MOWAT RESEARCH #140 | DECEMBER 2016

Future Drivers and Trends Affecting Energy Development in Ontario

A LITERATURE REVIEW

Emerging Energy Trends

Mowat ENERGY
MOWAT'S ENERGY POLICY RESEARCH HUB

Mowat ENERGY
MOWAT'S ENERGY POLICY RESEARCH HUB

Mowat Energy's *Emerging Energy Trends* is a comprehensive study of how technological and consumer disruptions in the energy sector could affect Ontario and beyond.

This paper is part of a series of background reports informing the final report. Initial funding for this research was in part provided by the Ministry of Energy of Ontario. The final report and all other background reports are available at mowatcentre.ca/emerging-energy-trends.

The Mowat Energy research hub provides independent, evidence-based research and analysis on systemic energy policy issues facing Ontario and Canada. With its strong relationship with the energy sector, Mowat Energy has provided thought leadership to stakeholders, decision-makers and the public to help advance discussions on the challenges that energy is facing in Ontario.

Author

Cynthia Chaplin

MOWATCENTRE.CA

@MOWATCENTRE

439 UNIVERSITY AVENUE
SUITE 2200, TORONTO, ON
M5G 1Y8 CANADA

School of Public Policy & Governance
UNIVERSITY OF TORONTO

DECEMBER 2016

 ISBN 978-1-77259-027-2

Contents

Executive Summary 3

Introduction 6

Portfolio 1: The New Energy Customer 8

Concluding Observations 10

Portfolio 2: Meeting Energy Demand behind the Meter 11

Distributed Generation 11

Other Distributed Resources 13

Emergence of Transactive Energy 15

Distributor's Role in DER 17

Concluding Observations 19

Portfolio 3: Grid Modernization and the Utility of the Future 20

Rate Design for Distributed Generation: Net Metering and the Alternatives 21

Rate Design for DER 25

The Utility Business Model 28

Distribution System Planning 32

Advancing the Regulatory Framework 34

Select Regulatory Developments in Leading Jurisdictions 37

Concluding Observations 43

Portfolio 4: The Future of Centralized Supply 45

Stranded Asset Risk 45

Grid Level Resources and Grid Operations 48

Market Structure Reform 50

Concluding Observations 53

Conclusions 54

Appendix: Bibliography 56

Executive Summary

Ontario's energy sector is expected to undergo a significant transformation. The rapid development of new technologies and the entry of new service providers are expected to change the way customers interact with the energy sector and reshape the business models of the electricity transmission and distribution monopolies. Mowat Energy is conducting a comprehensive study of these emerging trends to produce recommendations for the sector, including policymakers and regulators. The goal is to facilitate the transformation of Ontario's energy system to one which is more innovative, flexible, reliable, clean and affordable.

The purpose of this report is to provide a literature review to support Mowat Energy's work. This report is not intended to be a complete survey of all available material; rather it is intended as a review of the leading work over the last two years. The goal is to provide readers with an understanding of the key trends and issues and the range of opinions. This literature review is structured along the four key portfolios in the research project:

- Portfolio 1: The New Energy Customer
- Portfolio 2: Meeting Energy Demand behind the Meter
- Portfolio 3: Grid Modernization and the Utility of the Future
- Portfolio 4: The Future of Centralized Supply

Portfolio 1: The New Energy Customer

Customers adopting new technologies and responding to new service options in the form of DER will expect utilities to be responsive in terms of service, pricing and compensation. All customers will continue to expect reliable and affordable service. It will be a significant challenge for utilities and regulators to meet these diverse and rising customer expectations.

Portfolio 2: Meeting Energy Demand behind the Meter

The literature related to Portfolio 2 examines the issues of DER, the emergence of transactive energy, and the distributor's role in DER. Effective integration of DER has the potential to benefit all customers, utilities, the system as a whole and society. However, utilities, policymakers and regulators will be challenged to keep pace with the technology and customer-driven changes. They must balance the demands of the new energy customers with the expectations of all customers for reliable and affordable service. Although solutions will be based on the specific characteristics of an individual utility or system, there is much that can be learned as DER is being developed and adopted worldwide.

Portfolio 3: Grid Modernization and the Utility of the Future

The literature related to Portfolio 3 covers the issues of rate design, utility business model, distribution system planning, and the regulatory framework. Rate design for DER is the subject of intense study and debate. Net metering is a simple, but potentially inaccurate way of recognizing the costs and benefits of distributed resources. It will be a significant challenge to develop rate designs which are accurate and effective without being excessively complex. More fundamentally, the utility business model and regulatory framework will need to evolve in order to effectively integrate DER into the system and the market.

Portfolio 4: The Future of Centralized Supply

The literature related to Portfolio 4 covers the issues of stranded assets, grid level resources and operations, and market structure reform. The risks of stranded assets are significant for distributors, transmitters and generators. While the risk is particularly pronounced if there is significant grid defection, it is less clear what the potential impact will be with integrated DER. Many systems are at a cross-roads: will utilities, policy makers and regulators adopt policies and frameworks which seek to retard deeper penetration of DER, or will they embrace the potential of DER and incent it where is economically efficient. The literature suggests that the first approach will ultimately be unsuccessful, while the second approach is complex and requires a coordinated effort to resolving the technical, regulatory and market issues.

Conclusions

A number of key themes in the literature will be relevant to Ontario as it addresses the challenges and opportunities of the emerging energy sector transformation:

- DER has evolved from a relatively simple load displacement tool (distributed generation) to an integrated resource which can provide a variety of services to the grid. This evolution has been enabled by the technology advancements and driven by rising customer expectations.
- DER has the potential to bring significant benefits in terms of reliability, resilience, cost, and environmental impact, but also introduces greater complexity in terms of planning, operations, rate design, and market structure, and may result in stranded costs.

- The evolution of the utility business model, the regulatory framework, and the market structure will need to be coordinated, but utilities and regulators will be challenged to match the pace of technology change and customer expectations.
- The optimal solutions for a jurisdiction will be driven by its particular characteristics and policy drivers, but solutions can be developed based on learnings from other jurisdictions. The stakes are high given the need to provide reliable and affordable services for all customers and the potential for significant stranded assets.
- Ongoing consultation, cooperative efforts, evidence-based processes, customer engagement, pilot projects, and transition mechanisms will each facilitate the successful navigation of the emerging transformation.

Based on the literature surveyed, Ontario already has some of the attributes which have been identified as important for the integration of DER:

- performance-based regulation
- smart meters and TOU rates for energy
- distribution system planning and regional planning which is becoming more transparent, organized and rigorous
- Experience with connecting renewable electricity generation on the distribution system, particularly at the individual customer level
- Increased customer engagement

Ontario can draw on the experience of others, as well as the analysis which has been done, to chart its own course through the energy market transformation. The work being conducted by Mowat Energy will be an important contribution to that effort.

Introduction

Ontario's energy sector is expected to undergo a significant transformation. The rapid development of new technologies and the entry of new service providers are expected to change the way customers interact with the energy sector and reshape the business models of the electricity transmission and distribution monopolies. This change is happening while the electricity sector is facing aging infrastructure and a significant shift to more distributed renewable sources of electricity generation. The pace and extent of the expected market transformation remains uncertain, although the same key trends and drivers are being experienced across North America, Europe and Australia. Governments are working to establish energy policy frameworks which support climate change and economic objectives, and regulators are working to establish regulatory policies and approaches which support those government policies and address the changing market.

Mowat Energy is conducting a comprehensive study of these emerging trends facing the energy sector. The study will focus on the drivers and potential trajectories of energy transformation in Ontario and on the effects of energy transformation on Ontario's energy sector and beyond. The purpose of the study is to produce recommendations for the sector, including policymakers and regulators.

Mowat Energy has engaged a number of international experts to support its work. These experts will prepare reports which provide critical analyses of the options available to facilitate the transformation of Ontario's energy system to one which is more innovative, flexible, reliable, clean and affordable. To support this work, Mowat Energy also requires a review of the recent relevant literature. The purpose of this report is to provide a literature review to support Mowat Energy's assessment of the expert reports and its development of recommendations for policymakers and regulators.

The material for this literature review is drawn from the Mowat Energy digital archive and from other recent relevant work. The reports, studies, articles and presentations come from a variety of sources, primarily academic and professional, although also from key industry participants. Although much of the work is from North America, there is also material from Europe and Australia. This body of work can provide Mowat Energy and others with valuable insights into the trends associated with this energy transformation and current thinking on how best to address the issues. A tremendous amount has been written about these emerging trends, and additional material is released daily. This report is not intended to be a complete survey of all available material; rather it is intended as a review of the leading work over the last two years. The goal is to provide readers with an understanding of the key trends and issues and the range of opinions. Readers are encouraged to refer to the specific reports and articles for greater detail. Appendix 1 contains a bibliography, with direct links to many of the materials.

The trends in Ontario are being experienced across North America, Europe and Australia. Industry leaders are recognizing the drive toward cleaner electricity generation, a more digital and distributed grid, and more individual customer services (Institute for Electric Innovation, 2015). Utilities themselves are acknowledging the significant change they are facing and recognizing both the external barriers (an outdated regulatory model) and internal barriers (resistance to change and the technological challenges of integration) (Utility Dive, 2016).

There is pressure to undertake significant investment to replace aging assets, but the changing market dynamics make it imperative that planning recognize the greater level of decentralization and adopt a long-term holistic approach (Energy UK, 2016). Experience from past electricity market restructuring highlights the importance of independent regulators and system operators, a robust pricing framework set through effective regulation and market design, and the removal of barriers to customer engagement with the market (IEA, 2005). While the trends and issues are largely the same across jurisdictions, there is a consensus that solutions should be developed on the basis of the technical and policy context of a particular jurisdiction, or even an individual utility.

This literature review is structured along the four key portfolios in the research project:

- Portfolio 1: The New Energy Customer
- Portfolio 2: Meeting Energy Demand behind the Meter
- Portfolio 3: Grid Modernization and the Utility of the Future
- Portfolio 4: The Future of Centralized Supply

Portfolio 1: The New Energy Customer

Changes in technology and economic factors are driving changes in customer behaviour. The pace and extent of change is influenced by demographics and economic circumstances. Customers have traditionally been delineated as residential, commercial or industrial, with each customer type sharing a set of general characteristics, including expectations for service, quality and affordability. In other words, commercial customers generally have more in common with each other than they do with residential customers. Broadly speaking, residential customers have been homogenous, with the only significant variation being in the size of load and socio-economic circumstances. In the future, there is expected to be greater variability, particularly amongst residential customers, in terms of service expectations and technology adoption. The differences between the groups may also shift.

The key technology drivers for these shifts include information and communication technologies, small scale solar PV, electrical vehicles, and conservation (energy efficiency and demand response). The key social, economic and policy drivers include growing customer expectations, demographic trends, and socio-economic conditions.

Traditionally, the electricity grid was unidirectional, delivering power produced at large central generating stations through transmission and distribution systems to end use customers. Pricing provided some signals to which customers could respond, but metering and billing was done monthly or bi-monthly so the pricing signals were fairly blunt. For residential customers in particular, electricity demand was relatively inelastic; in other words demand did not change much with changes in prices.

This overall structure is changing. Customers, including residential and small commercial customers, can now meet some or all of their demand using behind the meter distributed energy resources (DER). DER is a general term which includes a wide variety of technologies, including distributed generation (solar PV, geothermal, CHP, etc), distributed storage, smart appliances, microgrids, and advanced communication and control technologies which allow these resources to be aggregated and dispatched to the grid. DER is being adopted across many U.S. states and by a variety of customer types. Adoption is being driven by a number of factors affecting customer decision-making, including declining costs of technology, net metering programs and other tariff structures, and tax incentives. However, DER also brings added complexity for customers around interconnection policies, tariffs and fair compensation. (DNV GL, 2014)

Jacobs (2015) explains that as DER achieves greater adoption, traditional consumers are being replaced by “prosumers”, consumers who are also producers. This erosion of the boundary between consumer and producer challenges traditional energy law and regulation paradigms. These prosumers are more autonomous but also more active market participants (Jacobs, 2015). The rise of the prosumer will also lead to greater differentiation amongst residential or low volume customers. Customers with DER will potentially have a very different relationship with their utility than traditional customers. A study in Australia looking at future scenarios identifies three potential customer types:

- Empowered, who will be autonomous or technology focussed
- Engaged, who will be active or passive
- “On the edge” and Essential, who are the most vulnerable customers

The needs and expectations of these groups will vary, potentially quite widely between the empowered group and the vulnerable group. This framework is being used as the basis for the customer-oriented approach to the study’s scenario analysis (work which is ongoing). (Commonwealth Scientific and Industrial Research Organisation and Energy Networks Association, 2015)

Customers generally are expecting greater engagement with their utilities. This is being recognized by utility leaders as a growing trend (Utility Dive, 2016) and by regulators that are incorporating explicit customer engagement requirements.

Communities, and other groups of customers, are also becoming active energy customers. Some are developing microgrids in order to be autonomous and self-sufficient in the event of extreme weather events. Another driver for these microgrids is the desire to retain more control over energy choices to meet community climate change goals. Cities and counties are also exploring potential synergies among municipal services, implementing climate action plans, and making renewable energy available to renters and underserved communities. In some cases there have been efforts to municipalise utilities in order to achieve these goals. (De Martini and Kristov, 2015 and Jacobs, 2015) This trend may present opportunities for some of Ontario’s municipally-owned distributors to pursue local policy objectives.

Concluding Observations

All customers will continue to expect reliable and affordable service, even though systems are facing cost pressures from aging infrastructure and climate change policies. Customers adopting new technologies and responding to new service options in the form of DER will also expect utilities to be responsive in terms of service, pricing and compensation. Non-DER customers will expect costs to be shared fairly between the customers adopting new technologies (such as solar PV) and those who do not. It will be a significant challenge for utilities and regulators to meet these diverse and rising customer expectations. Regulators in the U.K., Australia and Ontario have been requiring utilities to undertake greater customer engagement, particularly in relation to system planning and rate proposals, and have been undertaking deeper customer engagement themselves. This will provide a useful foundation going forward as customers' expectations increase and become more diverse.

The issues related to the growing integration of customer expectations, technology and the grid are discussed further in Portfolios 2, 3 and 4.

Portfolio 2: Meeting Energy Demand behind the Meter

Rising customer expectations and new technologies provide the opportunity for more customer demand to be met behind-the-meter through DER. The technology drivers for behind-the-meter options include solar PV and battery storage, small scale CHP, fuel cells, heat pumps, microturbines, microgrids, virtual power plants, customer aggregation, and the integration of distributed resources with the grid (including data flows). The social, economic and policy drivers include:

- Declining costs of solar PV, battery storage, and other technologies
- Barriers and incentives to grid integration and grid defection
- The identification and allocation of costs and benefits between behind the meter resources and the grid (net metering, reliability, supply, etc.)
- Potential service offerings through the aggregation of behind the meter resources
- New service providers and new market mechanisms

The literature related to these drivers will be reviewed through the following key issues:

- Distributed generation
- Other distributed resources
- Emergence of transactive energy
- Distributor role in DER

Distributed Generation

DER originally took the form of distributed generation and was a means of satisfying customer demand, although often not the total level of that demand. The primary technology was gas-fired combined heat and power facilities (CHP). Recent policies promoting renewable generation have seen a surge in distributed generation, primarily in the form of solar PV. Increases in smart grid technologies have brought about new opportunities to deepen the integration between DER and the distribution grid (and between the distribution and transmission grids).

Solar PV is now the leading form of distributed generation, with 90% of the installations in the U.S., or about 500,000 homes and businesses (Costello, 2015). Costello observes that the economics of solar PV varies by region, but that the average price has fallen by 40% between

2010 and 2014. He notes that solar PV continues to be subsidized through rates and tax incentives. A review done for New York reports that the costs of commercial solar PV declined 31% between 2010 and 2014, noting that the costs have declined more for solar PV (and storage) than for CHP. The study reports that public and private investment is leading to further price reductions, while the drivers for increased adoption include net metering, value of solar tariffs, Renewable Portfolio Standards, and tax incentives. New York is now among the top five states for total distributed generation capacity under 2MW, and within the top 10 for solar PV, energy storage and CHP under 2 MW. (DNV GL, 2014)

Lawrence Berkeley Laboratory prepares an annual report on the installed prices of residential and non-residential solar PV systems in the U.S. (*Tracking the Sun VIII*, August 2015). The most recent report looks at data for 400,000 PV systems (81% of the total installed capacity through 2014, and 62% of the capacity installed in 2014). The findings show that prices continue to decline, although they can vary significantly. The key trends for 2014 include:

- Installed prices continued to decline in 2014: 9% for residential systems, 10% for small non-residential systems, and 21% for large non-residential systems.
- The recent price declines have primarily been driven by “soft” costs, including marketing, system design, installation labor, permitting, and installer margins.
- Incentives for solar PV have declined.
- Prices in the U.S. are still higher than in some other markets (Germany, China, Australia), and vary widely across individual projects, within states, and between states.

Opinion remains mixed, however, as to the future prospects for distributed generation, especially solar PV, and whether it will lead to a market transformation. Some argue that the combination of declining technology costs, policy drivers and customer preferences will result in significant additional penetration of distributed generation and market transformation. Others take the view that adoption is being primarily driven by subsidies and incentives and without those distributed generation would have limited scope.

Graffy and Kihm (2014) argue that the synergy of technology, policy, social preferences, and business are driving disruptive competition in the electricity sector which has the potential to transform the market structure. They point to declining costs of wind and solar PV, the growth in renewable portfolio standards, and latent demand due to public attitudes toward renewable generation. They note that regulators cannot protect utilities from the impacts of competition, noting that there is no utility “right” to such protection. Raskin (2015) responds to Graffy and Kihm, arguing that they have overstated the competitive threat of distributed generation, and underestimated the utility and regulatory response. Raskin maintains that distributed generation is only viable as a result of significant subsidies (primarily in the form of net metering) and that Graffy and Kihm have overlooked the higher reliability of the grid and the potential for technological advancements on the grid. Costello (2015) concludes that it is still an open question as to whether solar PV will be a disruptive technology or a niche player, but he concludes that cautious action is warranted. In particular he sees the potential for distributed generation combined with smart grid (real-time information and communication and the integration of software, hardware, data management and analytics) to contribute to cheaper, cleaner, higher-quality power.

Ontario has extensive experience with distributed generation, in particular as a result of the province’s microFIT incentive program. As the policy shifts to a net metering approach (as indicated in the province’s most recent Long Term Energy Plan), the literature suggests that it is uncertain whether distributed generation will expand further or not. The issues driving the outcome (particularly rate design) are discussed later in this report.

Other Distributed Resources

Small scale storage technology is another aspect of the rise of DER. A study at the Rocky Mountain Institute identifies 13 potential services provided by storage to customers, utilities and system operators:

- For customers: Time of Use (TOU) bill management, backup supply, demand charge reduction, increased solar PV self-consumption
- Utilities: resource adequacy, distribution infrastructure deferral, transmission congestion relief, transmission infrastructure deferral
- System operators (ISOs/RTOs[1]): energy arbitrage, frequency regulation, spin/non-spin reserves, voltage support, black start

The study notes that the largest number of services is available if storage is sited behind-the-meter. As a result, storage should be sited as far down the system as possible, although the

[1] ISO – Independent System Operator. RTO – Regional Transmission Operator

value of storage will vary depending on the specifics of the grid. The authors conclude that barriers to market participation for behind-the-meter storage need to be removed and the analysis models should be changed so that storage is considered as an alternative to wire or other traditional solutions. (Fitzgerald et al, 2015)

Electric vehicles are an example of a technology with DER potential which would also provide overall load growth. Shepard (2015) observes that electricity vehicles are a potential market for electricity utilities which are otherwise facing stagnant sales. He points to studies that show electric vehicles generally improve load factor through off-peak charging, without requiring significant system upgrades. He notes that electric vehicles could provide grid services as a form of distributed storage or demand response and concludes that utilities should promote electric vehicles more actively.

Microgrids are another type of distributed resource. They are formed from the aggregation of DER in a specific geographic area. A microgrid could include a small group of customers, a particular development, or an entire community. Microgrids can act to support the grid, but can disconnect from the grid and remain running in times of major disruption, thereby providing additional resilience benefits to the microgrid customers. Although microgrids have been developed over time in a number of areas, they have received greater attention recently as a result of major weather events, such as superstorm Sandy on the U.S. east coast, and the resulting desire to increase system resilience.

Stadler et al (2015) reviews the literature on value streams from microgrids. The complexity of microgrids, which require islanding detection, protection systems, and power quality assurance, adds to the costs of these systems. However the study concludes that the additional value streams from demand response, power exports, resilience, and local energy markets have significant economic potential and could offset the added costs. Microgrids also raise regulatory and legal issues. A report (Jones et al., 2015) on four microgrid case studies identified five key issues:

- The need for a clear definition: is a microgrid an electricity distributor or not?
- The need to address issue of franchise exclusivity
- Liability for power and service quality
- Rate design for services provided to, and taken from, the grid
- Consumer protection issues

The report notes that one option is to apply the traditional public utility regulatory paradigm to microgrids. The authors conclude that this is a workable alternative for integrated utilities operating microgrids, but that there need to be solutions which allow third-party provision of microgrids. (Jones et al., 2015)

There may be parallels between microgrids and sub-metering in terms of some of the issues and challenges which arise. It would be relevant for Ontario to consider these parallels a it addresses the development of microgrids.

Emergence of Transactive Energy

As the costs of distributed generation technology decline, more customers will be incented to offset all or part of their demand from traditional sources. Customers with distributed generation (without storage) will, however, remain attached to the grid. This “load defection” presents a challenge for utilities, to the extent they have fixed costs that will need to be recovered over a lower level of demand. With the declining cost of storage, however, customers may find it becomes more economical to become completely self-sufficient, leading to the potential bypass of the grid altogether. This “grid defection” presents a potentially greater challenge for utilities.

However, another path is possible. The costs of other DER technologies are also declining, including smart appliances and communications and control technologies. These advancements open up new opportunities for DER to integrate with the grid, allowing DER customers to provide services to the grid as well as take services from the grid. This has the potential to discourage grid defection and to increase the efficiency and reliability of the grid, thereby bringing benefits to all customers. This deepening integration between DER and the grid is known as “transactive energy”. New York’s Reforming the Energy Vision (REV) is an example of a regulatory initiative which has as its goal using distributors as the platform operators for transactive energy services.

Kielsing (2015) explains how digital technologies enable and reduce the cost of two-way communication, thereby enabling and lowering the cost of transactions and reducing the scale economies driver for vertical integration. This opens the way for value creation through new services and products (energy management, home automation, remote access, etc.). In particular, she discusses transactive control (the use of smart grid technology to communicate incentive and feedback signals to distributed agents) as a potential tool to deliver system-wide and customer benefits.

Transactive energy can take place at the level of individual appliances. The customer participates passively, and appliance controls, grid communications, and price signals govern decision-making. This integration of demand flexibility by using automatic control can reshape a customer's demand profile in time in a way that has little or no effect on the customer experience. As one commentator has described it:

> *I like to think of TE [transactive energy] as Smart Grid 2.0 – the place where smart technologies, energy economics and humanity meet. It is all about the seamless coordination of millions of grid-connected devices to optimize the system as a whole. It aims to do this without impacting customer lifestyles and shares the benefits through dynamic, market-based incentives.* (in Queen and Shilad, 2015)

The benefits of this integration are potentially significant. One U.S. study has estimated the value to customers and to the grid from the automatic control of water heating and air conditioning. The estimated potential grid savings are $9 billion per year in avoided infrastructure costs, $3 billion in avoided energy costs, and $1 billion saved from providing ancillary services to the grid (total $13 billion). The study analyzed four scenarios to estimate customer impacts as well, and the results were bill savings ranging from 10%-40%. (Dyson et al, 2015)

Each DER customer can provide flexibility to the system through the operation of its generating and storage capabilities, although it is unlikely that individual low volume customers will want to do this actively. A study done for the European Commission on the integration of DER explains that aggregators will be needed to capture the flexibility of many small DER customers. There are many potential aggregators including suppliers, retailers, telecom companies, and new companies. There are, however, barriers to aggregators and DER. For example, market rules and product definitions were designed for central generation facilities not distributed resources. The value of DER flexibility varies across time and space, and the true value of flexibility is not always in the market price. Feed-in tariffs and net-metering can distort signals, and tax and tariff arrangements create barriers for storage options. Tariffs need to create proper incentives based on local conditions. (SWECO, 2015)

Payne (2015) notes that interconnection policies are important for DER deployment, but are frequently a barrier due to the stringent technical requirements, regulatory barriers, and obstructive utility practices. In her view, both need to be simplified and made more consistent.

The literature shows that there are many technical, institutional, and regulatory barriers to the integration of DER, which is not surprising given how fundamental the change would be. The literature is also clear that because integrating DER results in a more technically complex system, it will be challenging for policy and regulatory frameworks, and utilities, to match the pace of the technology change.

Distributor's Role in DER

Determining the appropriate role for distribution utilities in distributed energy is a key issue in many jurisdictions. Should utilities be permitted to invest in these assets as part of their regulated rate base? Should they be precluded from doing so? The challenge is to develop a framework which ensures the economically efficient development of DER, while protecting customers, fostering competition and innovation, and providing utilities with the opportunity to remain viable.

Corneli and Kihm (2015) identify three factors which are driving the need to determine the distributor's role:

- Competitive alternatives are increasing the elasticity of demand.
- Bulk power will have little growth. The distribution monopoly will be eroded, and replaced by economies of scope, where utilities can lower costs and increase the benefits to customers thereby providing an incentive to remain grid connected.
- The utility role can support lower cost higher value service, coordinating DER to support the distribution utility and the grid.

The authors present two competing views of the distributor's role:

- Distributor as an energy services utility: In this scenario utilities evolve to play major role in using DER to provide services to customers by being active in developing, owning and aggregating DER.

- Distributor as enabling and integrating utility: In this scenario utilities provide the infrastructure for basic energy and capacity services and, through digital technologies, rely on competitive firms to provide DER services and to keep customers on the grid.

They use the tools of economic and policy analysis to explore the implications of potentially competitive services on the natural monopoly and conclude that regulators will have less ability to protect utilities from competition and utilities themselves will be more responsible for their economic health through the choices they make. (Corneli and Kihm, 2015)

Costello (NRRI 2015) reviews the advantages and disadvantages of allowing expanded utility activities. The potential benefits of direct utility involvement include economies of scale and scope, faster adoption of distributed generation, and the avoidance of a death spiral. The potential risks include discouraging third-party entry, leveraging market power, an absence of fair competition, and entry barriers. Regulators will have to find the balance between not overburdening the incumbent and not discriminating against new entrants.

The Council of European Energy Regulators (CEER) has concluded that that the role of the distributor should be that of a neutral market facilitator acting in the public interest. This approach will ensure a level playing field for new entrants and protect customers. A key issue in the distributor relationship with customers is data management, and CEER concludes that a customer, not the distributor, owns the customer's data. Despite the preferred neutrality for utilities, CEER does conclude that distributors should be permitted to participate in some "grey areas", such as energy efficiency advice, flexibility and storage, and customer engagement. (CEER, 2015)

O'Boyle (2015) reviews a series of case studies to present the strengths and weaknesses of utility owned and operated DER, and non-utility owned DER (third-party operated and customer operated). He concludes that each ownership model may be appropriate, depending upon policy priorities. Both approaches should prioritize fair compensation, foster innovation and competition, and provide transparency for market participants. He finds that utility owned and operated DER works best when narrowly tailored to public policy goals, but that concerns about market power and cost overruns may arise. Utility projects are generally successful for early adoption and demonstration projects. Third-party DER excels when the participants can ascertain and access the full value of DERs, but this requires dynamic rate design and competitive markets for bulk-system and distribution level services. (O'Boyle, 2015)

The literature shows that opinion is mixed as to the appropriate role for distributors. However, an early policy and regulatory decision is likely an important foundational step in the sector's transformation. Given the number and variety of distributors in Ontario there may not need to be a uniform model across the province, at least not initially. The utility business model is discussed further under Portfolio 3.

Concluding Observations

Technology in the electricity sector is changing and advancing, and the costs are declining. As a result, customers have an increasing number of options to meet their energy demands, ranging in scale from individual appliances and individual houses (e.g. solar PV with battery storage), to groups of customer and whole communities (microgrids). Customers have the potential to become self-sufficient, but they also have the potential to be more deeply integrated with the grid.

Effective integration of DER has the potential to benefit all customers, utilities, the system as a whole and society. However, utilities, policymakers and regulators will be challenged to keep pace with these technology and customer-driven changes. They must balance the demands of the new energy customers with the expectations of all customers for reliable and affordable service. Although solutions will be based on the specific characteristics of an individual utility or system, there is much that can be learned as DER is being developed and adopted worldwide. These issues are addressed further in Portfolio 3 and Portfolio 4.

Portfolio 3: Grid Modernization and the Utility of the Future

The electricity grid will face increasing pressure to adapt to technology changes at the customer level and to the increased penetration of DER. The potential impacts on the distribution utility business model are expected to be significant. Distribution utilities will look to offer new services to enable reliable, integrated and innovative opportunities, potentially in competition with other services providers or potentially as an enabler of competition amongst third-party service providers. Transmission systems and grid operators will be challenged to maintain reliability and enhance efficiency through the effective integration of new resources using enhanced grid technologies. Together, these trends will lead to a transformation of the sector.

The technology drivers for this transformation include:

- Smart grid, including information and communications technologies
- Distributed generation and storage
- Resource integration, including microgrids, virtual power plants, and demand response
- Grid control, including situational awareness and interoperability
- Cybersecurity

The economic and policy factors include rate design for new services, policy barriers and incentives, and regulatory barriers and incentives. The literature related to these drivers provides a wealth of analysis of the key developments and issues, and will be reviewed here under the following key topics:

- Rate design for distributed generation: net metering and the alternatives
- Rate design for DER
- The utility business model
- Distribution system planning
- Advancing the regulatory framework
- Select regulatory developments in leading jurisdictions

Rate Design for Distributed Generation: Net Metering and the Alternatives

Costello (*Electricity Journal*, 2015) identifies the importance of rate design as the regulatory intersection between distributed generation and the utility business model: "ratemaking affects the utility's incentive to accommodate or promote DG [distributed generation], the economics of third-party DG investments, and the well-being of non-DG customers."

Under net metering, customers are billed at retail rates for the net amount of energy they consume, and as a result the compensation they receive for the electricity they generate is equivalent to the retail value. Net metering has been one of the drivers of distributed generation, and has been the primary pricing tool for distributed energy. Net metering has the benefit of being relatively straightforward and easy to understand. However, the simplicity has given rise to significant criticism, and a debate has arisen as to the fairness of net metering. Some argue that net metering undervalues the services provided by distributed generation and others argue it over-compensates distributed generation customers. The issue has become more pressing given the significant and growing penetration of distributed generation installations.

Raskin (2013) observes that under net metering the energy produced by distributed generation is valued at the bundled retail rate for electricity, which is between two and six times the market price for energy. These customers, however, continue to rely on the grid for backup and supplemental energy. He notes that in many jurisdictions the result is a wealth transfer to the high-income adopters from low-income customers. Costello (2015) is similarly critical of net metering, which in his view lacks a rational economic foundation and is essentially a regressive cross-subsidy to higher income customers. Bayless (2015) also provides a spirited critique of net metering at the full retail rate. This concern that net metering provides a cross-subsidy for affluent customers has also been raised in Australia. One commentator sees the cross-subsidy happening two ways. First, customers with distributed generation and large air conditioning load are not paying for their peak load on the grid. Second, these same customers receive more compensation for what they generate than the power is worth to the system. (Queen and Shilad, 2015)

The alternatives to net metering, however, are also the subject of criticism. Lazar and Gonzalez (2015) observe that rate designs such as minimum bills, straight fixed/variable (monthly fixed charge), distribution surcharges (for distributed generation customers), and exit fees all actively discourage distributed generation. They are particularly critical of high fixed monthly charges, noting that these rate responses risk driving customers away entirely. Graffy and Kihm (2014) go further, arguing that the traditional utility response of protecting cost recovery (e.g. through fixed rates, higher returns, exit fees, etc.) will exacerbate the competitive pressure by raising the cost of utility service. In their view, this approach also distracts utilities from taking a more proactive approach, impedes innovation and competition and ultimately risks customer backlash. Costello (NRRI 2015 and *Electricity Journal* 2015) reviews the following ratemaking responses to net metering:

- More cost-based charges (e.g. demand charges for capacity costs)
- Separate compensation for on-site generation (value of solar tariffs)
- Standby rates for distribution service
- Avoided cost rates for the generation provided

In his view, each raises significant issues, especially in relation to valuing costs and benefits. He supports redesigning retail rates to better reflect costs (including demand charges) and developing robust standby charges. He is less supportive of structures like value for solar tariffs if the result is compensation for distributed generation which exceeds the utility's avoided cost.

Revesz and Unel (2016) review the net metering debate, analyze the costs and benefits of the options, and highlight the flaws and missing elements in the competing positions and in all current policies. They note that under net metering customers are not paying for the costs of their reliance on grid-delivered electricity or the demands they place on the grid and grid services. Because retail rates are not time-differentiated, customers with distributed generation are sometimes over or under-compensated for value. Net metering also does not capture coincident peak demand, and location-specific value. Ultimately, the lost revenues are shifted to other customers. However, they are also critical of fixed charges, as these ignore the actual variation in delivery costs and undervalue the savings achieved by the distributed nature of DER. They are also critical of the various caps some jurisdictions have implemented, noting that this tries to fix the inefficiencies of net metering with another inefficient policy.

Despite the criticisms of net metering, a number of authors maintain that net metering in some form remains an important tool. Payne (2015) argues that net metering is vital to the success of distributed resources in enhancing system resilience. However, she notes that the form and application of net metering varies widely across states. She describes the extent of the variations and complexity in terms of fuel source, size, proportion of utility load, standby charges, credits for excess generation, etc. Lazar and Gonzalez (2015) review a number of rate structures used to compensate distributed generation: feed-in tariffs, value of solar tariffs, net energy metering, and bi-directional pricing, and conclude that net metering is appropriate where distributed solar PV saturation is low.

Jacobs (2015) notes the jurisdictional challenges around net metering and demand response and the boundary between FERC and state jurisdiction. The regulatory challenge is to incent the DER contributions to the system without unfairly shifting costs to traditional customers. While net metering may have aspects of a cross-subsidy, prosumers also provide benefits to traditional customers, and fixed charges may even have adverse impacts on traditional customers.

Sappington and Brown (December 2015) conclude that the optimal policy to support distributed generation varies with the instruments available and with the prevailing distributed generation technology. In their analysis, capacity charges are often valuable for non-intermittent distributed generation sources, while net metering may be optimal sometimes (but usually not for non-intermittent sources). In their view, being able to use both enhances the ability to drive efficient levels of capacity and production, although other instruments should also be analyzed, including demand charges, demand response, and conservation.

Muro and Saha (2016) review a variety of recent studies (public utility commission-sponsored studies, Lawrence Berkeley Laboratory work, and academic and think tank work) and observe that a consensus is building that net metering frequently benefits all ratepayers when all the costs and benefits are taken into account. They note that net metering has been criticized and is being challenged in several states, and has even been rolled back in some states (Nevada). In their view, regulators need to consider the full range of costs and benefits when assessing net metering. Benefits come from deferred infrastructure expenditure, relief on peak, reduced costs from displacement of more expensive generation, and reduced environmental compliance costs. They conclude that regulators should have a rigorous transparent cost/benefit analysis framework.

A variety of studies have been done to identify and value the costs and benefits of distributed generation. This work demonstrates the challenges of identifying and measuring these factors, and shows how system characteristics and local policy priorities influence the results. One review of 16 distributed solar PV benefit/cost studies undertaken between 2005 and 2013 found a significant range of values, driven by differences in local context, differing input assumptions (natural gas prices, solar production, etc.), and differing methodologies. The methodology differences were mainly related to the level of granularity of the data, the categories of cost and benefit, and the approaches to calculating individual values. The study identified methodological gaps where further work should be undertaken, such as the granular nature of distribution system benefits/costs, the value of grid support services, and assessing the unmonetized values for security and the environment. (eLab, September 2013)

Some commentators support an approach grounded in traditional regulatory principles. Raskin (2015) cites the key legal and economic principles around cost recovery and the need to attract investment. He argues for a levelling of the competitive playing field, by unbundling retail service rates and appropriately deriving compensation for distributed generation based on those unbundled rates. Others have presented analysis which includes environmental externalities. For example, Revesz and Unel (2016) propose an “avoided cost plus social benefit” approach, where distributed generation customers are compensated for the net avoided costs, including externalities. The direct benefits of distributed generation include avoided fuel purchases, avoided distribution capacity, lower losses, deferral of larger generation and transmission investment, and resilience. The societal benefits include reduced CO_2 emissions, water and land conservation, and health benefits. The costs include ramping flexibility to balance supply and demand (especially for solar PV), flow management and voltage regulation (related to bi-directional flow), and balancing for more variable demand. They note that technology improvements should lower many of these costs.

Brown and Sappington (2015) develop an economic model to study the optimal compensation for distributed generation and find that the optimal compensation depends upon the level of externalities, namely pollution from each generation source. As a result the optimal compensation varies as industry conditions change. Optimal compensation could be below the retail rate when the externalities of the distributed generation and the grid generation are similar. Compensation could be above the retail rate when distributed generation entails a substantial reduction in externalities.

The literature suggests that as the level of distributed generation has increased, the relatively simple tool of net metering has become more contentious. However, the main alternatives at this point may be even less desirable if they drive grid defection or discourage economically efficient distributed generation. While net metering may be blunt, in the absence of more precise rate tools, it may be a reasonable proxy for the various costs and benefits of distributed generation.

Rate Design for DER

Many commentators note that work needs to be done on rate design generally, not just for distributed generation. Revesz and Unel (2016) conclude that a broader ranging reform of retail rates should be a longer-term goal, including consideration of time-varying and demand-varying rate design. Similarly, Brown and Sappington (2015) note that overall welfare may be enhanced through policies such as TOU rates and demand response rates.

A 2014 report by the Electricity Innovation Lab (eLab) explains that pricing needs to change to reflect the costs and benefits of electricity services exchanged between customers and the grid to facilitate innovation, reduce costs, and maintain or improve resilience and reliability. Current rate structures have the opposite effect and risk lost opportunities. Pricing needs more granularity and to reflect a two-way exchange of value and services. New pricing structures should be developed through collaboration because they are likely to be complex and could disrupt DER business models. Prices will need to move to greater attribute unbundling, greater temporal granularity and locational granularity. The report recommends an evolutionary approach with customization to local circumstances, and examines six options which could be implemented individually or in combination:

- TOU rates, demand charges, and distribution hot-spot credits should be considered in the short term.
- Real-time pricing, attribute-based pricing, and distribution locational marginal pricing should be considered in the longer term.

Technology and aggregators could facilitate a simpler customer experience in conjunction with more sophisticated and differentiated rate structures. (eLab, *Rate Design*, 2014)

Lazar and Gonzalez (2015) also comment that more advanced rate designs will be necessary to realize the full potential of new technology (customer owned generation, electric vehicles, storage, advanced metering and data systems), open up new markets (demand response, voltage regulation and other services, storage, smart controls) and accommodate distributed generation. They caution that if regulators and industry do not adapt, the risk is losing customers entirely. They conclude that "bidirectional, time-sensitive prices that more accurately reflect costs most closely align with the principles of modern rate design." They review the current standard rate designs (flat rate, customer charges, demand charges) and find significant flaws, particularly with high fixed monthly charges. Instead, they argue for time-varying energy charges as the best way to reflect costs and to encourage efficient use of electricity. TOU, critical peak pricing or peak-time rebate and real-time pricing should all be considered. (Lazar and Gonzalez, 2015)

Stanton (2015) surveys the DER processes which are currently underway. Almost every U.S. state[2] is reviewing review rate design and program structure issues related to distributed solar PV in an attempt to more accurately account for the costs and benefits of distributed generation, and DER more generally. The report concludes that the analysis of rate design options would be improved with better modelling of the impacts on different types of customers (by size, income, etc.), impacts on utilities, impacts on the DER market, and impacts on society.

A recent report for the NY Public Service Commission presents a proposal for a Full Value Tariff (FVT). "Full value" is the sum of the time-variant and area-specific avoided cost components of DERs and load changes. This includes local and system capacity values, zonal or nodal energy pricing, and energy losses. These components are currently monetized in retail rates. Full value could also include non-monetized components such as environmental, health, and resilience benefits. The purpose of FVT pricing is to draw out the non-utility market-based alternatives to provide, avoid or defer utility services and investments, in other words to unlock the distribution value of DER. An FVT could include a customer charge, a network subscription charge (demand charge), and a dynamic price (marginal cost). FVT would be complex but with technology, loads (e.g. appliances) have the ability to intelligently and autonomously respond. The report sets out proposals with a gradual transition and a rapid transition. (Energy and Environmental Economics, 2016)

[2] At the time of the report 43 states and the District of Columbia.

Work is also being done to analyze the impacts of various rate design alternatives. For example, a recent meta-analysis of studies, reports and analyses of time-based and demand charge rates finds that time-based rates are found to reduce peak by 0%-50% and total consumption by 0%-10%. The impacts depend primarily on the peak-non peak ratio (a larger ratio is more effective); peak duration and frequency (shorter peak periods are more acceptable); the financial mechanism (a charge is more effective than rebate); the enrollment method (opt-out is more effective than opt-in); and enabling technology (automated customer response increases response). The study notes that much less analysis is available on the impact of demand charge rates. There has been little experience in the mass-market, and therefore claims as to the impact are largely speculative. However, the authors suggest that the impact of demand charges is likely to be influenced by the cost components and allocation; peak coincidence (as a more targeted price signal than non-coincident); ratchet mechanisms (floor to stabilize utility revenue); and enabling technology (allowing for automated customer response). (Sherwood et al, 2016)

Lazar and Colborn (2015) consider the impact of rate design on emissions. The U.S. Clean Power Plan requires significant CO_2 reductions from the power sector, and Lazar and Colburn examine the impacts of using rate design as a tool to explicitly reduce CO_2. They note that the least efficient, most emitting units are often dispatched last, and therefore a small reduction in demand could have a significant impact on emissions. They conclude that a high fixed charge will increase usage compared to a flat volumetric rate, leading to increased compliance costs. Alternatively, an inclining block rate will reduce usage compared to a flat volumetric rate, providing a low cost way to reduce compliance costs. The impact of TOU rates will depend on the system characteristics of dispatch. (Lazar and Colburn, 2015)

Hledik and Lazar (2016) in a recent study for Lawrence Berkeley Laboratory look at four approaches to pricing services between utilities and DER customers (to and from customers):

- Granular rates - separate price for each service to and from DER customers
- Buy/sell - services to customers are a form of bundled utility rate, services from customers are priced on the characteristics of the specific service
- Procurement model - bundled utility price for services to customers, competitive procurement for services provided from customers, probably through third-party aggregators

- DER-specific rates: separate rates for specific services provided to and from DER customers based on the characteristics.

Although any of the approaches could work, success will depend upon the implementation. They suggest five criteria for assessment: economic efficiency, equity/fairness, customer satisfaction, utility revenue stability, and customer price/bill stability. They analyze the options from the perspective of the utility and the perspective of customers. Although no firm conclusions are reached, they comment that the granular approach could be very complicated, while the procurement approach and buy/sell show significant potential. The study is intended to stimulate further analysis, and they recommend pilots to test multiple concepts. The best solution will likely depend on the individual utility. For example, a utility with high penetration of electric hot water heaters could call on those appliances to provide frequency regulation and load shifting (diurnal storage). (Hledik and Lazar, 2016)

Rate design for DER has the potential to be highly precise, but also highly complex. The literature presents a rich technical analysis of the costs and benefits of DER. However, translating those costs and benefits into rates which customers can understand will be challenging. Ontario has the benefit of having already adopted smart meters and TOU rates for energy. Ontario also has experience with pricing pilots, and these will likely continue to be a valuable tool to assess the various options.

The Utility Business Model

In addition to rate design reforms, broader considerations have arisen about the overall business model for distribution utilities. Increasingly, commentators are concluding that the adoption of DER will require more structural responses from utilities, if they are to remain viable and if the overall system is to benefit from the technological advances related to DER. The utility business model, along with the regulatory framework (which is discussed later in this section), will shape the overall response to the threat and opportunity of DER. A study from 2013 explains that the electricity sector is evolving from a traditional value chain to a highly participatory network or constellation of interconnected business models where retail customers interface with the distribution grid. Existing utility business models are outdated, but the distribution grid can be a partner to coordinate DER. (eLab, *New Distribution Models*, 2013)

A survey of 515 utility executives in late 2015 and early 2016 demonstrates the broad recognition of the changing nature of utilities. Utilities are looking for new revenue streams from energy management and efficiency services, community solar, and EV charging. They are also looking for TOU rates, higher fixed charges and demand charges. (*Utility Dive*, 2016)

Hyman (2015) presents a financial analyst's assessment of the current state of the electric utility sector. He notes that prices for electricity service are rising and customers demand is not. Utilities want to do the same work better, but keep being driven by rate base incentives despite static sales. He cautions that this situation creates the opportunity for disruptive investors, and their solutions will not necessarily benefit incumbents or society. In his view, disruption will come from outside the industry, and utilities are not responding effectively. They should be using existing assets better and keeping prices down. He concludes that utilities are becoming an uncertain investment. (Hyman, 2015)

Newbury (2013) explains that a periodic disruptive event can fundamentally change the structure of a market or industry. Incumbents generally have difficulty responding, and monopolies are more likely to change their processes to lower cost because they have little to gain from introducing new products. He has observed that technological change in the sector is disrupting traditional scale economies, but utilities are not yet responding effectively. For example, Australian distributors had clear intentions to respond but few had a formal innovation strategy or policy. He finds that innovation is more structured amongst UK utilities, but it is siloed. (Newbury, 2013)

Costello (NRRI, 2015) notes that the death spiral[3] risk has been seen before. While he is of the view that a death spiral would hurt customers in the long term, he also takes the position that it is not good public policy to overprotect utilities from competition. In his view, the appropriate regulatory response lies in better ratemaking for DER and reviewing the utility business model. (Costello, NRRI 2015)

A number of studies examine how utilities might respond strategically to the rise of DER. Kielsing (2015) discusses the impact of smart grid and distributed energy on the structure and

[3] A death spiral is the result of the interplay between utility fixed costs and the costs of a competitive alternative. As customers reduce their load, fixed costs are spread over lower volumes, which raises rates and drives more customers to the competitive alternative. If this pattern continues, the utility becomes financially unsustainable.

business models of distribution utilities and concludes that organizational and institutional change which integrates these new technologies into the system will bring benefits. She explains that the new model will be influenced by individual market and utility characteristics. Graffy and Kihm (2014) examine the role of strategic decision-making by utilities in response to the emergence of disruptive competition. In their view, utilities must adopt a value creation strategy to increase their long-term viability, although this requires significant adaptation. Each utility will also need to respond differently in terms of leveraging their strengths in service reliability and customer trust and creating combinations of products and services which meet the customer's desire for choice. They point out that regulation and utilities must evolve together. Raskin (*Energy Law Journal* 2015 and *Harvard Business Review Online,* 2015) argues similarly that utilities will need to focus on cost recovery and greater value creation.

There is a growing focus on the specifics of new distributor business models. Vrins et al (2015) describe how the grid is transforming into an energy cloud. Utilities will benefit if they can transform themselves into "network orchestrators." They have some natural advantages (customer relationship, knowledge of supply and demand, understanding of how to integrate DER), but will need to change the culture and business focus, and adopt new technologies. A study prepared by a group of industry participants conclude that the focus should be on the development of new business models to better align incentives and opportunities. Their report compares two in particular: the distributed system platform model and the independent distribution system operator model. (Advanced Energy Economy Institute, 2015)

A 2013 report from the Electricity Innovation Lab examines three potential business models, all based on a platform approach: the distributed resource finance aggregator (DER FinanceCo), the integrated distributed resource manager (DER dispatcher), and the independent distribution system operator (DNO). Regulators and policymakers should consider the following attributes when assessing the options:

- Network efficiency, resilience and reliability
- Level playing field for resources
- Innovation
- Transparent incentives
- Minimize complexity
- Workable transition

- Harmonized business models for regulated and non-regulated. (eLab, *New Distribution Models*, 2013)

In Costello's view (NRRI 2015), the utility business model must exhibit three qualities:

- It must respond to new technological and market developments.
- It must support traditional regulatory objectives (cost-based rates, fairness, reliability).
- It must satisfy predetermined broad social objectives (affordability, clean energy).

He explores some of the alternatives, including platform provider, and identifies some of the issues which utilities and regulators will need to address.

Kielsing (2015) supports retail competition, and focusses the discussion on what functions and transactions distribution utilities should perform in addition to wires ownership. She examines three categories of business model: ownership, management, and coordination:

- Ownership entails the continuation of vertical integration where the distributor is a direct market participant.
- Management entails operating the system on behalf of the market participants, where the distributor retains responsibility for reliability and balancing. This model corresponds in many respects to the current net metering approaches.
- Coordination means that the distributor is not a market participant at the wholesale or retail level, but instead facilitates the transactions of independent agents. This is the platform service provider model which has the potential to provide economic coordination, reliability coordination and information provision, and can help the network in aggregate meet environmental and other policy mandates.

While the platform service provider model offers many potential benefits, she notes the complexity of this approach and identifies some of the issues which need to be addressed, including pricing related to recovering fixed costs.

Satchwell et al (2015) examine the potential regulatory and business model responses to address the impacts of disruptive technologies and present a framework by which to evaluate particular proposals. They explain that their framework is more holistic than other approaches because it focuses on the link between regulatory/utility business models and the goals of policymakers. The framework examines utility business and regulatory paradigms on two characteristics: profit motivation and profit achievement. Each can be viewed as a continuum.

- For profit motivation the continuum runs from Assets (in other words utilities maximize their profits by focussing on investing in assets to expand ratebase, thereby earning the regulated return) to Value (where profit is maximized by extracting maximum value from existing assets or building incremental assets which create value). Regulators can incent a shift along the continuum by linking earnings to the achievement of targets and goals through performance-based regulation.
- For profit achievement, the continuum runs from Commodity (where greater profits are achieved through increased sales) to Services (where profit is increased by providing more services). If regulators want to incent utilities to deliver value-added services (energy efficiency, home automation, electric vehicle charging, energy storage) then profit achievement needs to be more closely linked to those services and changes in rate structures are needed.

These two continuums are combined to create a two-by-two grid. The objective is to move utilities from the Asset/Commodity quadrant toward the Value/Services quadrant. The authors emphasize that the pace and pattern for DER adoption will vary by region, based on technology costs, customer preferences and policy frameworks, and therefore regulatory frameworks and utility business models will also vary. However, effective transition strategies can help mitigate risk for utility shareholders, customers and third-party providers while facilitating the achievement of DER objectives.

The literature suggests that effective integration of DER will require significant changes in the utility business model. These changes go to the very foundations of the traditional monopoly utility business, and it is not yet clear whether electricity monopolies will be able to make a successful transition.

Distribution System Planning

DER has important implications for distribution system planning. One study examines how higher penetration of DER requires new tools and methods for distribution system planning (Colman et al, 2016). The study looks at five leading utilities, and analyzes how each is pursuing a different mix of methodologies and tools in their planning, including:

- Methods and tools for assessing DER hosting capacity
- Valuing locational costs and benefits of DER

- Guiding DER installations to preferred locations
- Assessing the need for rate restructuring
- Monitoring and control of DER
- New organizational structures to support planning

The study goes on to outline a comprehensive proactive framework for utility planning, including the following elements:

- Load and DER adoption forecast
- Transmission and distribution grid impacts
- Bulk power impacts
- Finance, rates and regulation (including locational costs and benefits, DER to avoid traditional infrastructure investments, financial and rate impacts of DER, and policies related to incentives, tariffs, contracts, and competitive processes)
- Strategy and operations

The five processes are interdependent and the process is iterative. The goal is to converge on an optimal portfolio of DER. The study highlights that there are other key issues, including ownership/control, DER markets and procurement, data sharing, rate impacts, IT, staff, local customer and regulator preferences. (Colman et al, 2016)

Kind (2015) also highlights the importance of system planning. He explains that the impacts of the disruptive forces are currently being borne by ratepayers through higher rates, but will soon become a challenge for investors. He maintains that utilities and regulators need to shift away from higher fixed charges to approaches which better align customer, utility and policy goals. More broadly, what is needed is a pathway to a "21st century utility" system. He envisions the distributor at the center of resource integration and stakeholder collaboration and recommends a shift in regulatory focus to planning and transparent accountability metrics and the linking of utility revenues to results and new services. In his view, this will ensure financially healthy utilities, which are essential to maintaining the grid. (Kind, 2015)

Tierney (2016) presents an analysis of the value of DER to the distribution system and implications for distribution planning, DER procurement, and DER compensation through case studies of Consolidated Edison (NYC) and Southern California Edison. The conclusions include the following:

- DER is proliferating, but net metering is coming to be seen as a blunt and imprecise instrument.
- Different technologies have different attributes, and value depends on location on the grid and characteristics of availability, dependability and durability.
- Location-specific analysis of value will be needed. Analysis should be based on fairness and efficiency, long-standing regulatory principles.
- Utilities should integrate DER into their planning, so DER can substitute for traditional investments. Market mechanisms are likely better than administrative payment based on avoided costs. Forward contracting for DER capacity may be good place to start. (Tierney, 2016)

The literature shows that the integration of DER requires new tools and approaches to distribution system planning. The Ontario Energy Board has moved to advance the transparency and rigour of distribution planning to address a number of issues, including smart grid and greater connection of renewable generation. These advancements should facilitate the further evolution of distribution system planning in Ontario.

Advancing the Regulatory Framework

Regulators have a key role in assessing proposed utility business models and utility planning and advancing a regulatory framework which facilitates the success of DER. A report from industry leaders acknowledges the challenges regulators face in keeping up with the pace of change and in aligning the goals of universal service, customer choice, policy objectives, and fair cost sharing. In examining the regulatory framework, the regulator's focus should be on the development of new business models that better align incentives and opportunities (Advanced Energy Economy Institute, 2015).

Kielsing (2015) examines the history of the electricity sector and explains how from the beginning technology has driven the business model and the regulatory framework. Market liberalisation and the development of wholesale markets and the unbundling of the vertically integrated utilities were a continuation of that historical trend. She concludes that organizational and institutional change can integrate new technologies which will enable more efficient, transparent, competitive and decentralized electricity markets for the benefit of customers and the system.

DeCotis (2016) comments that while utilities are supportive of greater DER, they need clarity as to the regulatory paradigm, including the rules around DER asset ownership, recovery of the costs related to interconnection and system operations, IT and data management, and management of customer data. In his view, utilities need to evolve and treat DER as an opportunity rather than threat, and regulators need to better understand risks utilities face. Both need to work collaboratively. Similarly, Costello (2015) notes that the utility business model and regulation must evolve together to ensure the best alignment of outcomes.

A recent survey of customers, utility executives, and regulatory commissioners/staff shows there is customer interest in DER installation, but utilities are only supporting this through actual investments if they are mandated to do so. The survey suggests that regulators are more confident than utilities that the regulatory model allows support for DER. (westMonroe, 2016)

A number of reports call for reforms to the overall ratemaking framework and the adoption of performance base regulation (PBR). Harvey (2015) argues that utilities need to be in charge of system optimization, not just the supply of electrons, and that utilities need to be rewarded for performance rather than sales. Regulators should institute PBR through incremental performance benchmarks linked to explicit public goals, with collars and safety valves to protect excessive downside or upside risk. He explains that this approach creates an adaptive structure within the utility. He points out that public utility commissions are accessible and functional decision-making bodies, as opposed to Congress, and therefore are the appropriate forum to examine and resolve these issues.

Similarly, O'Brien (2015) points out that the current regulatory system creates a competitive barrier for incumbents. PBR and rate re-design, along with a platform business model, are needed to allow utilities to respond to the pressures of flat total demand, rising peak demand, aging infrastructure, and customer expectations. PBR would provide more flexibility, while requiring more accountability for outcomes and greater transparency into capital spending and operations.

Lowry and Woolf (2016) explain out that cost of service regulation creates disincentives for DER, even with a lost revenue adjustment mechanism. PBR, with a multi-year rate plan and/or performance incentive mechanisms, provides a better alternative. The authors review the advantages and disadvantages of multi-year rate plans and performance incentives, from the utility and the customer perspective. They also review some of the options to address the challenges of multi-year plans and performance incentives. The report concludes that if a regulator wants to support DER, it should improve utility performance and streamline regulation. If openness to regulatory change is high within the jurisdiction, then the regulator can adopt performance incentives for DER, a multi-year rate plan, and revenue regulation. UK's RIIO framework is presented as a potential model.

Satchwell et al (2015) emphasizes the importance of transition strategies as part of broader regulatory reform. The report notes that the pace and pattern for DER adoption will vary by region, based on technology costs, customer preferences and policy frameworks, and therefore regulatory frameworks and utility business models will also vary. Effective transition strategies can help mitigate risk for utility shareholders, customers and third-party providers while facilitating the achievement of DER objectives.

Along with transition strategies, regulators should consider pilots and other incremental approaches. CEER (2015) supports the use of regulatory incentives for smart flexible solutions and the acceptance of controlled experimentation in pursuing benefits for current and future consumers through these complex tariff issues.

A variety of studies have created more general frameworks for regulators to use as they pursue regulatory reform for DER. Costello (2015) presents a set of real-world policy objectives and aligns each with a set of utility strategies to achieve them, supporting regulatory practices, and indicators of achievement. He highlights that a key issue for regulators will be to assess the potential benefits of direct utility investment in distributed generation against the potential adverse impact on competition in this area.

De Martini and Kristov (2015) set out a practical framework for regulators to:

- Understand and consider DER growth in their jurisdictions
- Address its impacts in a manageable, logical sequence
- Guide distribution system evolution with clear lines of sight to overarching public policy objectives

For the transmission/distribution interface, they recommend that regulators focus first on engineering studies, infrastructure planning, and interconnection rules and procedures. Next, regulators should consider DER service definitions and procurement mechanisms. They caution that regulators must be adaptable because the evolution is being driven from the bottom by customer demand.

Stanton (2015) observes a growing trend marked by a shift away from the issue-specific incremental regulatory approach to a more comprehensive, holistic, multi-stakeholder “win-win” approach. New York’s REV approach is an example. Stanton notes that a more holistic approach would be aided by more transparent and coordinated planning and modelling and analysis of the impacts of various policy options on utilities and the economy. (Stanton, 2015)

A report by the National Renewable Energy Laboratory (NREL) looks at the adaptive, reconstructive and evolutionary approaches to policy decision-making in the face of the worldwide trends in the sector. Rather than just focusing on the utility business model or rate frameworks, policy should take a broader approach and be focused on the power sector “ecosystem”. Next generation PBR is an adaptive approach to reorient vertically integrated utilities toward broader set of public policy outcomes. A reconstructive pathway would restructure power markets based on lessons of the last 20 years. An evolutionary pathway would empower the distributor as a system operator (examples include RIIO and REV). The report also looks at the integration of pathways to provide greater energy access. (NREL, 2015)

The literature demonstrates that in addition to detailed technical and rate design issues, regulators must also review their overall regulatory frameworks and determine what changes are necessary to support market transformation and integration of DER. Ontario has been moving from incentive regulation to a more performance based approach (the Renewed Regulatory Framework). In line with the literature, further evolution of the regulatory framework will likely need to consider specific incentives for targeted performance outcomes, among other tools. Several jurisdictions have been addressing the issues of DER integration and utility transformation from a structural or holistic perspective. A discussion of developments in these jurisdictions is presented next.

Select Regulatory Developments in Leading Jurisdictions

Significant work related to electricity market transformation is taking place in a number of jurisdictions, including New York, California, the UK, and Australia. The following discussion is not intended to be a comprehensive presentation of the regulatory issues in these jurisdictions. Instead, it is intended to be a targeted exploration of some of the key issues which will likely have particular relevance for Ontario.

New York

Under New York's Reforming the Energy Visions (REV), distributors will act as Distributed System Platform (DSP) providers. The Public Service Commission (PSC) REV Order discusses the trends which are driving the need for reform: aging infrastructure, flat demand, climate change, technology, etc. and notes that many other jurisdictions are facing similar trends. The Order establishes the long-term vision, identifies key issues, sets out the main steps, and provides policy direction on some initial detailed issues (e.g. distributors will not own DER). The Order also documents the very broad stakeholder input, including public comments on line and public statement hearings around the state, and responds to the input received. (*NY PSC Order*, February 2015)

The New York PSC has already considered some of the key issues though individual utility applications. For example, in late 2014 the PSC approved a plan by Consolidated Edison to use a mix of traditional utility infrastructure and non-traditional resources to meet system needs in New York City (the Brooklyn/Queen's Demand Management Program). The Program and the decision have been the subject of comment and analysis. For example, Hu et al (2015) review the decision and find it accords with the five principles of grid neutrality for a fair and open electricity network:

- Empowering the consumer while maintaining universal access to safe, reliable electricity at reasonable cost
- Demarcating and protecting the "commons"
- Aligning risks and rewards across the industry
- Creating a transparent, level playing field
- Fostering open access to the grid

The New York PSC is now in the process of developing ratemaking reforms to remove disincentives and create alignment between customer and distributor interests in support of REV. A staff white paper sets out proposals related to the utility model and earnings opportunities. The proposals were developed through outreach and public comment. The paper also addresses technology issues, operability issues, market structure issues, ratemaking issues, and rate design issues. They emphasize transition mechanisms to drive initial change and success, and to gain broad acceptance. As changes take hold, the transition mechanisms may fall away (*Staff White Paper*, 2015). Responses to the staff paper were detailed and broad ranging, often arguing that the proposals did not go far enough. (See, for example, *Comments of the National Energy Marketers Association (2015)* and *Comments of the Institute for Policy Integrity* (2015).)

The PSC has just recently released its Order setting out its policy framework for the new ratemaking and utility revenue model. The PSC's objective is to create a modern regulatory model that better aligns utility shareholder financial interest with consumer interest. The Order states: "The public interest is best served when utilities' economic objectives are decisively and substantially aligned with public policy and consumer interests." (p.6) The Order sets out a framework where over time revenues will be increasingly earned through facilitation and operation of more transactive retail markets, based on three principles:

- The unidirectional grid must evolve into a more diversified and resilient distributed grid engaging customers and third parties.
- Universal, reliable, resilient, and secure delivery service at just and reasonable rates remains a function of regulated utilities.
- Overall efficiency of the system and consumer value and choice must be improved through mix of utility and third-party investment.

Under the new framework, utilities will have four revenue tools:

- Traditional cost-of-service
- Earnings tied to achievement of alternatives that reduce utility capex and provide definitive consumer benefit
- Earnings from market-facing platform activities
- Transitional outcome-based performance measures

(*Order Adopting a Ratemaking and Utility Revenue Model Policy Framework*. May 19, 2016**.**)[4]

New York has embarked on an ambitious plan to develop the DER market and to reform ratemaking for distributors to ensure they embrace rather than resist change. New York's

[4] The Order also addresses competitive market-based earnings through unregulated subsidiaries, data access, clawback reform, standby service, opt-in rate design, large customer demand charges, scorecard metrics, and mass-market rate design.

approach is notable for the regulator's overarching vision and the magnitude of change being undertaken. The REV initiative is becoming a model against which other reforms are being measured. It is a jurisdiction which Ontario should watch closely.

United Kingdom

The UK energy regulator, the Office of Gas and Electricity Markets (Ofgem), undertook a complete review of its price cap regulation and developed a new framework, named RIIO for revenue = incentives + innovation + outputs. RIIO was designed to encourage network companies to:

- Put stakeholders at the heart of their decision-making process
- Invest efficiently to ensure continued safe and reliable services
- Innovate to reduce network costs for current and future consumers
- Play a full role in delivering a low carbon economy and wider environmental objectives.

The Chairman of Ofgem reviews the principles of RIIO in a recent industry lecture. He comments on the initial results in terms of improved customer service and higher quality business plans, but highlights that the future is uncertain, and the regulatory approach will continue to evolve. He identifies future work in the areas of new business models and the structure of charges (rate design), and notes that Ofgem does not want regulation to stifle innovation by new entrants. (Gray, 2015)

In the foreword to a 2015 Ofgem discussion paper related to new business models, Dermot Nolan, Ofgem CEO states:

> *I want us to get out of the way where regulation poses barriers, and to support innovation where the benefits are clear. But energy is an essential service, so we have to balance getting out of the way with the paramount need to minimise potential risks and keep costs to existing and future consumers down, and to ensure all consumers – especially those in vulnerable situations – are treated fairly.*[5]

The discussion paper is the initial stage of a long-term conversation looking at regulatory impacts and responses to non-traditional business models. Responses to the discussion paper noted that non-traditional business models can bring significant flexibility benefits, but there are

[5] Ofgem, *Non-traditional business models: Supporting transformative change in the energy market: Discussion paper*, February 25, 2015.

barriers in terms of integration with the grid and the market. There are also regulatory barriers to local energy solutions. The regulatory system needs to be more flexible and principles-based, but consumer protection remains a strong concern. (Ofgem, September 30, 2015.)

Others have also noted that the UK regulatory system will need to change along with the system and the market. Strbac et al (2016) recommend that the focus be on setting commercial incentives rather than detailed investment evaluation. They also propose that there be incentives for smart grid, a level playing field for technologies in competitive markets, and the full integration of wholesale and retail markets.(Strbac et al, 2016)

The experience in the UK demonstrates that even a jurisdiction which has undertaken a significant program of regulatory reform to address the issues of aging infrastructure and a changing generation mix must continue to evolve in order to respond effectively to the emerging issues around DER and expected further market transformation. The UK is also an example of a jurisdiction which is simultaneously driven to promote competition and protect customers, particularly vulnerable customers.

California

The California Public Utilities Commission (CPUC) recently released its *Draft Regulatory Incentives Proposal* (April, 2016). As in New York, the CPUC's objective is to align the utility's financial objectives with the CPUC's desire to foster cost-effective DER. The CPUC has assessed that a utility's financial interest is governed by the principle that a utility invests when the allowed return on equity is greater than the cost of equity. The proposed incentive is therefore related to the differential, which is estimated at 2.5%-3.5%. The structure of the incentive would allow shareholders to earn about 3.5% (of the payment to the DER) when the utility chooses DER over more traditional rate base investments. (The CPUC notes that under this approach it would need an iterative and automatic way to determine allowed return and cost of equity going forward.) A DER project would be considered cost effective if the costs of the DER plus the incentive (in present value revenue requirement terms) is less than what utility would have recovered through the alternative investment. The analysis may include system level costs for energy, capacity and ancillary services, as well as avoided GHG emissions. The intention is for the proposal to go forward on a pilot basis, but eventually the process will be integrated into the Distribution Resource Plan, which is the subject of a separate coordinated CPUC proceeding.

California also provides some interesting examples of cooperative work being undertaken by a variety of parties. For example, the Advanced Energy Economy Institute has prepared a position paper setting out recommendations and proposals arising from the cooperative efforts of a large group of electricity sector players, including utilities, technology companies, and consultancies. It presents a broad vision of an integrated approach to market transformation at the wholesale and retail level. The report identifies three areas to be pursued: innovation in product and service delivery, system design and technology, and regulatory framework, incentives and revenue mechanisms. (Advanced Energy Economy Institute, 2015)

Another example is a report on energy storage, prepared jointly by the three California regulatory agencies (the CPUC, the California Energy Commission and the California Independent System Operator) and based on the input of over 400 stakeholders. The report looks to support the advancement of grid storage by presenting a common view of the issues to be addressed, the level of priority and which agency is responsible. The report serves to coordinate their efforts and provide a platform of common understanding. This approach shows the importance of agency cooperation in identifying and prioritizing the technical, market, and institutional issues which must be addressed. (CPUC, the California Energy Commission and the California Independent System Operator, 2014)

California is like other key jurisdictions in its goal of aligning the incentives of utilities with the policy and regulatory goals of DER. It presents an interesting example of ratemaking reforms being implemented on a pilot basis. This provides the opportunity to learn from experience while mitigating risk. In dealing with the complexity and breadth of issues around integrating DER and modernizing the electricity grid, California's experience demonstrates the value of cooperative efforts to identify and prioritize issues and establish an overall vision.

Australia

A recent study from Australia further demonstrates the potential for cooperative analysis.[6] The Commonwealth Scientific and Industrial Research Organisation and the Energy Networks Association are partnering to develop a blueprint for the transition of Australia's electricity

---

[6] CSIRO and Energy Networks Association. *Electricity Network Transformation Roadmap: Interim Program Report*. December 2015.

system, using long-term scenario analysis to 2050 and more focused plans for 2015-2025. They are using broad stakeholder engagement, and placing customers at the centre of the project.

The report outlines work in three areas: customers at the centre of the future grid (customer orientation for future work), the drivers for the transformation, and technical challenges and opportunities of DER. A balanced scorecard is being used to compare the options, including lower costs, fair rewards and cost recovery, more choice and control, and securing the clean energy transition. The scenario modelling shows that customer bills in 2030-2050 could be lower than they were in 2013. Work is also ongoing in three other areas: direction for business models, prices and incentives, and priorities for policy and regulation. In the area of the business model, they identify work to be done around four broad models: Information services, Beyond-the-meter services, Intelligent Grid, and Platform Enabled. They note however that there is no one-size-fits-all model and most progressive utilities are planning multiple evolutions.

The report advises that policy and regulation should focus on long term customer interests, be flexible and enabling (of new technology and new competition), align network incentives with long term customer value, and be proportional, bounded, non-discriminatory, consistent, independent, and accountable. In the area of pricing and incentives they note that the first wave of reforms focussed on fair and efficient cost recovery and pricing, fixed cost recovery and demand-based rates. The second wave of reform will focus on fair and efficient operation of networks as integrated enabling platforms, with prices that are more location-specific and dynamic.

Concluding Observations

The drivers for electricity market transformation are the same in many countries: aging infrastructure, rising customer expectations, technology advancement, and climate change policies. Technological change is leading to more distributed systems which have the potential to be more efficient and more reliable. The issues which must be addressed are complex and the stakes are high. As De Martini and Kristov (2015) say, “If grid defection occurs at scale, we will have failed from a societal perspective.” Ontario’s approach must be customized to its particular circumstances, but solutions can be developed from the lessons learned elsewhere.

New technology is making new rate structures necessary, but the technology is also making new rate structures possible. Rate design for DER is the subject of intense study and debate. Net metering is a simple, but potentially inaccurate way of recognizing the costs and benefits of distributed resources. Work is being done to develop more precise and nuanced approaches, but these tend to lead to more granularity and complexity, which speaks to the difficulty of trying to fairly apportion costs and benefits. It will be a significant challenge to develop rate designs which are accurate and effective without being excessively complex. More structured analysis is needed, which recognizes the policy drivers (e.g. in terms of including externalities) as well as system characteristics. Pilots are a means of testing the implementation of new rate designs are assessing whether they are having the intended effect.

More fundamentally, the utility business model and regulatory framework will need to evolve in order to effectively integrate DER into the system and the market. In developing practical approaches to address the issues, cooperative efforts are one approach to move forward on these complex and multi-faceted issues. It is likely the pilot projects will be a pragmatic approach to determine the most effective rate design tools and ratemaking reforms, and transition mechanisms may be useful given the potential extent of the required change.

Portfolio 4: The Future of Centralized Supply

The traditional system of large-scale centralized supply, long-distance transmission, and one-way distribution is being replaced by smaller scale, more distributed generation, along with more flexible transmission and distribution systems. The shift is being driven by technology, economics and policy. A more integrated web network brings the potential for significant efficiency and reliability improvements as well as the risk of significant stranded costs and system disruption.

The technology drivers for a more integrated network include renewable generation and distributed generation, grid level storage, smart grid (including information and communications technologies), energy efficiency and demand response, and big data. The drivers for a more integrated network include:

- Climate change and economic development policies
- Policy and regulatory barriers and incentives for grid integration
- Planning processes at the regional and provincial level
- Integrated electricity and natural gas planning
- Reliability requirements

The literature related to these drivers will be reviewed through the following key issues:

- Stranded asset risk
- Grid level resources and grid operations
- Market structure reform

Stranded Asset Risk

With increased penetration of DER, certain assets which are already part of the system may no longer be needed. The risk is that this happens before the assets have been fully recovered through rates. Utilities will generally seek recovery of these “stranded” costs. Commentators have observed the potential for the growth of DER to trigger a “death spiral” in utilities. A death spiral is the result of the interplay between the fixed costs on the utility system and the costs of a customer’s competitive alternative. As more customers reduce their load (“load defection”) or leave the utility altogether (“grid defection”), the fixed costs are recovered from a smaller number of customers, which in turn pushes more customers to the competitive alternative. Stranded costs may also arise if distributed generation displaces central generation.

Dyson et al. (2015) point out that needed grid infrastructure investment is estimated at $1 trillion over the next 15 years, but electricity sales are slowing. The resulting rate increases could make DER increasingly cost effective, leading to possible grid defection. Costello (NRRI 2015) notes that Moody's has identified the risk of customers leaving the grid as part of its analysis. Raskin (2014) argues that recovery of some level of stranded costs is a necessary to ensure a reasonable market transition, to respect the regulatory compact, to ensure that utilities continue to cooperate on the implementation of public policies such as distributed generation, and to protect the majority of customers who continue to be served by utilities. He points to the compromise reached in the last round of market restructuring which resulted in the recovery of most stranded costs. He notes that legislation setting out the framework for recovery may be a better tool than relying on the courts.

Grid parity is the point at which the cost of DER meets the cost of conventional electricity service. An analysis by the Rocky Mountain Institute in 2014 looked at when grid parity would be reached in New York, Hawaii, California, Texas, and Kentucky. The study includes a conservative base case, along with three scenarios: accelerated technology, demand-side improvement (i.e. greater customer responsiveness), and both factors combined. The results show that even in the base case, grid parity comes by 2030 for California and New York, and has already been reached in Hawaii. Grid parity is not reached until the late 2040's for Kentucky and Texas, but it is reached much sooner under the improvement scenarios. (Rocky Mountain Institute, 2014)

A further study by the Rocky Mountain Institute analyzes the timing for shifting from grid-connected installations to grid-plus-solar to grid-plus-solar-plus-battery. The study estimates that 50% of residential sales and 60% of commercial sales in northeast could be lost by 2030. The study concludes that eliminating net metering and using fixed charges delays the timing, but does not "fix" problem of greater DER and load defection. They maintain that solar PV plus batteries could provide benefits to the grid, but need the right pricing, business models and regulatory structures. The alternative is significant risk of stranded transmission and centralized generation assets. The study concludes that we are at a "fork in the road": one path leads to an integrated grid, the other to grid defection. (Rocky Mountain Institute, 2015)

The analysis of grid parity, however, is quite sensitive to assumptions about tax incentives and other subsidies. Motyka and Given (2015) provide an analysis of grid parity, without subsidies, across a variety of scenarios for utility scale onshore wind and solar PV. They find that grid parity is not imminent, except in a few states, and onshore wind reaches parity before solar PV in most cases. When incentives for wind and solar are included, grid parity is advanced by as much as a decade. They note that technology innovation could change this outlook, as could rising natural gas prices and wholesale power market rebalancing to reduce over-supply. (Motyka and Given, 2015)

A recent study on the economic potential of renewable electricity generation (utility level and distributed) looks at the issue of grid parity from a different perspective. The study estimates the economic potential for utility level and distributed generation in the U.S. across a variety of scenarios. The economic potential ranges from 1/3 to 10 times total U.S. generation in 2013. In most of the study's scenarios utility-level PV is the largest component, which is due in part to its large estimated technical potential. However, in another scenario which considers avoided external costs and the declining value of variable generation as its deployment increases, the potential for utility-level solar PV is reduced significantly, but there is no impact on the economic potential of distributed solar PV. (The estimates are based on the assumptions of full net metering for distributed PV and permanent tax incentives.) (Brown et al, 2015)

Cooper (2015) examines a variety of cost estimates for nuclear power and alternatives and finds that costs of new nuclear are two to three times higher than distributed alternatives (energy efficiency, wind, solar, and storage). The analysis finds that maintaining aging nuclear reactors is also not competitive with distributed alternatives. In his view, distributed alternatives are superior in terms of risk, and the technical potential is more than adequate. He notes that nuclear operators claim that shutting aging plants will reduce reliability and reduce the ability to meet carbon emission reductions. However, he maintains these claims are false; he examines the situation in Illinois and finds no adverse impact on reliability. (Cooper, 2015)

The literature suggests that the risks of stranded assets are significant for distributors, transmitters and generators. While the risk is particularly pronounced if there is significant grid defection, it is less clear what the potential impact will be with integrated DER. Ontario will need to assess these potential impacts given the already substantial investments which have been made to drive to a low carbon electricity sector and the resulting impact on rates.

Grid Level Resources and Grid Operations

Although much of the focus is on DER, technological advancements are also occurring at the transmission grid level. Grid-level storage and enhanced grid operations are two examples.

Three California regulatory agencies (California Public Utilities Commission, California Energy Commission and California Independent System Operator) have collaborated in an effort to support the advancement of grid storage. Their report, based on the input of over 400 stakeholders, identifies three challenges: increasing revenue opportunities, reducing the costs of integrating with and connecting to the grid, and streamlining processes to increase certainty. The report identifies the specific issues to address these challenges, establishes the level of priority for each issue, and clarifies which agency is responsible for its resolution. The issues are discussed in terms of planning, procurement, rate treatment, interconnection, and market participation. The report does not set out an agreed or proposed timeline for the individual regulators to resolve the issues in their area. However, the report does serve to coordinate their efforts and provide a platform for common understanding. (California Public Utilities Commission, California Energy Commission and California Independent System Operator, 2014)

Other work has focused on the importance of grid flexibility to accommodate increased renewables. Aggarwal and Orvis (2016) explain the potential for the following enhancements:

- Improved operations: shorter dispatch schedules (5 minutes), better weather forecasting, consolidated balancing areas
- Demand response: up and down with full participation in energy and capacity markets
- Transmission and distribution infrastructure
- Flexible generation, such as combined cycle fast ramping gas and hydroelectric
- Storage

The report includes case studies related to short-term operational flexibility: ERCOT's Fast Frequency Response creates value for new resources (pilot included storage and EVs) and CAISO's Flexible Ramping Product creates value by using existing resources better. The report also includes case studies related to longer-term measures: California's storage mandate; capacity markets; and a staircase capabilities market (a sequence of long-term, small volume procurements for new capabilities). (Aggarwal and Orvis, 2016)

Work by the New York Independent System Operation examines the benefits and challenges of integrating DER with the grid, particularly demand response. DER changes load shape, making forecasting more difficult. DER also potentially impacts the market due to surplus generation and the interaction of wholesale prices and net metering prices. However, the grid still needs ancillary services especially ramping. The study concludes that new technology and incentives will be needed to influence the location of DER and to facilitate integration of DER in order to get the benefits and deal with the challenges. (NY ISO, 2014)

Analysis has also been done on the potential value of DER to reduce the risk of blackouts and to reduce losses. Govindarajan and Blumsack (2015) have analyzed the value of distributed generation from CHP in terms of reduced blackout risk (related to equipment overload, not weather events). Using a case study in Philadelphia, they analyze the costs and the social and private benefits. They estimate that deploying 1,000 building-integrated CHP units would bring benefits of $2 million to $2.5 million per year to CHP owners, and social benefits (the reduced risk of a blackout when the system is stressed) of $14 million to $40 million per year, depending on how the systems are operated. Further modelling of the social benefits from microgrid CHP for blackout risk in cases of extreme weather could also be done (Govindarajan and Blumsack, 2015). Costa-Campi et al (2016) analyze the potential benefits of reduced losses from demand-side management policies and distributed generation. The pattern of losses appears to be U-shaped, with higher losses resulting at greater penetration of distributed generation. (Costa-Campi et al, 2016)

The U.S. Department of Energy is sponsoring a broad-ranging platform of work under its multi-year Grid Modernization Program. The DOE sets out its vision in its program plan report:

> *The future grid will solve the challenges of seamlessly integrating conventional and renewable sources, storage, and central and distributed generation. It will provide a critical platform for U.S. prosperity, competitiveness, and innovation in a global clean energy economy. It will deliver* ***resilient, reliable, flexible, secure, sustainable,*** *and*

> ***affordable*** *electricity to consumers where they want it, when they want it, how they want it.*[7]

Grid modernization is being driven, and enabled, by changes in the generation mix, demand for a more resilient and reliable grid, opportunities for customers to participate in the market on the demand and supply side, interconnected information and control systems, and aging infrastructure. The DOE is sponsoring work in six technical areas across a consortium of national laboratories. The work has included the following initiatives:

- Renewables integration: including technical field work
- Energy storage: including battery development (technical and cost focussed)
- Systems operations and control: research, software platforms, demonstration projects.
- Security and resilience: examining all hazards, including cybersecurity; focussing on actions to identify, protect, detect, respond, and recover. Projects include the New Jersey transportation microgrid
- Institutional support: providing technical assistance and support for regional planning and reliability organizations; developing methods and resources for assessing grid modernization; researching future utility regulation. Work includes detailed mapping, case studies of net metering on investor-owned utilities; and a California DER siting/optimization tool for large-scale DER deployment[8]

The literature demonstrates the scope of the challenges at the grid level from increased DER, and the breadth of potential tools available to advance the physical operation of the grid. The U.S. Department of Energy is sponsoring significant work in this area which may well be relevant for Ontario.

Market Structure Reform

A variety of studies related to utility-focused regulatory reform were presented under Portfolio 3. A number of studies are also looking at broader market reforms to facilitate the integration of DER. These initiatives are closely related to the advancement of the regulatory framework.

---

[7] U.S. DOE, *Grid Modernization Multi-Year Program Plan,* November 2015, P. xi.
[8] U.S. Department of Energy Presentations to FERC, April 21, 2016.

Germany has issued its plan for "electricity market 2.0" which will bring competition in flexibility services (customers, generators, trade). The goals are security, cost savings, and innovation. The White Paper sets out the plan for implementation, with specific measures for each component of the new market structure. The paper includes a thorough review of the broad consultations, the reasons for the government's decisions and the evidence supporting those decisions (from expert reports). (*White Paper*, 2015)

The UK's National Infrastructure Commission recently released its *Smart Power* report (March 2016), which presents the results of its large stakeholder initiative to examine policies and make recommendations. The report estimates that Smart Power could save up to £8 billion per year by 2030 and help meet the UK's 2050 carbon targets. Existing generation plant is reaching end of life and demand for electricity is changing; the system needs smarter ways to balance supply and demand for reliability and resilience, including:

- Interconnection to other markets is expected to rise 11.3 GW by early 2020s, but other interconnections should be considered, including to Norway and Iceland.
- Storage resources are growing and becoming competitive without subsidies, but there are regulatory barriers to market access.
- Demand flexibility remains underused in UK because of barriers to fair market access.
- A more independent system operator to invest in and operate a more complex grid. Local networks will also need to be more actively managed and have closer coordination with national network.

One of the studies supporting the Commission's work included a series of recommendations for the grid, the market and regulation as the UK electricity system goes to low carbon. The grid will be more complex and peakier, and potentially more costly as wind is curtailed in order to keep gas online. The grid will need more flexible generation, ancillary services, interconnections, demand response and storage. The future system will need to move away from redundancy and instead enhance asset utilisation through improved system control, big data, greater integration of transmission and distribution and decentralized control (microgrids). Design and planning will need to reflect these imperatives with greater coordination. (Strbac et al, 2016)

Hogan et al (2015) note that a low-carbon system will likely rely on wind and solar, both variable resources, and that the cost and complexity of integrating these resources and maintaining reliability can vary greatly. However, a low-carbon system must continue to be reliable and affordable. The report points to market rules, market design, and market operations as the means to achieve a low-cost and reliable transition. A number of tools are identified, including

- A shift to more flexible portfolio of generation (less inflexible baseload, more mid-merit)
- Balancing over larger areas
- Economic dispatch
- Tighter integration of intra-day and day-ahead and balancing market operations
- Dispatchable demand-side flexibility
- Improved energy and capacity markets

Each of these tools is technically feasible and already used in varying degrees. The challenge is for policy to be developed in the most effective way. The authors focus on capacity mechanisms, noting that a capacity mechanism will enhance resource adequacy only if the operational characteristics of the resources are considered.

Kristov (2015) expects that DER will be the dominant factor of the electricity system in 2030. This “integrated decentralized” system will be characterized by local self-reliant distribution-based systems which remain connected to the transmission grid and the wholesale market, except in emergencies. The variability of DER and customer load will increasingly be addressed locally, and the distributor will be the aggregator of DER at the transmission/distribution interface and in the wholesale market. Storage will become ubiquitous across the system, along with new uses of electricity to use excess supply.

In a more technical analysis, Kristov et al (2016) analyze the optimal grid configuration from an operations perspective and consider two alternatives: the “layered optimization” paradigm, and the “grand optimization” paradigm. In the “layered optimization” paradigm the distributor operates like a mini ISO, balancing supply/demand on its system and aggregating and bidding DER services to the grid via the wholesale market at the distribution/transmission interface. In the “grand optimization” paradigm, the ISO (or RTO or TSO) optimizes for the whole system, with visibility down to the granular level. The study finds that from a grid architecture perspective and a control theory perspective, the layered optimisation paradigm is better than the centralized grand optimization vision, although both can support peer-to-peer transactions. The authors conclude that making this design decision first clears the way to address all the subsequent issues.

The literature indicates that board market reforms will likely be needed to support the evolution of the grid and the effective integration of DER. Although there is potential for significant benefits, the changes will need to be coordinated with the evolution of the utility model and the regulatory framework.

Concluding Observations

The costs of distributed generation have continued to decline, leading more customers to offset at least part of their demand. This "load defection" has become a growing challenge for utilities as they seek to spread the largely fixed costs of the transmission and distribution grid over lower demand. Load defection has also led to the displacement of large, capital intensive, centralized generation. Now that the cost of distributed storage is declining as well, it is becoming more economical to be self-sufficient. This risk of "grid defection" would result in even more serious cost recovery issues for utilities and centralized generation.

However, distributed generation and storage, coupled with advanced communication and control technologies, can enable customers to offer more services to the grid. Other forms of DER can do the same (e.g. smart appliances).

The consensus appears to be that the full integration of economically efficient DER can lead to lower cost, higher reliability grids. However, current pricing and utility approaches may be discouraging integrated DER and risking grid defection. And current regulatory frameworks and and market structures may be barriers to advancement. So the system is at a cross-roads: will utilities, policy makers and regulators adopt policies and frameworks which seek to retard deeper penetration of DER, or will they embrace the potential of DER and seek to adopt policies and frameworks which fully recognize the costs and benefits of DER, and incent it where is economically efficient. The literature suggests that the first approach will ultimately be unsuccessful, while the second approach is complex and requires a coordinated effort to resolving the technical, regulatory and market issues.

Conclusions

The emerging trends in Ontario's energy sector are being experienced in many jurisdictions. As a result, there is a rich and varied literature examining many of the overarching themes, as well many of the more narrow and technical issues. This report has attempted to distill many of the ideas and issues explored in the more recent literature. Based on this body of work, a number of key themes have arisen which will be relevant to Ontario as it addresses the challenges and opportunities of the emerging energy sector transformation. These key themes include:

- DER has evolved from a relatively simple load displacement tool (distributed generation) to an integrated resource which can provide a variety of services to the grid. This evolution has been enabled by the technology advancements and driven by rising customer expectations.
- DER has the potential to bring significant benefits in terms of reliability, resilience, cost, and environmental impact, but also introduces greater complexity in terms of planning, operations, rate design, and market structure, and may result in stranded costs.
- The evolution of the utility business model, the regulatory framework, and the market structure will need to be coordinated, but utilities and regulators will be challenged to match the pace of technology change and customer expectations.
- The optimal solutions for a jurisdiction will be driven by its particular characteristics and policy drivers, but solutions can be developed based on learnings from other jurisdictions. The stakes are high given the need to provide reliable and affordable services for all customers and the potential for significant stranded assets.
- Ongoing consultation, cooperative efforts, evidence-based processes, customer engagement, pilot projects, and transition mechanisms will each facilitate the successful navigation of the emerging transformation.

Based on the literature surveyed, Ontario already has some of the attributes which have been identified as important for the integration of DER:

- performance-based regulation
- smart meters and TOU rates for energy
- distribution system planning and regional planning which is becoming more transparent, organized and rigorous

- Experience with connecting renewable electricity generation on the distribution system, particularly at the individual customer level
- Increased customer engagement

Ontario can draw on the experience of others, as well as the analysis which has been done, to chart its own course through the energy market transformation. The work being conducted by Mowat Energy will be an important contribution to that effort.

Appendix: Bibliography

Articles in the Mowat Archive

Academic Articles

Costello, Kenneth W. "Major Challenges of Distributed Generation for State Utility Regulators*."* *Electricity Journal*, April 2015.

Graffy, Elisabeth and Steven Kihm. "Does Disruptive Competition Mean a Death Spiral for Electric Utilities?" *Energy Law Journal*, Vol. 35, No. 1, 2014. https://www.seventhwave.org/sites/default/files/graffy-kihm-elj-article-may-2014.pdf

Kiesling, Lynne. "Implications of Smart Grid Innovation for Organizational Models in Electricity Distribution*."* February 2015 (forthcoming in Wiley *Handbook of Smart Grid Development*.) Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2571251

Raskin, David. "Getting Distributed Generation Right: A Response to "Does Disruptive Competition Mean a Death Spiral for Electric Utilities"*."* *Energy Law Journal*, Vol. 35, No. 263, Nov. 2014. http://www.felj.org/sites/default/files/docs/elj352/14-263-282-Raskin-final-11.1.pdf

Raskin, David. "The Regulatory Challenge of Distributed Generation*." Harvard Business Law Review Online*, Vol. 4, 2013. http://www.hblr.org/2013/12/the-regulatory-challenge-of-distributed-generation/

US General

Brown, Austin et al. *Estimating Renewable Energy Economic Potential in the US: Methodology and Initial Results.* National Renewable Energy Lab, July 2015. http://www.nrel.gov/docs/fy15osti/64503.pdf

Costello, Kenneth W. *Utility Involvement in Distributed Generation: Regulatory Consideration.* NRRI for EISPC and NARUC, February 2015. http://pubs.naruc.org/pub/536EF3DF-2354-D714-510E-B20295D42469

Dyson, Mark, James Mandel, et al. *The Economics of Demand Flexibility: How "flexiwatts" create quantifiable value for customers and the grid.* Rocky Mountain Institute, August 2015. http://www.rmi.org/electricity_demand_ flexibility

Electricity Innovation Lab (eLab). *A Review of Solar PV Benefit and Cost Studies, 2nd Edition.* Rocky Mountain Institute, September 2013. http://www.rmi.org/cms/Download.aspx?id=10793&file=eLab_DERBenefitCost

Electricity Innovation Lab (eLab). *New Business Models for the Distribution Edge: The transition from Value Chain to value constellation.* Rocky Mountain Institute, April 2013. http://www.rmi.org/cms/Download.aspx?id=10469&file=2013-06_eLabNewBusinessModels.pdf&title=eLab+New+Business+Models+Report

Electricity Innovation Lab (eLab). *Rate Design for the Distribution Edge: Electricity Pricing for a Distributed Resource Future.* Rocky Mountain Institute, August 2014. http://www.fortnightly.com/sites/default/files/whitepapers/Rate%20Design%20for%20the%20Distibution%20Edge.pdf

Hogan, M., Weston, F., and Gottstein, M. *Power Market Operations and System Reliability in the Transition to a Low-Carbon Power System: A Contribution to the Market Design Debate.* Brussels, Belgium: The Regulatory Assistance Project, 2015. http://www.raponline.org/document/download/id/7600

Lazar, J. and Gonzalez, W. (2015). *Smart Rate Design for a Smart Future.* Montpelier, VT: Regulatory Assistance Project. Available at: http://www.raponline.org/document/download/id/7680

Power Systems of the Future: A 21st Century Power Partnership Thought Leadership Report, Technical Report NREL/TP-6A20-62611. February 2015. http://www.nrel.gov/docs/fy15osti/62611.pdf

Satchwell , Andrew, Peter Cappers, Lisa Schwartz, and Emily Martin Fadrhonc. *A Framework for Organizing Current and Future Electric Utility Regulatory and Business Models.* Lawrence Berkeley National Laboratory, June 2015. https://emp.lbl.gov/sites/all/files/lbnl-181246_0.pdf

California

Advanced Energy Economy Institute. *Toward a 21st Century Electricity System in California: A Joint Utility and Advanced Energy Industry Working Group Position Paper*. August 2015. http://info.aee.net/hubfs/PDF/aeei-toward-21ces-ca.pdf?t=1439326205320

California Energy Commission, California Public Utilities Commission and California Independent System Operator. *Advancing and Maximizing the Value of Energy Storage Technology: A California Roadmap.* December 2014. https://www.caiso.com/Documents/Advancing-MaximizingValueofEnergyStorageTechnology_CaliforniaRoadmap.pdf

New York

New York Public Service Commission. CASE 14-M-0101 Reforming the Energy Vision. *Order Adopting Regulatory Policy Framework and Implementation Plan*. February 26, 2015. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b0B599D87-445B-4197-9815-24C27623A6A0%7d

New York Department of Public Service. CASE 14-M-0101 Reforming the Energy Vision. *Staff White Paper on Ratemaking and Utility Business Models.* July 28, 2015. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b48954621-2BE8-40A8-903E-41D2AD268798%7d

Comments of the Institute for Policy Integrity (New York University School of Law). REV staff white paper on Ratemaking and Utility Business Models. Docket No. 416. October 26, 2015.

Comments of the National Energy Marketers Association. REV track 2 proceeding, October 26, 2015.

Sedano, Richard. *Power Sector Transformation: The Case of New York REV, presentation to EUCI.* Regulatory Assistance Project, August 10, 2015. https://raponline.org/document/download/id/7737

Europe

An electricity market for Germany's energy transition. White Paper by the Federal Ministry for Economic Affairs and Energy, July 2015. http://www.bmwi.de/English/Redaktion/Pdf/weissbuch-englisch,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

Council of European Energy Regulators. *The Future Role of DSOs: A CEER Conclusions Paper*. Ref: C15-DSO-16-03, July 13, 2015. http://www.ceer.eu/portal/page/portal/EER_HOME/EER_PUBLICATIONS/CEER_PAPERS/Cross-Sectoral/Tab1/C15-DSO-16-03_DSO%20Conclusions_13%20July%202015.pdf

Ofgem. *Non-traditional business models: Supporting transformative change in the energy market: Discussion paper.* February 25, 2015. https://www.ofgem.gov.uk/ofgem-publications/93586/non-traditionalbusinessmodelsdiscussionpaper-pdf

Ofgem. *Non-traditional business models: Supporting transformative change in the energy market: Summary of responses to discussion paper.* September 30, 2015. https://www.ofgem.gov.uk/publications-and-updates/non-traditional-business-models-supporting-transformative-change-energy-market

Other

A Review of Distributed Energy Resources. New York Independent System Operator. Prepared by DNV GL, September 2014. http://www.nyiso.com/public/webdocs/media_room/publications_presentations/Other_Reports/Other_Reports/A_Review_of_Distributed_Energy_Resources_September_2014.pdf

Dorey, Steve. *Expert Report*, MESA proceeding. https://www.pcacases.com/web/sendAttach/289

Energy UK. *Pathways for the GB Electricity Sector to 2030*. February 2016. https://www.energy-uk.org.uk/publication.html?task=file.download&id=5722

International Energy Agency*. Energy Market Experience: Lessons from Liberalised Electricity Markets.* OECD, 2005.
https://www.iea.org/publications/freepublications/publication/LessonsNet.pdf

Kristov, Lorenzo. "The Future History of Tomorrow's Energy Network*." Public Utilities Fortnightly*, May 2015. Available at: http://www.fortnightly.com/fortnightly/2015/05/future-history-tomorrows-energy-network

Kristov, Lorenzo (CA ISO), Paul De Martini and Jeffrey D. Taft. "Two Visions of a Transactive Electric System." Accepted for publication in *IEEE Power and Energy Magazine*. January 15, 2016. http://resnick.caltech.edu/docs/Two_Visions.pdf

Lo, Susan. *Witness Statement in MESA Power proceeding.* February 28, 2014.

Queen, Karen and Justin Shilad. *Growing Pains: The Experts: Taking on the most urgent challenges of renewables*. Smart Grid Today Industry Report, March 2015.
http://www.smartgridtoday.com/public/GROWING-PAINS-Facing-up-to-the-challenges-of-renewables.cfm

SWECO. *Study on the effective integration of Distributed Energy Resources for providing flexibility to the electricity system*, report to the European Commission. March 5, 2015.
http://ec.europa.eu/energy/en/studies/study-effective-integration-distributed-energy-resources-providing-flexibility-electricity

Warren, Robert B. *The Governance of Regulatory Agencies: A Case Study of the Ontario Energy Board.* December 2014. http://www.weirfoulds.com/_WF-Governance-of-Regulatory-Agencies

Additional Materials (alphabetical by author)

Aggarwal, Sonia aand Robbie Orvis. *Modernizing the Power Grid*. Energy Innovation. March 2016. http://energyinnovation.org/wp-content/uploads/2016/05/Grid-Flexibility-report.pdf

Addressing the Challenge of Distributed Energy Resource Growth and Keeping the Lights On. Study by westMonroe, April 2016. available at: http://www.westmonroepartners.com/Insights/White-Papers/Distributed-Energy-Resources

Barbose, Galen and Naïm Darghouth. *Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States*. Lawrence Berkeley Laboratory and U.S. Department of Energy, August 2015. https://emp.lbl.gov/sites/all/files/lbnl-188238_1.pdf

Bayless, Charles E. "*Piggybacking on the Grid: Why net metering is unfair and inefficient."* Public Utilities Fortnightly, July 2015. Available at: http://www.fortnightly.com/fortnightly/2015/07/piggybacking-grid

Brown, David and David Sappington. *Optimal Policies to Promote Efficient Distributed Generation of Electricity*, January 2016. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2719920 (See also Brown, David P. *Optimal Policies to Promote Efficient Distributed Generation of Electricity* (January 21, 2016). USAEE Working Paper No. 16-236. Available at SSRN: http://ssrn.com/abstract=2719920)

Colman, Andy and Dan Wilson, and Daisy Chung. *Planning the Distributed Energy Future: Emerging Electric Utility Distribution Planning Practices for Distributed Energy Resources*. Black & Veatch and SEPA. February 2016. Available at: https://pages.bv.com/planning-the-distributed-energy-future-whitepaper.html

Cooper, Mark. *Power Shift: The Deployment of a 21st Century Electricity Sector and the Nuclear War to Stop It*. Institute for Energy and the Environment, Vermont Law School. June 2015. http://www-assets.vermontlaw.edu/Assets/iee/Power_Shift_Mark_Cooper_June_2015.PDF

Corneli, Steve and Steve Kihm. *Electric Industry Structure and Regulatory Responses in a Distributed Energy Resources (DERs) Future.* Lawrence Berkeley Laboratory, November 2015. Available at: https://emp.lbl.gov/future-electric-utility-regulation-series

Costa-Campi, Maria Teresa et al. "*The economic impact of electricity losses"* (Working Paper - 04/03/2016) http://www.ieb.ub.edu/phocadownload/documentostrabajo/2016/doc2016-4.pdf

California Public Utilities Commission. *Assigned Commissioner's Ruling Introducing a Draft Regulatory Incentives Proposal for Discussion and Comment*. Rulemaking 14-10-003. April 4, 2016. http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M159/K702/159702148.PDF

CSIRO and Energy Networks Association. *Electricity Network Transformation Roadmap: Interim Program Report.* December 2015. http://www.ena.asn.au/sites/default/files/roadmap_interim_program_report.pdf

DeCotis, Paul. "*New Regulatory Paradigm Needed Now to Support Distributed Energy Resources*." Public Utilities Fortnightly, March 2016. Available at: http://www.fortnightly.com/fortnightly/2016/03/new-regulatory-paradigm-needed-now

De Martini, Paul and Lorenzo Kristov. *Distribution Systems in a High DER Future: Planning, Market Design, Operation and Oversight.* Lawrence Berkeley Laboratory. October 2015. https://emp.lbl.gov/future-electric-utility-regulation-series

Energy and Environmental Economics. *Full Value Tariff Design and Retail Rate Choices: Prepared for New York State Energy Research and Development Authority and New York State Department of Public Service*. April 18, 2016. http://on.ny.gov/1T3JPKi

Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. *The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid*. Rocky Mountain Institute, September 2015. Available at: http://www.rmi.org/electricity_battery_value

Gray, David. *How can network regulation be designed for industries undergoing transformation?* The Beesley Lectures. no date https://www.ofgem.gov.uk/ofgem-publications/97048/thebeesleylectures-speechdeliveredbygemachairman-pdf

Govindarajan, Anand and Seth Blumsack. *The Private and Social Value of Blackout Risk Reduction.* (no date for paper) presentation to USAEE Conference October 2015. http://www.usaee.org/usaee2015/submissions/OnlineProceedings/reliability%20paper%202-27-2015.docx
presentation:
http://www.usaee.org/usaee2015/submissions/Presentations/AnandGovindarajan.pdf

Harvey, Hal. *The Great Reinvention of the Electric Utility*. Energy Innovation LLC. 2015. http://energyinnovation.org/wp-content/uploads/2015/01/Reinventing-the-Electric-Utility.pdf

Hledik, Ryan and Jim Lazar. *Distribution System Pricing with Distributed Energy Resources*. Lawrence Berkeley Lab, May 2016. http://www.brattle.com/system/publications/pdfs/000/005/291/original/Distribution_System_Pricing_with_Distributed_Energy_Resources.pdf?1464019143

Hu, Jenny et al. "*Grid Neutrality: Five Principles for Tomorrow's Electricity Sector*." Public Utilities Fortnightly, October 2015. http://www.greentechmedia.com/articles/read/grid-neutrality-principles-for-tomorrows-electricity-sector

Hyman, Leonard S. "Hailed a Taxi Lately?: Economic Disruption and the Future of Electric Utilities." *Public Utilities Fortnightly*, October 2015. Available at: http://www.fortnightly.com/fortnightly/2015/10/hailed-taxi-lately

Jacobs, Sharon B. *Consumer Generation – Discussion Draft*, August 12, 2015. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2662924

Jones, Kevin B. et al. "The Urban Microgrid: Smart Legal and Regulatory Policies to Support Electric Grid Resiliency and Climate Mitigation." *Fordham Urban Law Journal,* Volume 41, Issue 5 2015 http://ir.lawnet.fordham.edu/cgi/viewcontent.cgi?article=2552&context=ulj

Kind, Peter H. *Pathway to a 21st Century Electric Utility*. Ceres, November 2015. http://www.ceres.org/resources/reports/pathway-to-a-21st-century-electric-utility

Lazar, Jim and Ken Colburn. *Rate Design as a Compliance Strategy for the EPA's Clean Power Plan.* Regulatory Assistance Project, November 2015. https://www.raponline.org/document/download/id/7842

Lowry, Mark Newton and Tim Woolf. *Performance-based Regulation in a High Distributed Energy Resources Future.* Lawrence Berkeley Laboratory, January 2016. https://emp.lbl.gov/future-electric-utility-regulation-series

New York Public Service Commission. *Order Adopting a Ratemaking and Utility Revenue Model Policy Framework*. May 19, 2016. http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7BD6EC8F0B-6141-4A82-A857-B79CF0A71BF0%7D

Minnesota Public Utilities Commission. *Staff Report on Grid Modernization*. March 2016. https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={E04F7495-01E6-49EA-965E-21E8F0DD2D2A}&documentTitle=20163-119406-01

Motyka, Marlene and George Given. *Journey to grid parity: Three converging forces provide a tailwind for US renewable power*. Deloitte Center for Energy Solutions, 2015. Available at: http://www2.deloitte.com/us/en/pages/energy-and-resources/articles/journey-to-grid-parity.html

Muro, Mark and Devashree Saha. *Rooftop Solar: Net Metering is a net benefit.* Brookings Institute, May 2016. http://www.brookings.edu/research/papers/2016/05/23-rooftop-solar-net-metering-muro-saha

National Infrastructure Commission Report. *Smart Power*. March 4, 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/505218/IC_Energy_Report_web.pdf

Newbury, Paul. *Creative Destruction and the Natural Monopoly 'Death Spiral': Can Electricity Distribution Utilities Survive the Incumbent's Curse?* February 28, 2013 and undated

presentation. Available at SSRN:
http://ssrn.com/abstract=2418076 or http://dx.doi.org/10.2139/ssrn.2418076

O'Boyle, Michael. *Who Should Own and Operate Distributed Energy Resources? Energy Innovation.* August 2015. http://sepa51.org/phaseII/OBoyle_51stState_Addendum.pdf

O'Brien, David J. "Searching for Equilibrium: How to Achieve It in the Era of Distributed Energy." *Public Utilities Fortnightly,* August 2015.
http://www.fortnightly.com/fortnightly/2015/08/searching-equilibrium?authkey=1b8f573ff31babae044128d6c9f9c6755bd259c00f01b6cc6f6320f438d8a7f0

Payne, Heather. "A Tale of Two Solar Installations: How Electricity Regulations Impact Distributed Generation." Pending Publication – 38 U. HAW. L. REV. (forthcoming late 2015)
http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2600220

Revesz, Richard L. and Burcin Unel, *Managing the Future of the Electricity Grid: Distributed Generation and Net Metering.* Institute for Policy Integrity, New York University School of Law. Working Paper No. 2016/1. February 2016.
http://policyintegrity.org/files/publications/ManagingFutureElectricityGrid.pdf

Rocky Mountain Institute. *The Economics of Load Defection: How Grid-Connected Solar-Plus-Battery Systems will Compete with Traditional Electricity Service, Why It Matters and Possible Paths Forward*. April 2015. www.RMI.org http://www.rmi.org/electricity_load_defection

Rocky Mountain Institute, *The Economics of Grid Defection.* February 2014,
http://www.rmi.org/electricity_grid_defection

Brown, David P. and David Sappington. *On the Design of Distributed Generation Policies: Are Common Net Metering Policies Optimal?* October 2015.
http://people.clas.ufl.edu/sapping/files/Net-Metering-JIE.pdf

Shepard, Michael. “Playing Offense with EVs: How Much of a $100 billion market in electric vehicles can utilities capture – or afford not to?” *Public Utilities Fortnightly*, October 2015. http://mag.fortnightly.com/article/Playing+Offense+with+EVs/2291439/276011/article.html

James Sherwood et al. *A Review of Alternative Rate Designs: Industry experience with time-based and demand charge rates for mass-market customers.* Rocky Mountain Institute, May 2016. http://www.rmi.org/alternative_rate_designs

Stadler, Michael et al. “Value Streams in Microgrids: A literature Review.” To be published in *Applied Energy* October 2015. http://eetd.lbl.gov/publications/value-streams-in-microgrids-a-literat

Stanton, Tom. *Distributed Energy Resources: Status Report on Evaluating Proposals and Practices for Electric Utility Rate Design*. NRRI Report 15-08. October 2015. Available at: http://nrri.org/download/nrri-15-08-rate-design-for-der/

Strbac, Goran et al. *Delivering future-proof energy infrastructure*. Report for National Infrastructure Commission. February 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/507256/Future-proof_energy_infrastructure_Imp_Cam_Feb_2016.pdf

Tierney, Susan F. *The Value of “DER” to “D”: The Role of Distributed Energy Resources in Supporting Local Electric Distribution System Reliability.* Analysis Group. March 30, 2016. http://www.analysisgroup.com/uploadedfiles/content/news_and_events/news/tierney_value_of_der_to_d_cpuc_thought_leaders_workshop_4-21-2016.pdf

Thought Leaders Speak Out: Key Trends Driving Change in the Electric Power Industry, Institute for Electric Innovation. December 2015. http://www.edisonfoundation.net/iei/Documents/IEI_KeyTrendsDrivingChange_FINAL.pdf

U.S. Department of Energy Presentations to FERC, April 21, 2016:

- U.S. Department of Energy. *Grid Modernization Initiative*. Presentation to FERC, April 21, 2016. http://www.ferc.gov/CalendarFiles/20160421110651-A-DOE.pdf

- Lawrence Berkeley National Laboratory. *Institutional Support*. Presentation to FERC, April 21, 2016. https://www.ferc.gov/industries/electric/indus-act/smart-grid/lawrence-berkeley.pdf
  Link to LBL reports in the series (including links to presentations and webinars): https://emp.lbl.gov/future-electric-utility-regulation-series
- SNL. *Security and Resilience.* Presentation to FERC. April 21, 2016. http://www.ferc.gov/CalendarFiles/20160421110927-4-Torres-Sandi-clean.pdf
- National Renewable Energy Laboratory. *Renewables Integration*. Presentation to FERC, April 21, 2016. https://www.ferc.gov/industries/electric/indus-act/smart-grid/national-renewable-energy.pdf
- Idaho National Laboratory. *Energy Storage*. Presentation to FERC, April 21, 2016.
- PNNL. *System Operations and Control*. Presentation to FERC, April 21, 2016. http://www.ferc.gov/CalendarFiles/20160421110823-2-Dagle-PNNL.pdf

U.S. DOE. *Grid Modernization Multi-Year Program Plan*. November 2015. http://energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf

Utility Dive. *2016 State of the Electric Utility Survey.* 2016. Available at: http://www.utilitydive.com/library/state-of-the-electric-utility-2016/

Vrins, Jan et al. "From Grid to Cloud: A network of networks – in search of an orchestrator." *Public Utilities Fortnightly*, October 2015. http://www.navigant.com/~/media/www/site/downloads/energy/2016/from-grid-to-cloud-reprint.pdf

Woolf, Tim et al. *Benefit-Cost Analysis for Distributed Energy Resources: A Framework for Accounting for All Relevant Costs and Benefits.* Prepared for the Advanced Energy Economy Institute. September 22, 2014. http://www.synapse-energy.com/sites/default/files/Final%20Report.pdf

Mowat Centre

ONTARIO'S VOICE ON PUBLIC POLICY

The Mowat Centre is an independent public policy think tank located at the School of Public Policy & Governance at the University of Toronto. The Mowat Centre is Ontario's non-partisan, evidence-based voice on public policy. It undertakes collaborative applied policy research, proposes innovative research-driven recommendations, and engages in public dialogue on Canada's most important national issues.

MOWATCENTRE.CA

@MOWATCENTRE

439 UNIVERSITY AVENUE
SUITE 2200, TORONTO, ON
M5G 1Y8 CANADA

School of Public Policy & Governance
UNIVERSITY OF TORONTO