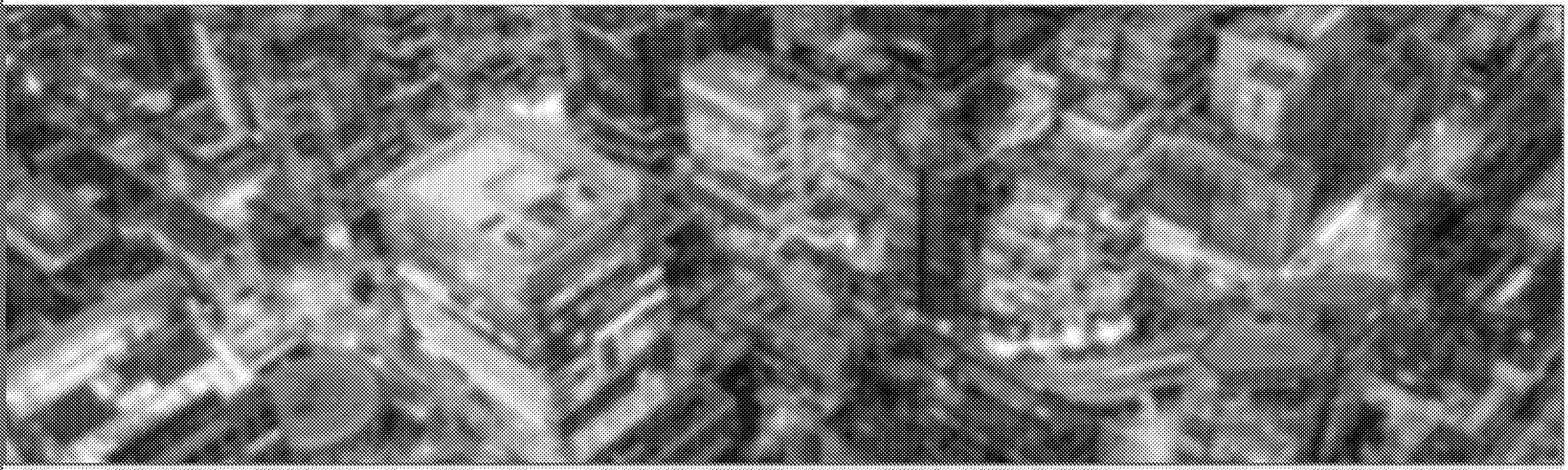
Regulatory Challenges with Transactive Energy in Urban Communities



Birendra (Bob) Singh,
Venkatesh Muthusamy,
Frances Okoye and
Dr. Bala Venkatesh

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Ryerson University

Centre for Urban Energy

Executive Summary

Driven by economics, growth in new technologies and above all customer choice to reduce GHG emission and to self-generate, distribution systems continue to see increasing numbers of distributed energy resources, mostly of renewable type, at customer premises. This has not only resulted in a sharp downward trend in utility revenue threatening their survival, but also in shifting/blurring operating and regulatory boundaries. Furthermore, this has also led to growing interdependence between generation, transmission, distribution and utilization systems.

The "band aid" approach of regulatory reform practiced hitherto has fallen short of utility and customer expectations on the electricity distribution side. The paper highlights the need for a comprehensive overhaul of the current electricity policy and regulatory structure in favour of one that is flexible, forward looking and allows for the creation of a transactive grid and market where a great number of market participants with diverse needs can buy and sell not just electricity but also related (ancillary) services in real time.

The white paper outlines an operational framework for a transactive energy system as well as policy and regulatory challenges associated with the transition. Transactive energy regulation needs to address, over and above the current needs of the electricity market, many new drivers including the needs of market participants in terms of financial gains, sustainability targets, resiliency etc. The infrastructure hardware/software must be scalable and flexible to adapt to new technologies. The paper sheds light on the transactive energy market risks and outlines leading thoughts on metrics design to track and improve transactive energy regulatory and market performance.

The traditional cost of service or simple incentive based regulation models are not adequate to address the emerging needs of the electric distribution industry. While in our research we did not find any example of a fully developed and functional transactive energy regulatory model utilizing a distribution grid, we were able to find and hence have provided examples of regulatory models that include some elements of transactive energy.

The white paper also sheds light on the organizational models under consideration by experts for a transactive energy system and provides some thoughts for Ontario on this issue. Because of the close relationship between policy and regulation, policy challenges are also highlighted in addition to regulatory challenges which have been discussed at length. Furthermore, integration of a plethora of renewable sources (such as PVs), automatic switching by a huge number of active elements (by DER controllers), and deliberate switching of load/generation by thousands of transacting parties in the new transactive market are expected to result in grid operating challenges at least in the short- to mid-term. The white paper outlines some of these operating challenges as well. Furthermore, considerations and guidelines for policy makers and regulators are provided.

The paper concludes with some pointers on regulatory excellence in a transactive energy environment.

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1. Introduction and Objective

Positive outcomes of deregulation in the telecom and natural gas industries in the 1970s and 80s led to the start of the electric power industry restructuring in the 1990s, breaking down its vertically integrated model. Innovative long-term power purchase agreements with private partners also began at that time, opening the doors of competition in the electricity generation sector. This was followed by changes in the environmental regulations leading to the development of renewable energy (wind first, solar much later) and its integration into the electric grid. Some customers also began generating electricity in an effort to lower their bills. Fast growth of new technologies, in particular, in the area of distributed energy resources (DERs) and controls, their declining cost as well as customer choice and drive to self-generate and interact with the grid are some of the key forces driving further changes to the electricity regulatory model.

1.1 Transactive Energy (TE) - What is it?

According to the GridWise® Architecture Council - The term "transactive energy" is used to refer to techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic or market based constructs while considering grid reliability constraints [9]. This would require open grid access for all supply and demand resources as well as transparent pricing of energy services.

A TE grid would be a flexible and multi-directional network, allowing interconnections of a myriad of intelligent devices including DERs and controls, and enabling millions of stakeholders to participate in the energy market for buying/selling energy and related services.

1.2. TE to Revolutionize the Urban Energy Sector

By integrating DERs, state-of-the-art controls, demand management, asset management, energy storage, cyber security, financial system, etc., TE is going to revolutionize the energy sector. The electricity distribution system would evolve to provide an interconnected network platform for integrating a wide range of diverse and disruptive technologies allowing interactions and transactions amongst different stakeholders engaged in new and complex relationships. This would allow prosumers a far greater choice than they now have in the way they generate, deliver and consume electricity.

Integrating DERs and demand-side resources (DSRs) is expected to result in benefits to all stakeholders in terms of lower net cost, higher reliability and resiliency of electricity supply.

1.3. Objective of White Paper

The objective of this white paper is to explore why the existing electricity regulatory model needs to transform and to highlight the challenges associated with the transformation.

Since policy and regulation are interlinked, brief discussions on policy and its challenges are also included. In addition, the paper outlines, at a high level, the framework and grid operating challenges for TE.

Since electricity distribution systems, as opposed to transmission systems, are expected to see most changes as TE unfolds, the terms "grid", "electricity grid", or "electric utility industry" used in this paper generally implies a distribution system or grid. This is not to say that the transmission grid is not impacted by TE and where it is impacted, such as in sharing market operating responsibilities between the two grids, it is outlined in the white paper.

2. Energy Regulation Evolution and Reform

2.1. Development in Energy Regulation

Under the present regulatory compact which includes obligation to serve, the purpose of regulation is to allow an electric utility to function as a monopoly while demonstrating efficiency in its operations and providing an affordable and reliable supply to customers.

The electric utility market restructuring started decades ago in many jurisdictions of North America when non-utility generators (NUGs) were first allowed to sell power to utilities and/or system operators under power purchase agreements (PPAs). The outcome of this was the breaking up of vertically integrated utilities in many jurisdictions, such as in Ontario, by separating their electricity generation and delivery sides of the business, and making the generation side compete with independent power producers (IPPs). In the 1990's, driven by (a) the need to lower electricity costs, (b) changes in the environmental regulation and (c) technological developments, policy makers started to incentivize the integration of more and more renewable energy (wind and solar) into the grid. As environmental concerns heightened and greater incentives for renewable energy were provided, the number of customers producing electricity within their premises saw a sharp upward trend, which still continues. This has posed a challenge to both the traditional utility business model and the competitive market structure that was created.

In restructuring to enable competition, the operation and control of the wires/grid (i.e., transmission and distribution - T&D) portion of the system has remained a monopoly due to high costs of constructing competing wires infrastructure and available right-of-way restrictions. The oversight for the management of the wires systems are vested in regulators with regional/independent system operators having the specific responsibility for bulk power system (i.e., transmission) reliability. [4]

2.2 Energy Regulation Transformation Imperative

According to a 2017 survey by Utility Dive, the general consensus amongst electric utilities in US is that we are moving towards a cleaner and more distributed grid where policy makers and regulators can assist in the transition. They also agree that significant changes need to be made to the traditional utility business model. While utilities in general are having difficulty recovering their fixed costs and justifying emerging investments, the majority supports incentive or performance-based regulation over traditional cost-of-service regulation. [11]

With growing environmental concerns, number of DERs/DSRs (including energy storage), microgrids, and interdependencies between generation, transmission, distribution and utilization levels, the structure of the electricity system is becoming more and more complex. Noteworthy is the fact that while decentralization of generation resources is occurring at a fast pace in an effort to self-generate and/or lower dependence on the grid, electric utilities continue to be not only the energy provider of the last resort, they are also responsible for guaranteeing overall safety, reliability and quality of power, all of which are becoming increasingly complex to manage.

The drivers of the regulatory reform can be classified as follows [5]:

(A) Shifting operating boundaries - With increasing numbers of prosumers, microgrids, net-zero loads, etc., who is ultimately accountable for load and generation balance, safety or reliability in a dynamic grid?

(B) Merging technologies and shifting technology boundaries - Integration of information, communication, and computer technologies (ICCTs) with the energy generation, delivery and utilization systems is ever increasing. New grid-service provider categories (such as load/generator aggregators to defer system upgrades) and multi-function equipment categories, such as energy storage with bi-directional converters, are going to play key roles in the future. How should the new service providers and technologies be classified in regulation since they do not fall in the currently well-defined categories?

(C) Weakening and blurring regulatory boundaries - Increasing interdependencies between (a) energy and environment sectors such as regulatory changes in environment driving energy projects, and (b) federal (FERC/NERC) requirements and state/province regulatory needs & actions such as increasing levels of distribution connected DERs driven by state/provincial initiatives impacting the reliability of transmission systems, demonstrate the need for a major regulatory reform in the energy sector and other mutually impactive sectors (e.g., environment, transportation, etc.).

The patchwork evolution of the electricity supply and demand framework along with its rules, regulations, and cost recovery models to pacify urgent requirements is not able to cope with the fast changing needs of the industry and its stakeholders. Furthermore, regulation always appears to be in the catch-up mode. Well thought out, flexible and forward looking regulatory strategies, policies and implementation plans for different levels of energy regulation, all streamlined for greater societal and environmental benefits, are needed to steer the electric utility industry through the transition period in a proactive manner.

3. Operational Framework for Regulatory Reform

As stated earlier, regulatory reform is critical to ensuring our continuing energy security and in our move towards a truly competitive energy market which TE embodies. A working group organized by GridWise Architecture Council (GWAC) in 2014 identified the following six guiding principles for an effective TE market/system operation [13]. Policies and regulatory rules need to be created to comply with these principles.

1. Transactive energy systems implement some form of highly coordinated self-optimization.
2. Transactive energy systems should maintain system reliability and control while enabling optimal integration of renewable and DERs.
3. Transactive energy systems should provide for non-discriminatory participation by qualified participants.
4. Transactive energy systems should be observable and auditable at interfaces.
5. Transactive energy systems should be scalable, adaptable, and extensible across a number of devices, participants, and geographic extents.
6. Transacting parties are accountable for standards of performance.

Evolution towards a highly integrated and automated TE market designed with the above principles in mind would be influenced by a number of factors which are also evolving and have potential to change the pace of TE evolution. Figure 1 presents a link between some of these influencing factors and the principles noted.

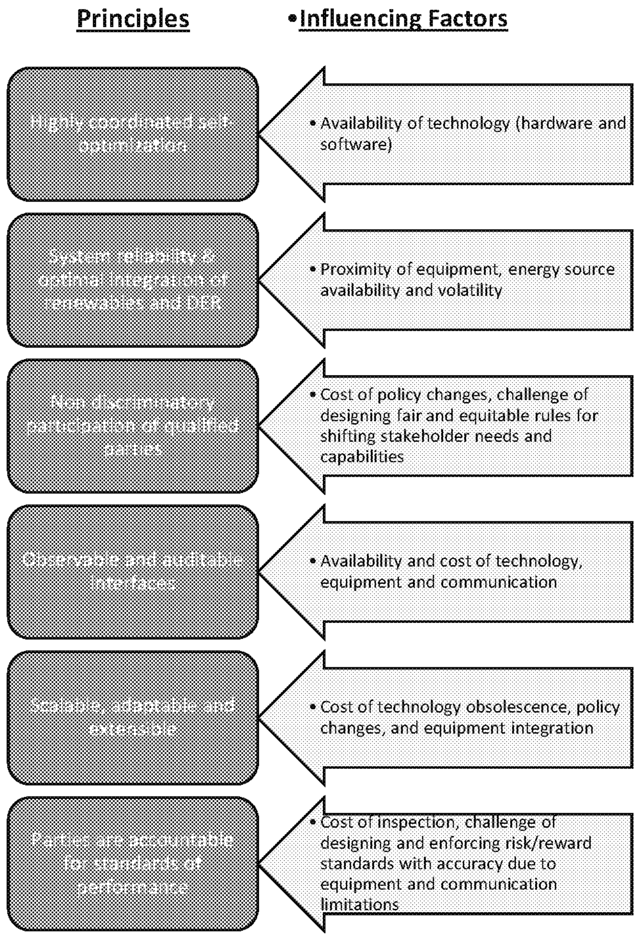

Figure 1: Principles and Influencing Factors for TE

Regulatory reform must be based on solid foundations of policy and framework to continually provide benefit to stakeholders, society and the environment. The success of regulatory reform would lie in ensuring appropriate governance, policy, regulatory construct, and enabling infrastructure (e.g., hardware, software, etc.) are in place to provide an evolving TE structure that meets the changing needs of all stakeholders and the energy market today and in the future.

3.1 Governance and Policy Needs for TE

The Business Dictionary defines governance as follows [17]:

"Establishment of policies, and continuous monitoring of their proper implementation, by the members of the governing body of an organization. It includes the mechanisms required to balance the powers of the members (with the associated accountability), and their primary duty of enhancing the prosperity and viability of the organization"

The governance of a complex system such as TE is expected to follow a structure similar to what exists for managing large corporations or universities with support groups as needed to take the electricity industry to a truly transactive level.

For example, California has established an Electricity Stewardship Board (ESB) to oversee the California State transition to a TE business and regulatory model. The ESB consists of a wide range of experts representing both professional and private interests. The board members are individuals that have experience and expertise in statewide and national policy making. As shown in Figure 2, the ESB directly makes high-level decisions on critical items such as framing, pilots, monitoring and communicating, which are then operationalized by the Science and Engineering Team with guidance from the Regional Stakeholders Group(s). [18]

The California ESB has the accountability for implementing policy and monitoring changes in parallel with established lines of authority and responsibility given to it by the California State legislature. This has been found effective in implementing high visibility, high impact policy [18].

Currently there is no TE grid or market in operation in California. Discussions are continuing on the pros and cons of the potential organizational models that would be most appropriate for California. Please refer to Section 3.5 for more details on the models.

Robust policy, governance and control are needed to ensure an effective TE system and market with equal access, transparency, sustainability and cost-effectiveness as key pillars. The electric utility industry transition is also characterized by "change and speed" especially in the area of technologies, stakeholder choices and expectations. The design of policy, governance and control needs to enable rather than impede regulators to manage change and to provide timely and effective resolution to regulatory issues.

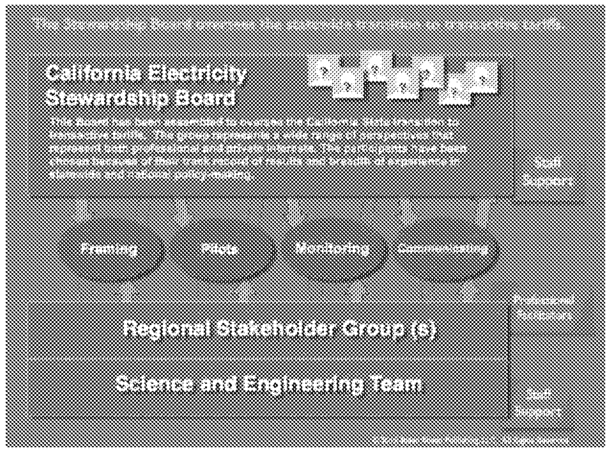

Figure 2 - Governance of California's TE System [18]

Consistent with the principles noted above, policies and regulatory rules need to be able to address the following market objectives/needs [3, 12, 13]:

- New market structures to deal with variability of large-scale renewable resources, such as energy imbalance markets
- Sustainable and decentralized energy with efficiency, reliability and resiliency as its key elements
- Promoting efficiency through new technologies in all sectors of the society such as efficient and high-performance buildings (including net-zero buildings), electric vehicles, etc.
- Coordinated and optimized decentralized investment and operation decisions
- Parties and their agents controlling their own devices, facilities, etc. and not those of others, unless dictated by contractual obligations
- Comprehensive market oversight and audit
- Monetization opportunities to utilities, prosumers, and aggregators to help them embrace technological innovations
- Acceleration of competitive and closely monitored markets
- Emergence of markets operating on shorter and shorter time scales (for energy balance,

demand balance, service delivery, etc.)

- Holding stakeholders accountable for standards of performance
- Creation of the distribution system operator (DSO) construct to take on the role of balancing supply and demand at the distribution level linking the wholesale and retail market agents
- Monitoring and identifying patterns and changes in the grid to forewarn regulators and utilities of upcoming impact on the business, e.g., increasing behind-the-meter sources resulting in declining sales from the grid
- Driving changes to the utility business model or the stakeholder compensation model due to changing drivers

A presentation titled "Energy Technologies and Policy-Making: Opportunities for Legislative Leadership", December 2015, by Tom Sloan highlights the fact that change is inevitable in the TE world, and offers the following advice to legislators [12]:

- Legislators, in collaboration with utilities and regulators, must become policy engineers to protect and permit customers and utilities to allow:
    - Customer's ability to monetize in response to price signals
    - Utility's ability to monetize in response to price signals
    - Customer's ability to interact with each other to monetize (outside utility control)
- Technological advances will continually define and redefine the relationships between customer-utility and customer-customer.
- Legislators ask for utility efficiency improvement plans to address rate pressures and declining energy demands in order to initiate utility corporate actions.

Policy makers, regulators, electric utility executives, generators, and customer advocates need to participate in designing policies and regulation that are capable of maximizing customer engagement, use of DERs, DR, ancillary services, etc. to create an innovative TE market providing value to all stakeholders.

The TE approaches include a combination of economic driven market practices and controls within the framework of existing policies and regulations to meet stakeholder and market objectives. There is a need, therefore, for convergence in policies across different levels from federal to provincial/state, suppliers to distributors, wholesale and retail markets, resource control systems, T&D control systems, and customer energy management systems in order to achieve policy objectives. These objectives may necessitate T&D utilities as well as Independent System Operators (ISOs) and Regional Transmission Operators (RTOs) to make use of distribution connected load/generation aggregators to help improve reliability at transmission and/or distribution levels [1].

3.2 Key Operational Needs for TE

The operational framework for TE is meant to provide guidance for developing a market structure within which a variety of transactive techniques can be implemented. For a transactive model to be fully developed, a variety of perspectives need to be considered both on the technical and non-technical sides. Discussions need to take place with stakeholders from varying backgrounds to capture their needs for consideration in the TE model development. This will enable the design of rules that ensure dynamic balance of supply and demand in TE market while meeting stakeholder needs [13].

3.2.1. Players and Their Roles in TE

While diverse groups of energy stakeholders would need to provide input into the creation of policies, regulation, etc., the following players and their roles are seen in TE:

A. Policy makers(legislators)
   a. Create and update policies to address the changing needs of the energy industry and its stakeholders
   b. Ensure policies are forward looking and allow for continual improvement of efficiency and sustainability through regulatory changes

B. Regulators
   a. Establish regulatory rules that ensure smooth operating of the TE market, license all market participants, set performance requirements and standards, address new customer options and equity issues, protect participants from predator practices, etc.
   b. Approve TE market rules, monitor TE market as well as its drivers and make

timely regulatory changes that keep pace with the changes in the industry.

C. System/Market Operators – Transmission and Distribution (ISOs/RTOs and DSOs)
   a. ISOs/RTOs – Regional oversight entities for transmission markets to facilitate competition, greater transparency, non-discriminatory access, grid planning and operation (to ensure reliability), interconnections and to provide protection against market manipulation. In a TE market, these entities would need to take on additional responsibilities of coordinating with DSOs/distribution utilities and at the same time would have access to additional energy and ancillary services located at distribution levels.
   b. DSOs – Responsibilities similar to ISOs/RTOs but for distribution markets. Under the TE environment, the complexity and mutual interactions of distribution and transmission markets would significantly increase due to customer and third party engagement.
D. Utilities – T&D
   a. Plan, maintain and operate the electric grid consistent with the established regulatory rules, and good utility practices
   b. Create and update market rules as needs dictate, seek necessary regulatory approval and operate the TE market
   c. Invest in innovative technologies to allow stakeholders to monetize customer capabilities (for products and services) and technological changes
E. Generators – Supply power/energy to T&D utilities and system operators
F. Aggregators – Provide ancillary services to T&D utilities and system operators
G. End Customers/Prosumers – Can consume and/or generate power/energy (bidirectional flows may result)
H. Other Stakeholders - Include researchers, economists, product vendors, etc. to address the technical and/or non-technical needs of the TE grid and market

E, F, G would drive the TE process forward through adoption of new technologies and active interaction with the grid/market [13].

3.2.2. Building Blocks of TE

A well-functioning TE market would require proper designing and implementation of the market rules, processes, standards and certifications. In addition, market business models with appropriate hardware and software are needed to execute the market and grid needs. The TE system optimization will be rendered through the engagement of market participants including prosumers, aggregators and DER owners, which can only be achieved when the regulatory framework allows flexibility and transparency in the system:

"Open access and transparency principles must apply to the interconnection process, distribution infrastructure planning, real-time operating procedures, rules for aggregating wholesale market bids from DERs within each LDA into a composite bid for the LDA as a whole, and rules for disaggregating and conveying instructions back to the appropriate DERs when the ISO market clears the composite bid." [14].

The principles that TE systems must implement are outlined in the beginning of Section 3. While these are high-level principles, the necessary regulatory rules and standards would need to be created and technologies utilized to achieve these principles.

<u>Market Design</u>
An effective market design needs to be based on the following guidelines [3]:

A. Simple products: subscriptions for energy and delivery (T&D)
B. Simple forward transactions: price, quantity, start, duration, interface, etc.
C. Coordination by mutually beneficial forward tenders and transactions among parties
D. Market clearing: peer-to-peer, bilateral, retail tariff, or exchange

The following points need to be considered in developing the detailed design of the TE market [16]:

- New pricing schemes in terms of rates, tariffs, market-based prices to be able to incorporate the full value of distributed resources in the power system, not just distribution
- Innovative demand side management programs
- Adoption of DERs that meet participant,

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utility and policy objectives
- Market maturity and liquidity (most DERs are for individual end user needs and cannot supply to other end users or produce very little, affects liquidity required in the distribution market structure)

Processes:
Applicable processes need to be identified in regulatory documents and market rules to ensure consistency, transparency and fairness in interactions between the market and market players. Market participants (e.g., utilities, etc.) will need to develop their own detailed internal processes based on the regulation and market rules taking into consideration the needs of market participants to satisfy the overarching goal of the market and the society.

Standards:
The adoption of TE will open the market to many participants including millions of customers. Communication and automation technologies are critical for TE and need to be a reliable and cost-effective from a broad stakeholder point of view. Demand data, pricing, reliability signaling etc. need to be collected and sent across complex distribution networks transferring information to operators and market participants. Open communication standards are necessary to develop the infrastructure that is required to facilitate communication across such large scale operation. OpenADR is one such communication standard that was developed to give demand response a larger role in grid operation [22].

Interoperability standards developed and adopted for TE would ensure that there is consistency in information exchange and operation across the diverse components and networks that are interconnected. While these standards may be primarily concerned with the interaction of system components and equipment, they should encourage innovation among component manufacturers, adoption of innovative technologies and practices improving reliability, cybersecurity and operating efficiency. Technical and non-technical standards, in general, developed for TE, for different layers of the electric power industry, need to be streamlined and have complementary objectives. Creation of appropriate standards and their compliance (i.e., certification) is necessary for the widespread adoption and effective functioning of TE [23].

Certifications and Testing:
Testing and certification of technologies tend to be the result of regulation or developed from the concerns of customers. Market participants and their requirements for safety, efficiency, flexibility, interoperability etc. motivate the development of testing programs and therefore should be actively engaged in the process of developing certifications and testing [23]. Some of the key players in the testing and certification program are the Interoperability Testing and Certification Authority (ITCA), accreditation body, testing laboratory and the certification body [25]. The ITCA is responsible for using best practices to develop the certification programs, establishing the qualification requirements for testing labs and ensuring that the cost of the certification process is reasonable with respect to other product costs and the risk associated with failure of the product [23].

Since testing and certifications are also used to ensure compliance of standards that have been developed, information from the programs can be used to improve the standards, identify errors and implementation difficulties [23]. When properly executed, testing programs can reduce costs, e.g., utilities (purchasers of products) can eliminate many internal tests needed to ensure that products will meet utility expectations. In addition, well established and accepted certifications will enhance innovation by facilitating acceptance of new technologies [24].

3.3 TE Market Risks

To be able to measure and assess market risk, it is important to create the success metrics and a validation plan keeping in mind the objectives for the market participants and the market. For example, if the business objective is new infrastructure cost avoidance triggered by load growth through the use of TE, 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 critical to understand the relationship between the elements of the success metrics and objectives of multiple stakeholders. The well-known principles of SMART (i.e., specific, measurable, attainable, relevant and time-limited) need to be considered in creating success metrics [1].

Some of the key market risks associated with TE are as follows:

3.3.1. Risks of not meeting market participant needs

Due to a mismatch between expected and actual outcomes caused by issues in market design and operation, market participant transaction needs may be compromised. For example, a customer may not be able to purchase the required amount of electricity within a specified timeframe as a result of a market problem suffering financial losses.

3.3.2. Risks associated with unpredictable real-time demand and supply

Due to a high number of switching activities by market participants, there may be risks associated with balancing supply and demand in real time causing system (technical) problems and/or market participant obligation not being met. Scenario analyses to address all possible contingencies will need to be carried out and solutions put in place beforehand. For example, greater levels of spinning reserves may be required to compensate for the uncertainties in resource predictions.

3.3.3 Risks Associated with Power Quality

With both the increasing numbers and switching operations of prosumers and load/generation aggregators in the TE market to satisfy their specific business objectives, increasing frequency and severity potential of power quality (PQ) issues exist. Furthermore, PQ problems in certain cases may be compounded due to concurrent switching operations, volatility of renewables, plethora of power electronic devices, etc. Here again, scenario analyses to understand and address PQ issues will need to be carried out and solutions put in place beforehand.

3.3.4 Risks associated with Faults and Failures

As the transactive grid is an Internet-of-things based system, it will be constantly supplied real time data from thousands of sensors. Malfunction or failure of sensors threatens system performance and transaction accuracy. Even a small sensor variation or software glitch can affect the performance of the grid. Furthermore, risks associated with the communication systems and servers can pose a significant to the TE operation due to its heavy dependence on them. The robustness and redundancy of the hardware and software design with regular testing and validation would be required to minimize the risk.

With an increasing number of microgrids, there will be increasing complexity in fault protection coordination with the grid and neighbouring microgrids. Without diligent attention paid to this at the design and testing stages, an improper coordination in protection or a misoperation of a protective device such as a circuit breaker can have wider consequences.

3.3.5 Cyber Security Risks

As stated earlier, the TE system will be very dependent on information and communication technologies (ICTs). As ICTs are always prone to hacking, danger exists leading to electricity thefts. Also virus and malware attacks to the TE system may lead to complete system shutdowns or blackouts. There have been cyber-attacks on electricity grids in the past. Hence the system must be robust in design and firewalled from any such attacks.

3.4 Regulatory and Market Performance Metrics

3.4.1 Regulatory Performance Metrics

Regulatory excellence requires a well-designed set of metrics/indicators as well as supporting structure to be able to track its own performance so that improvement measures can be taken. The metrics would reflect tracking regulatory performance in all key areas including achieving policy objectives, market operation effectiveness, customer protection, etc. Since results are to be tracked and not activities or input, there is an emphasis on creating metrics that would deliver on results in line with regulatory vision, mission, goals and objectives. This may necessitate internal organizational restructuring of the regulatory body to facilitate the tracking and reporting of metrics as well as to realize performance improvement.

While each regulator will develop its own set of performance metrics based on needs, given below are some examples [6]:

- Reduced compliance cost without lowering standards (i.e., improved efficiency minimizing administrative burden)
- Regulated community satisfaction index (through annual survey)
- Turnaround times and costs of regulatory approval processes (for operational efficiency)

3.4.2 Market Performance Metrics

The market designer needs to understand the risk associated with not being able to meet requirements and expectations of market participants. The TE market would need to be designed such that it is able to achieve multi-stakeholder objectives and measure many goals including financial outcome, sustainability targets, reliability targets, etc.

Some of the major evaluation metrics associated with TE involving DERs are as follows [2].

- Cost savings from peak reduction through the use of DERs and DSOs (from deferred generation and T&D upgrades, flexible buildings displacing their loads from high to low generation periods)
- Supply security to manage dynamic demand/supply imbalances
- Spinning Reserves to compensate for loss of one or more generator

The total cost savings from DERs of $22.1 billion per year (collectively) by estimates from PJM, CAISO, ERCOT, MISO, and NYISO are reported in [2], as shown in Fig.3 below.

Value Stream	Residential	Commercial	Res. & Com.
Peak Capacity	8.8	8.0	16.8
Wholesale/Production	2.7	1.0	3.7
Regulation			0.3
10-min. Spinning Reserve			1.2
Total			22.1

Figure 3: Cost Saving Opportunities from Transactive Grid [2]

3.5 Potential Organizational and Regulatory Models for TE

3.5.1 Organizational Models for TE

As the electricity market moves closer to the TE structure, the roles of the service providers, customers and third party aggregators will change. Currently there are two organizational models discussed in the literature in the context of TE.

The Distributed System Platform (DSP) and the Independent Distribution System Operator (IDSO) models are two potential structures that show the roles of the utility and the grid in the changing environment. Under the DSP model, a single utility will perform all distribution grid operation functions with the DSP having the responsibility for grid operations with the market, providing platform for DER integration and integrated planning. For this model to work effectively, the regulatory rules need to ensure that a DER-based solution and a traditional "wires" solution to address a distribution reliability need are both considered on an equal footing. However, there will need to be a functional separation of the integrated planning and asset owner roles within the utility [26].

The IDSO model would be similar to the (transmission) ISO/RTO model where the IDSO would be responsible for integrated planning, market operations and DER integration. Following established and approved criteria to address a reliability need, the ISDO can select between a traditional "wires" solution and a DER solution. Depending on the solution selected, the IDSO would contact the utility for potential distribution grid upgrade or take steps to procure DERs [26]. The distinctions between the two models are outlined in Table 1.

Ontario covers a large geographic area with about 60 local distribution companies (LDCs), the majority of which are in the southern zones where TE markets may be of value. Because of a large number of LDCs involved, creation of a few distribution system operators (DSOs) working with Ontario's Independent Electricity System Operator (IESO) might make sense. For example, southern Ontario where the concentration of LDCs exist can be divided into, let us say, five regional distribution system operating zones to address the distribution market operating needs. Ontario may choose one of the two models discussed in the literature or any other models that it thinks may be appropriate at the time. If the IDSO model is selected, there could be five regional distribution system operators (RDSOs) as independent operating entities. If, however, the DSP model is selected, the larger LDCs may take on the additional role of distribution system operators for designated areas as these LDCs may be able to cost effectively integrate the service territories of smaller LDCs for operating purposes.

3.5.2 Regulatory Models for TE

Regulation can encourage regulated entities, in this case utilities and market operators, through incentives and disincentives driving them towards achieving certain social and policy objectives. Traditional regulatory models urge utilities towards preserving system reliability and stability, meeting customer demands, etc., all in a cost effective manner. While these goals are still relevant today, other broader societal objectives such as reducing environmental impacts of the power system, integrating renewable and distributed energy resources, and protection against cyber security threats have emerged over the last decade for which traditional cost of service approaches are not adequate [19,20].

The Ontario Energy Board (OEB), regulator for electric utilities in Ontario, established the Renewed Regulatory Framework for Electricity distributors (RRFE) which is a performance based model that includes cost and formula based rate setting. It is a transition away from the traditional cost of service model that merges utilities' and customers' interest by encouraging their action in customer focus, operational effectiveness, public policy responsiveness, and financial performance [7, 15].

The three potential regulatory models presented here provide structures that can be adapted to suit the evolving utility and society needs. While these models are not specifically for a TE market, they do relate to some elements of evolution leading towards TE.

RIIO Model (United Kingdom)
The 'Revenue using Incentives to deliver Innovation and Outputs' was developed by the U.K electric regulator to reward or penalize utilities based on seven performance measures in addition to the regulation on price that was already in place. This model leads utilities to link financial success with achievements in customer satisfaction, system reliability, network safety, connection terms, environmental impacts, social obligations and price. The regulatory terms encourage the use of innovative technologies and reduction of inefficiency by utilities. [20, 21]

Iowa Model (United States)
Based on settlement agreements between stakeholders and overseen by regulators that ensured stable electricity prices in Iowa for 17 years, this model shows the possibility of agreeable negotiations among stakeholders to develop regulation that is profitable to all and is stable. The malleability of this model allows it to address changing and emerging goals and objectives of parties such as clean energy and climate change targets [20, 21].

Grand Bargain Model (United States)
This regulatory structure merges key aspects of the RIIO and Iowa model that is, it combines appropriate incentives and stakeholder negotiations to achieve regulatory objectives. The objective of this model is to move away from solutions that address individual issues towards wide range solutions that resolve groups of issues. This is to avoid cases of contradictory individual solutions and compel stakeholders to work together to develop more thorough and encompassing solutions [20, 21].

As electric utilities transition towards TE, stakeholder requirements, technology advancements and adoption, and other societal objectives would multiply. Since one size does not fit all, the essential element of these regulatory models is to provide a flexible and scalable framework which acts as a platform to support a stage by stage model creation and augmentation to address the changing TE system needs.

4. Challenges in Transitioning to New Regulatory Models

4.1 TE Policy Challenges

Because of the increasing complexity of the grid and a plethora of unknowns at this time, developing policies would be challenging. The unknowns include the following [13]:

- Extreme reliability - Can TE continue to provide the same high reliability that the customers are used to getting?
- Volatility of renewable generation and customer demand - How will variability in wind/solar generation as well as in demand impact the grid?
- Timescales of economics and grid control actions - Under long-term (lasting many decades) power purchase contracts, the grid is currently controlled adaptively, minute by minute, by a trained grid operator. In the next decade, thousands of prosumers, aggregators of load/generation, and devices will be making economic and control decisions at much different/faster time scales. How will the policy address this discrepancy?
- Rapid changes in technology - Technologies and their capabilities are growing at a fast pace while their costs are declining. Bulk power contracts last for decades during which changes in technology and cost can significantly alter energy economy. How will the policy account for this change in long-term power contracts?
- Reducing dependence on fossil fuels - Different levels of governments offer incentives for renewable energy, efficiency and electric vehicles. Since the influence of current incentives and expectations of future

incentives make long-term market analyses challenging, how will the policy address this issue in setting direction?

4.2 TE Regulatory Challenges

A mature regulatory model for TE is envisaged to be complex. This would require creation of a strategy which is evolutionary and flexible in nature and lends itself to the creation of a TE development and implementation plan in stages, with increasing complexity and maturity. As the TE implementation moves along, the strategy and the plan would need to be periodically reviewed and activities for future stages adjusted based on the lessons learned in earlier stages and updated projections of the future. The ICCT systems as well as all hardware and software for TE implementation would need to be scalable and adaptable to facilitate moving to the next stage with minimum cost. Regulatory challenges for implementing TE include the following:

- Complexity of a detailed framework with clear guidelines for evaluating benefit/cost of utility investments to make the electricity grid ready for stage by stage development & implementation of TE.
- Complexity of developing a scenario analysis tool based on benefit/cost assessment to guide the policy makers and regulators in staging TE implementation.
- Complexity in designing regulatory rules for cost recovery that drive and reward innovation in different sectors of the market. This would require creation of an innovative cost recovery model by the regulator that takes into account local as well as broader system benefits. These rules need to give consideration to the following: [10]
    - Utility cost sharing of smart projects
    - Sharing of lessons learned from smart investments amongst utilities
    - Need for leveraging municipal energy planning and regional planning processes to drive grid modernization through wider deployment of DERs
- Complexity of developing clear regulatory rules for qualifying new market participants, issuing licenses, and outlining their standards of performance as the TE market evolves. Examples include power quality improvement, grid resiliency improvement, GHG reduction services, licensing microgrid operators, etc.
- Complexity in integrating ICCT systems into the electrical grid for different stages of TE implementation in order to observe and audit transactions at interfaces.
    - The lack of complete interoperability between smart network components would result in higher integration costs, longer implementation timelines and technology risks. [10]
- Complexity in monetization of values for new services, e.g., commodity price risk mitigation, facilitating DER integration, etc.
- Complexity in ensuring alignment of appropriate benefits and costs to stakeholders in different segments of the market structure through standards and market rules in an effort to allow multi-party convergence.

4.3. TE Operating Challenges

While well thought out and crafted regulatory rules for every stage of the TE system evolution would definitely be a strong positive step forward, it is likely that utilities will still encounter operating challenges and will need to be prepared to deal with them in a manner that does not compromise the TE market operation. Grid operating challenges include the following: [8]

- Increased and unique distribution voltage and power quality management
- Increased variability in net load and hence balancing demand and supply
- Increased power flow reversals (peakier and faster) leading to increasing complexity of system protection and control and safety issues
- Cyber security and cyber-physical control to ensure reliable operation of distribution systems
- Timely adoption of a growing list of new technologies (since electric power industry is normally slow to adopt)

Distribution system operators (DSOs) will need to manage evolutionary changes for transitioning to the TE market by acquiring new skills, training, tools and processes including:

- New system modeling and analytical tools for distribution operating planning
- New processes for different services offered by market participants
- New system modeling and simulation tools for TE market analysis and delivering on market participant and regulatory needs

4.4 Regulatory Excellence

Energy regulation thought leaders emphasize "vision and execution" as key pillars to achieve an effective, responsive and efficient regulatory transformation. Given below are helpful points for consideration in regulatory reform [6]:

- Policy makers and regulatory agencies need to exercise the same rigour as business leaders in creating their mission, vision, core values, goals, objectives and metrics (to gauge progress) as part of their business strategy and reviewing/refining these on an annual basis. Furthermore, the execution plan of the business strategy must have clear delivery targets.
- Regulatory products, services and business models need to be grounded in "innovative and integrated" approaches. Regulatory rules need to give careful consideration to incentive creation and promotion, sources of investment financing by regulated entities and implementation details.
- The success in regulatory reform including transformation implementation process need to be judged based on tangible outcomes achieved where performance is tracked through carefully created metrics.
- Other regulatory excellence means include:
  - Restructuring operations for improved efficiency, effectiveness and transparency
  - Clear communication from top level management to change
  - "Bottom-up information flow" for buy-in and feedback
  - Offering incentives and rewards based on quantitative metrics and benchmarking
  - Taking integrated approach that covers all relevant costs, benefits, risks and impacts not only in the short-term but also in the long-term and considering trade-offs
  - Expanded role of public participation in regulatory processes and their redesign
  - Designing market-based regulatory strategies to promote innovation and to better leverage private sector funding
  - Clear regulatory requirements, standards and expectations.

5. Conclusions

Currently electricity markets operate at the transmission level with requirements only a few of which would match what would be needed in a mature TE market mostly geared to distribution systems where no such market exists. A TE market for electricity distribution networks will be a complex system of hardware and software allowing a vast number of market participants to interact with each other and utilities as well as T&D market operators in order to buy and sell energy and related services. The challenges associated with creating such a TE market is due to the complexity involved in developing, implementing and operationalizing a stage by stage transition plan which is evolutionary in nature and balances, minute by minute, the different and multiple wants and needs of all stakeholders as well as the energy market while recognizing the limitations of the existing infrastructure and technology. In addition, for a TE market to deliver on its objectives, alignment of policies and regulatory rules at federal, provincial/state, and municipal levels is required. Figure 4 shows the Drivers, Challenges and Considerations for Transactive Energy.

While the white paper gives much attention to regulatory challenges in a TE environment, it also sheds light on policy and operating challenges as these would contribute to a successful regulatory reform. The following points summarize the high-level needs to address regulatory challenges associated with creating a TE system:

- A well-functioning TE system would require a clear vision and execution plan with an appropriately designed and implemented governance, policy and regulatory structure.
- The policy and the regulatory model need to recognize customer side resources and grid service provision capabilities today and in future years.
- Regulatory rules need to provide market incentives, transparency, predictability, and quantifiable metrics for performance monitoring and continual improvement.
- Carefully thought out metrics along with supporting systems need to be in place for measuring regulatory success and performance improvement.

The stakeholders and their roles in the TE grid are discussed. The California Transactive Grid framework and models such as RIIO, Iowa Model and Grand Bargain which incorporate some elements of a transactive grid are briefly outlined. Some thoughts on organizational models for Ontario are provided. The success metrics for TE may include cost benefits, peak shaving, sustainability and reliability. Some pointers on regulatory excellence for policy makers and regulators are also provided.

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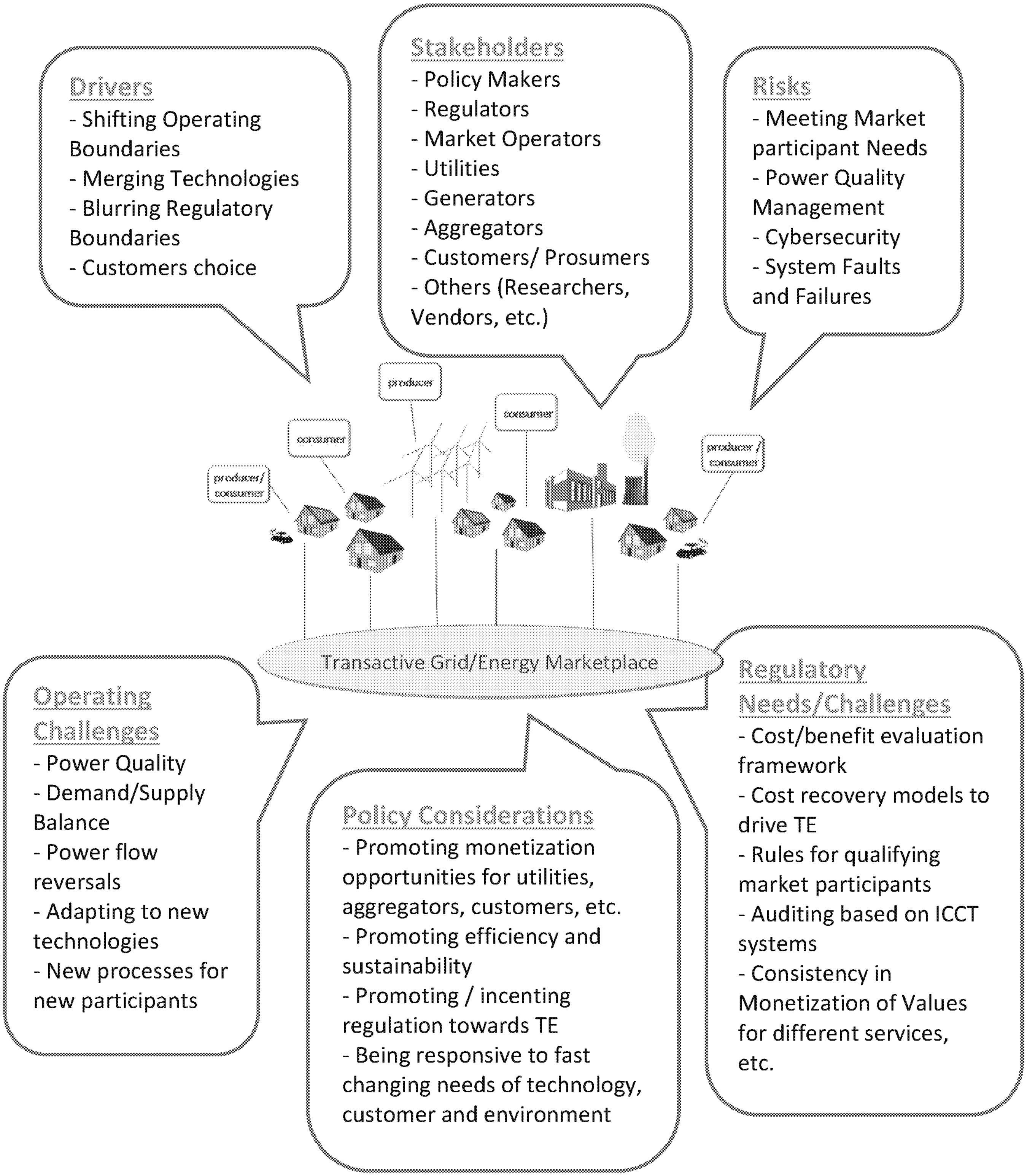
Table 1: Distinguishing characteristics and functions of DSP and IDSO structures (Source: [26])

Grid Functions			
Grid Function Categories	**Summary of Grid Function**	**Distribute System Platform Provider (DSP)**	**Independent Distribution System Operator (IDSO)**
Distribution Planning	**Planning:** Plan and design a safe and reliable distribution system in a manner that integrates DER as primary means of meeting system needs.	Distribution Utility	Independent Entity/ Distribution Utility (asset owner)
Distribution Market Facilitation	**Products/Services:** Identify and define products/ services to be exchanged between participants (e.g., via locational benefits of DER).	Distribution Utility	Independent Entity
	Pricing: Develop pricing structures for products/ services (market-based, tariff-based, contractual).		
	Scheduling and Settlement: Integrate resources plans, coordinate energy schedules, and administer and verify settlements.		
Distribution System Management	**Power Systems Operations:** Direct the operation and coordination of power flows to satisfy system needs and imbalance variations, including supply and demand; operate system to ensure economical, reliable and stable delivery of electric power.	Distribution Utility	Independent Entity
	Physical Operation: Coordination and operation of equipment in the field, including unplanned outage response, emergency response, circuit reconfiguration, equipment setting adjustments, routine clearances, etc.	Distribution Utility	Distribution Utility (asset owner)
	Distribution Grid Asset Management: Managing asset life cycle of the distribution grid to meet the desired level of reliability at the lowest total cost of ownership possible, where the distribution grid provides an integrating platform for competitive market participants selling products and services to end customers.	Distribution Utility	Distribution Utility (asset owner)

Figure 4: Drivers, Challenges and Considerations for Transactive Energy



Location

147 Dalhousie Street
Toronto, ON M5B 2R2

Mailing Address

350 Victoria Street
Toronto, ON M5B 2K3

Contact Us

416-979-5000 x2974
cueinfo@ryerson.ca

/CentreForUrbanEnergy

@RyersonCUE

ryerson.ca/cue

Ryerson University

Centre for Urban Energy