in discrete intervals - potentially many times a day. Not all customers will be able to respond manually and automation will be required to manage responses on their behalf according to their preferences.

For large scale deployments involving many participants or where participants can participate in many transactions per day driven by varying benefits, automation capabilities will be required. So even if automation is not an initial requirement, decision-makers need to consider the need for automation even if it is not initially implemented.

In consideration of automation there are several factors to consider. For example, regulators may need assurances that there is a healthy marketplace of automation available, but they shouldn’t worry about choosing automation products. Owner/operators will surely be interested in the choice of automation. Factors to consider may include:

- The choice of automation for deployment at customer premises
- How appliance and equipment makers can be motivated and incentivized to include automation for energy management in their products
- Ensuring that automation products conform to industry specifications and standards for interoperability
- The method in which customers will interact with these automated devices
- Whether the automation includes useful financial and energy data of interest to customers
- How the customer can set parameters that allows the system to operate within the scope that generates value for the customer
- How the automation platform interoperates with other potentially related customer needs, for example, water metering, home security, etc.
- The reliability, scalability, security, and reporting needs of the system
- The communication, data exchange and system operational control requirements

[6] The Energy Management Agent (EMA) is specified in an international standard, ISO/IEC 15067-3, "Model of a demand-response energy management system." The EMA allocates power from energy service providers, including a public utility, local power generation, and local storage. Power is allocated to appliances according to customer preferences for appliance operation (e.g., shower at 8 AM, pool at 7 PM, cooking at 8 PM, etc.) and the customer's budget for energy expenditures

3.6 What Form Will Transactions Take?

Transactions may be formal in the sense of bids and offers in a market or less formal in the sense of an iterative process to determine price and quantity. By exchanging information between participants (for example supply and demand) information about the elements of the electric power system and consuming devices or systems is used to make the decisions about what positions to take in the "market" so that value exchanges can be facilitated via transactions.

Message flow does not have to follow a hierarchy. It might be peer-to-peer, or it might jump from a regional node directly to a device, which in turn may respond very differently than it would have the day before. A transactive energy system must clearly define transactions within the context of that system. This means addressing who the transacting parties may be, what information needs to be exchanged between them to create a transaction, and what needs to be exchanged between them to execute a transaction once the parameters are agreed by the parties.

It is important to identify and discuss the rules governing transactions as well as the mechanism(s) for reaching agreement. This means understanding what information is needed to enable transactions in the system and to accommodate potential future changes. It also means providing explicit and unambiguous instructions for how decision making works related to transactions.

3.7 How Will The Market be Modeled And Forecast[7]?

Monetization and decision-making algorithms in transactive energy systems are still being developed. Some have been successfully developed and deployed and are operating today, but creativity in optimizing diverse objectives will continue to drive new ideas in this space. Modeling and simulation is recommended to confirm the ability of a transactive energy system to achieve operational objectives. Modeling and simulation is also able to help assess the potential scaling up of limited test deployments to broader scale deployments. Simulation tools and platforms that can be used to explore the impact of alternative ways to create and operate transactive energy systems to demonstrate how different transactive energy system approaches may be used to improve reliability and efficiency of the electric grid for different challenges and scenarios.

3.8 Market Interfaces - What is the Interface to Existing Markets?

Transactive energy systems offer flexibility to address the coordination of devices and will generally be introduced into an element of an existing electric power system. The existing electric power system will, at some level, have interactions with or be affected by existing markets. For example, a utility may be purchasing power on a spot market to meet peak loads. As a utility applies a transactive energy system to help coordinate DER integrations, this may also create an opportunity to offer flexibility from the distribution system to help balance variability in the bulk power system.

This type of capability will involve participation in a market established by the bulk power system operator. Thus, an important factor to consider in the deployment of a transactive energy system, even

[7] Note: This is still very much an emerging area and is the focus of work by NIST to engage a range of diverse participants to collaborate in advancing modeling and simulation tools and application of those tools. Also refer to Section 3.10

if the extent of the system is completely within a distribution system, is how that system can offer value through participation in related markets, and how those markets might support it.

This means researching and understanding those markets in order to be aware of:

- The form of interaction, i.e. how bids are made into the related market(s)
- How market positions are determined
- The risk will be associated with taking those positions and how that risk can be mitigated
- How benefit and risk stemming from market participation will flow down utility customers and transactive energy system participants
- The timescale of participation (e.g., minutes, hours, days)

3.9 Is There a Launch Plan and Horizon?

The launch of a new transactive energy system has several components to consider. Not least among these is how to engage and enroll participants (people, institutions, devices) and how to provide the capabilities to those participants to involve themselves in the opportunities presented to them. Depending on the scenario, the outreach and engagement may create a longer lead time than developing/implementing a market based system for value optimization. For a microgrid or campus system where a community is collectively driving the solution, the technology may have a more significant impact on planning timescales.

Additionally, the plan should be validated using an agreed upon model by all transacting parties. If adjustments are to be considered, a mechanism to implement changes should be included. This evaluation and retuning should be part of the launch plan and schedule.

3.10 What is the Relationship Between the Value of a Transactive Energy System from an Operational Perspective and a Long-Term Planning Perspective?

The timescale between operations and long term planning is vast. The speed of light is an equalizer in physics and this presents a challenge when operating a system where the commodity being managed and the control signals both move at the same speed. This means that planning and modeling have always been critical components of building an electricity delivery system. It also means that when conditions change and the performance does not match the model, we are at risk of unpredictable outcomes. At best we might understand what could happen but the great risk is being unable to react to it in time. The figure below shows the orders of magnitude in time that are spanned by an electricity delivery system from planning to real time management.

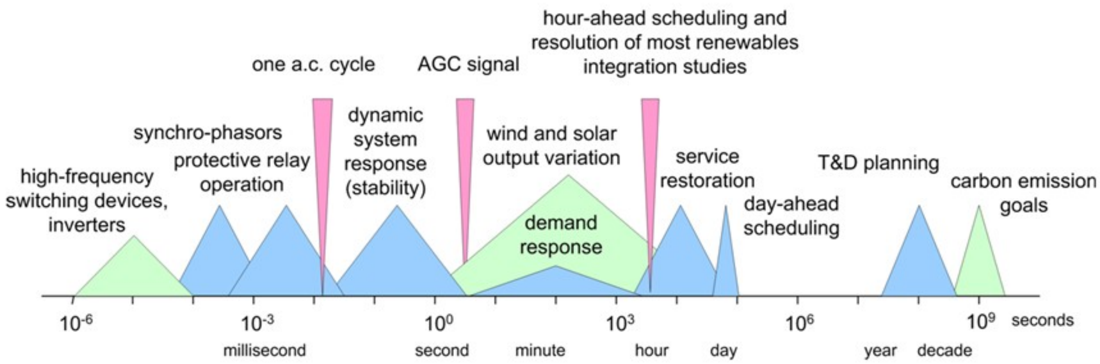


Figure 4 - Electric Power System Time Scales[8]

Modeling (see Section 3.7) is and always will be a critical component of building an electricity management system but it is increasingly necessary to increase the speed of control responses. This can be achieved by utilizing more automation and eliminating some human intervention in loop decisions, and also by distributing control authority rather than centralizing it. Since most electrical assets are durable, have long lives, and since modeling can take time it is not a quick proposition to build a new system. This presents a challenge when the system is changing. An effective transactive energy system needs to adapt to changes.

It is important to recognize that flexibility is important in two ways.

- The ability of a transactive energy system to distribute control and to optimize value based on inputs from each device makes it quick to respond and adaptable to system conditions. This may not be perfect for every situation but it may be the best approach to manage changeable conditions. In reacting to near time situations a transactive energy system provides the flexibility to coordinate activities relating to the distribution system.
- Whether today's distribution system will be the same as the distribution systems of tomorrow or in 5 years' time is difficult to say. A transactive energy system has a lot to offer with attributes that allow it to be flexible for adapting to changes in the broader system of which the transactive energy system is just one component. This is highlighted in the GWAC Transactive Energy Framework.

The Framework recommends that for maximum benefit the coordination component should be outside the transactive energy system so that transactive energy systems and other control components can be coordinated for best effect.

[8] "To 33% and Beyond: Grid Integration Challenges for Renewable Generation", Alexandra von Meier, CIEE, presented to: UCLA Smart Grid Thought Leadership Forum, March 28, 2012

4 Concluding Thoughts

There is only so much detail a document like this can cover and yet remain easily readable. The important things to understand are those that were described in Section 1.3 and as such the objectives of this document are to:

- Help decision-makers to identify ***what*** the challenge is
- Help decision-makers to understand the implementation topics that relate to ***how*** the proposed system would work

As one progresses through the questions posed and discussed in this document, new questions will probably be generated specific to the opportunity being analyzed. Some of these questions may overlap the scope of other questions in this document and some will be specific to the situation. It is helpful to make a note of these questions to ensure that they get addressed while making sure that time is allocated to work through all the questions in this document.

To help track progress in addressing these questions the following checklist provides paraphrased versions of the questions in the two main sections of this document.

- ☑ Find a source to learn more about transactive energy systems
- ☐ Document the operational objective for which a transactive energy system is being considered
- ☐ Describe how the objectives or problems being addressed are related
- ☐ Understand who can participate and how
- ☐ Ensure there is adequate stakeholder representation
- ☐ Quantify and monetize the value associated with the objectives (for each stakeholder group)
- ☐ Specify up front how success will be measured
- ☐ Analyze how the regulatory environment will or will not support the proposed system
- ☐ Review how the existing regulations supports the plans
- ☐ Explore and understand any alternatives to current transactive energy plans
- ☐ Assess how the proposed system addresses the transactive energy system principles
- ☐ Ask potential vendors to explain how they are aligned with transactive requirements
- ☐ Codify the process by which transacting parties come to an agreement on value
- ☐ Express the objectives in a manner that facilitates transactions to take place
- ☐ Consider the need for automation even if it is not initially implemented
- ☐ Identify the rules governing transactions as well as the mechanism(s) for reaching agreement
- ☐ Consider the use of simulation tools to explore the impact of alternative ways to create and operate the proposed system
- ☐ Understand how the system can offer value through participation in related markets, and how those markets might support it
- ☐ Validate the launch plan with all transacting parties using an agreed upon model
- ☐ Try to keep the coordination component outside the transactive energy system so that other control components can be coordinated for best effect

Having successfully considered the questions and discussions posed in this document the following questions are intended to provide further food for thought.

What questions should policy-makers and regulators ask of their utilities?

1) Do generation and distribution system operational requirement models include distributed energy resource and the transactive energy system potential in their calculations?
2) Do business revenue models include distributed energy resource and transactive energy system implications in their calculations?
3) Does the regulatory framework recognize evolving customer communications, generation, demand management, and customer-customer transaction potentials so that utilities and customers can monetize the value of services provided, especially in a time and need basis?

What questions should utility executives ask themselves, their policy-makers, and regulatory partners?

1) How will the utility manage its load forecasting and operational requirements within the Critical Peak Pricing requirements when customer generation cannot be accurately forecast?
2) How can customer monetization of their generation and demand management capabilities be accomplished without adversely impacting other customers?
3) How can individual rights of customers to manage their electric consumption/generation be accommodated politically and in terms of public relations so that all customers understand what must be done to avoid cost shifting between/within customer classes?

What questions should both public sector and utility sector executives ask each other:

1) Can the transactive energy system and interoperability standards work of the GridWise Architecture Council assist with deliberations and discussions?
2) Is one prepared to address the convergence of communications and energy consumption/production capabilities within a system that permits both the utility and customer to monetize their options?

Transactive energy systems are ***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.

Economics will prove to be the benefit or bane of utilities. Those that can identify ways to sell new services in support of customer options will thrive in the new energy era; those that remain committed to the sale of electrons will have greater difficulties. Customers that are capable of managing their energy production and/or use will have opportunities to succeed monetarily; those who do not have such opportunities will need to be protected by the policy-makers and regulators.

Regardless of whether one represents an electric utility or customers, change is here and will only accelerate as opportunities for customers to interact with their utilities, with their fellow customers, and with third party aggregators improve. Being prepared means thinking about how the new utility-customer relations can be shaped to be mutually beneficial.