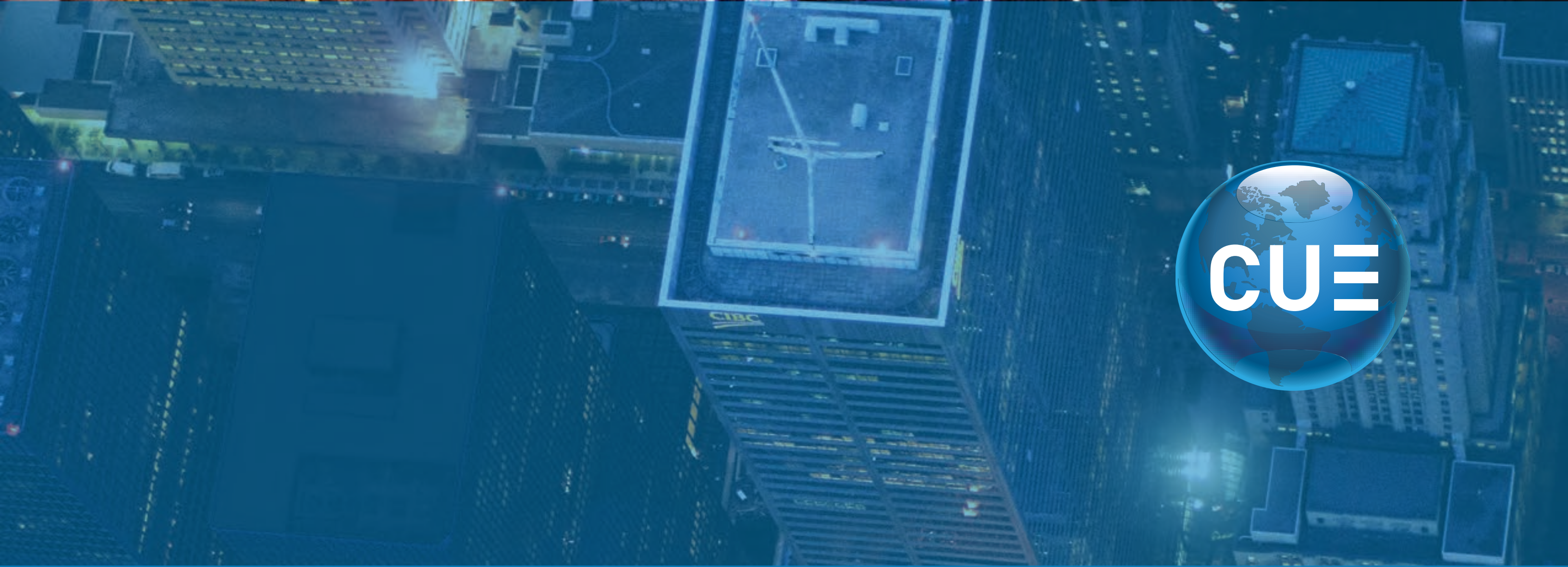

December 1, 2014

LDC ASSET RENEWAL SERIES

Part 1: New Technology

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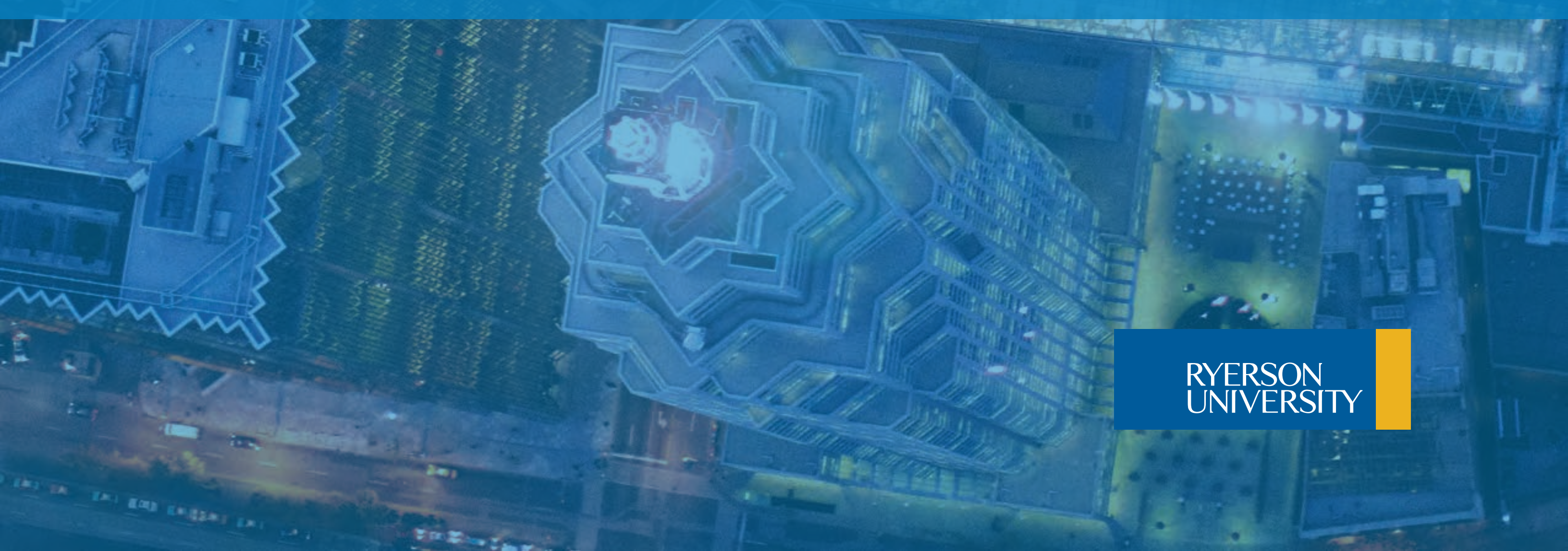

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1.0 Executive Summary

Recent advances in engineering have led to the development of new electricity distribution assets. These new technologies are changing the structure of our grid from a centralized, monopolistic, one-way system with large generators towards distributed generation (DG) and a two-way paradigm, supported by advanced communications infrastructure. Much of our existing distribution system requires refurbishment within the next decades; by incorporating these new technologies, Ontario's electricity system will transform from a centralized model to a mixed model with a smart, clean, localized, and reliable configuration for the 21st century. Ontario's local distribution companies (LDCs) will be at the forefront of this change.

Ontario's supply mix will increasingly incorporate renewable generation: solar photovoltaics (PV), wind, and biomass. These technologies will become cheaper and more efficient in the coming years, increasing their appeal to provide customers both clean energy and a profit opportunity. Advances in energy storage (ES) can support the intermittency and power quality issues inherent with weather-dependent generation. Batteries, flywheels, and thermal storage will encourage increased reliability and allow for price arbitrage. Finally, the electric vehicle (EV) will affect both demand and supply.

Changing demand patterns and technology will alter the relationship between customers and LDCs. Increased reliance on electric devices means that consumers require greater reliability. New structures in the future will draw net-zero energy by way of amended building codes, PV generation, conservation and demand management (CDM) programs, and ES solutions. The transition to the smart grid and the smart home will result in a more robust, reliable, automatic, yet more complex distribution network. It will consist of comprehensive control systems to increase efficiency and reduce interruptions.

LDCs need to invest in asset renewal, while concurrently building the smart grid. They do so with uncertainty about when net-zero homes and micro-grids will become popular. Even their customer base might change: some will be more reliant on LDCs, while others will need distributors solely for backup supply or might even choose to disconnect altogether. Understanding how new technology will change customer demand must inform the investments we are making today.

1.1 Glossary

AC – Alternating Current
AMI – Advanced Metering Infrastructure
ADMS – Advanced Distribution Management System
AMPCO – Association of Major Power Consumers of Ontario
CDM – Conservation and Demand Management
CIC – Customer interruption costs
DC – Direct current
DG – Distributed generation
Dispatchable Generation – electricity that can generated and released into the grid with limited lead-time
DM – Demand management
Energy arbitrage – Storing electricity when prices are low and reintroducing it into the grid when prices are higher
ES – Energy storage
EV – Electric vehicle
FIT – Feed-in-tariff
GIS – Geographic information system
Grid parity – The point at which generation technology can produce electricity at a cost that provides both a rate of return for the investor, and a price equal to that of the retail price for electricity.
HOV – High occupancy vehicle
IEA – International Energy Agency
IESO – Independent Electricity System Operator
LDCs – Local distribution companies
LTEP – Long-term Energy Plan
LRAM – Lost Revenue Adjustment Mechanism
MDM/R – (Smart) Meter Data Management and Repository
MW – Megawatt
N-1 reliability – Transmission system design principle: that any line can handle its regular load, plus the load from another failing line connected to the same destination.
Net Zero entity – A building that, on average, produces the same amount of electricity it consumes
OEB – Ontario Energy Board
Off-peak hours – periods of low electricity demand and price
OPG – Ontario Power Generation
Peak hours – periods of high electricity demand and price
PV - Photovoltaic
RESOP – Renewable Energy Standard Offer Program
RFP – Request for proposals
SCADA – Supervisory control and data acquisition
TS – Transformer station
TWh – Terawatt hour
V - Volt
V2H – Vehicle-to-home

2.0 New Technologies: Overview

2.1 Renewable Energy: Solar

There are various ways to generate electricity from solar energy, including concentrated power systems and solar heating. Currently, photovoltaic (PV) panels produce the majority of worldwide solar electricity. Global PV capacity has grown 40% a year, driven primarily by Germany, Japan, Spain, and the United States. The IEA roadmap predicts 11% of worldwide electricity production will come from solar energy by 2050, half of which will be PV-derived. Concentrated solar power – solar farms, best suited for dry and warm climates – will make up most of the other half (IEA, *Solar Photovoltaic* 9-10, 13-14).

PVs are becoming increasingly economical for consumers, as prices have decreased steadily over the last decades. For example, British IKEA retailers now sell solar panels; a typical customer will see a return on investment within seven years (Steiner). From 2009 to 2013, the average cost of new PVs in Ontario fell by over 40% (Ontario, *LTEP* 43). Within a decade, it is feasible that PV costs could reach grid parity in the province (Campbell 9-10). Currently, 60% of worldwide PV systems are residential-based, but their overall market share should decline to 40% by 2050 as large-scale commercial and utility PV projects become economically viable (IEA, *Solar Photovoltaic* 17).

In Ontario, PVs – most of which are embedded in LDC networks – produced 1TWh of production in 2013, less than 1% of that year's generation. The Ministry of Energy's 2013 *Long-Term Energy Plan* (LTEP) forecasts output to double by 2032. As a share of capacity, PVs should grow from 2% to 5% in the same period. It is expected that 1,900MW of PV capacity will be installed by the end of 2014, and that the province will procure an additional 140MW in 2015 (24, 33). Considering that PV output is greatest during those hot, sunny, summer days where demand is high, PVs will be an increasingly valuable investment for Ontarians.

2.2 Renewable Energy: Wind

In Ontario, wind turbines accounted for 3% of provincial electricity production in 2013; that share should triple to 9% by 2032. By that time, turbines will constitute 15% of installed capacity, up from 6% today. The province intends to procure 300MW in 2014 and 2015 (Ontario, *LTEP* 24, 33). The IEA has set a target for wind generation to provide 15% and 18% of global energy production by 2050 (IEA, *Technology Roadmap: Wind* 5).

In the past, increasing the capacity of wind turbines required taller towers and longer blades. Now, advances in blade design, control strategies, and materials are increasing energy yields. Installed wind power today generally has a capacity rating between 1.5MW and 2.5MW, while newer turbines can reach up to 7.5MW. Although turbines typically do not operate in arctic environments, commercial prototypes for cold-weather wind generation will emerge the next few years (IEA, *Technology Roadmap: Wind* 5, 12-13).

Like PVs, the cost of wind power is declining. Since 2007, the cost of onshore turbines has declined by 33%. Turbines have greater maintenance costs than PVs due to their mechanical parts, but maintenance costs for these generators have fallen nearly 50% in the last seven years (IEA, *Technology Roadmap: Wind* 14, 16).

Further, system operators are becoming more adept at forecasting wind speeds. Spain – a world leader in wind energy – has reduced forecast errors by one-third from 2008 to 2012 (IEA, *Technology Roadmap: Wind* 13). In Ontario, the Independent Electricity System Operator (IESO) now has a centralized forecasting service. Wind and solar market participants with capacities over 5MW report weather and telemetry data to the operator every 30 seconds (IESO, *Centralized* 2-3).

Despite falling costs, there are obstacles to widespread adoption of wind generation. There is considerable public opposition against wind farms in this province. The installation of a turbine requires municipal permits that neighbourly opposition might delay. Further, turbines are most effective in rural areas with open spaces (Ontario OMAFRA). Accordingly, turbines will likely prove to be attractive to only a small, rural market.

2.3 Renewable Energy: Bioenergy

Bioenergy uses organic material from forestry, agriculture, and landfills to generate electricity. By the end of 2016, 365MW of bioelectric generation will be online, with the *LTEP* committing Ontario to procure an additional 50MW in the coming years (33). These systems scale from a few megawatts on a local farm to Ontario Power Generation's (OPG) conversion of the Atikokan Generating Station to a 205MW biomass/wood pellet burner ("Atikokan Station"; Ontario, *LTEP* 33-34).

2.4 Energy Storage

Generators typically produce electricity the moment customers require and consume it. Historically, the only means to "stockpile" energy was with water reservoirs. Recent advances in technology now allow electrical energy to be stored in different forms. The emergence of these energy storage systems (ES) will provide numerous benefits to consumers:

- They will serve as backup supply during an outage;
- They will act as a way to exploit price differentials throughout the day (arbitrage): generators can store potential energy when market prices are low and release it back into the grid during times of peak demand;
- They can add predictability to Ontario's increasing stock of renewable yet intermittent electricity supply by providing energy to the grid during periods of low wind or sunshine;
- They can act as voltage controllers, improving power quality;
- They allow buildings to operate off-grid;
- They can provide seasonal energy storage;
- They allow deferral of investments and refurbishment of utility infrastructure; and,
- They assist in conservation and demand management (Rastler 2.1-2.15; Akhil et. al. 1-45; IEA, *Energy Stora*ge 9-10).

Storage converts electricity into another form of energy, only to turn it back into electricity when required. Storage technologies include:

- Flywheels
  Flywheels convert electrical into kinetic energy by applying torque to a flywheel. When torque and rotational energy decreases, electricity is released (Rastler 4.2-4.3; Akhil et. al. 89-95; IESO, *RFP* 3).

- Batteries
  Like the rechargeable batteries that power many consumer electronics, large-scale batteries convert electrical energy to chemical energy and vice versa. There are many different types of battery solutions, including lithium-ion, sodium-sulphur, nickel-cadmium, nickel-metal hydride, zinc-bromine, and electrochemical capacitors. Each battery varies in size, capacities, discharge durations, and cycle capabilities (Rastler 4.6-4.20; Akhil et. al. 41-88; IESO, *RFP* 3). The market for advanced batteries worldwide will grow from $182 million this year to $9.4 billion in 2023. ("Next-Generation Advanced Batteries"). This development and investment in batteries will lead to economies-of-scale and lower prices (Leistikow).
- Thermal storage
  Electrical energy can be stored as heat in different forms of matter (water, molten salt, gas, compressed air) and released when required (IEA, *Energy Storage* 20). In Ontario, abandoned mines present an opportunity to store both compressed air and gas.
- Hydrogen storage
  Through electrolysis, electricity is converted into hydrogen. This method provides two opportunities to produce electricity: through reconversion to electrical energy, or as fuel within existing gas turbines. Re-electrified hydrogen using fuel cells are up to 50% efficient. Efficiency can reach 60% when consumed in a gas power plant. This storage method is scalable: hydrogen can be stored in vessels from the size of standard gas tank to a large cavern. ("Hydrogen Energy Storage"; IEA, *Energy Storage* 21). Hydrogenics Corporation is exploring ways to store hydrogen within Ontario's natural gas pipelines (Hydrogenics).

Various technologies are at different stages of development. Compressed air is entering a second generation of prototyping. Flywheels remain in the demonstration phase. Battery technology ranges from theoretical to commercially viable and adopted energy solutions. (Akhil et. al. 39, 51, 56, 61, 65, 72, 81, 93).

In Ontario, utilities are experimenting with storage prototypes. For example, Toronto Hydro is exploring ice storage at the Toronto Zoo (Toronto Hydro). In late 2012, the IESO selected NRStor Inc. along with Temporal Power and OPG to provide 2MW of grid-balancing, regulation service (IESO, *RFP* 2). In the *LTEP*, the government has committed to 50MW of new ES by the end of 2014 (Ontario, *LTEP* 7). In July 2014, the IESO awarded five proponents a total of $14 million over three years to provide about 34MW of battery, flywheel, thermal, and hydrogen storage (IESO, *RFP* 3). The OPA will procure the remaining 15MW and explore the potential of storage to help northern and remote First Nation communities (IESO & OPA 2).

2.5 Electric Vehicle

The electric vehicle (EV) uses electricity as opposed to gasoline. To encourage adoption of this mode of environmentally friendly transportation, the Ontario Ministry of Transportation offers up to $8,500 in rebates for the purchase of EVs or hybrids, up to $1,000 in support for the installation of an in-home charging station, and access to HOV lanes. The government aims for 20% of the public service passenger vehicle fleet to be electric by 2020. GO Transit is installing charging stations at several of its parking facilities, as well as moving ahead with electrification of its rail network. The government's goal is to have 5% of all cars in Ontario powered by a type of electric engine by 2020 (Scratch 3, 12; Canizares 3).

EVs offer potential for energy storage. PowerStream and Nissan Canada are prototyping V2H systems that will allow a car to provide load-balancing electricity to the grid and potentially generate revenue for the owner during the 90% of the day a typical EV remains dormant. An EV could potentially keep a home powered for 24 hours during an interruption (Mulrooney).

EV adoption is not widespread. In 2010, there were less than 100 electric vehicles in Canada. In 2013, that number rose to 3,000, with just under half of those in Ontario. Electric car sales represent 0.1% of total vehicle sales in the country (Scratch 3). Challenges facing the EV market include:

- Consumer views on EVs are mixed;
- Rising electricity prices may produce assumptions that EVs are more expensive to fuel;
- Vehicles are coming to market later than expected;
- Range, reliability, maintenance, operating costs, and charging concerns;
- Consumers are reluctant to incur higher upfront costs for lower lifecycle costs;
- Competing transportation and infrastructure priorities;
- Adoption will be hindered by the lack of charging infrastructure; (Scratch 8, 13; Canizares 137, 142, 144; Natural Resources Canada 12).

Further, battery efficiency and maximum distance will impede adoption in Ontario. The size of the province and low population densities will require advances in battery capacity for EVs to become a viable alternative in rural and northern areas. Cold temperatures further reduce battery efficiency. Accordingly, EV market penetration in Northern Ontario is effectively null. Towards the end of 2013, there were 7.8 million vehicles on Ontario's roads (Scratch 3). It is difficult to predict the uptake of EVs, but if Ontario reaches its target of 5% market share by 2020. We can expect approximately 360,000 EVs will be on the road that year (Beare 12-13, 42).

EVs may present a challenge to LDCs. As 240V level two chargers increasingly replace 120V (standard home plug) chargers, and with 300-600V level three chargers not far off, a concentration or cluster of homeowners or condo residents charging concurrently could put a strain on transformers, lines and other equipment. Ultimately, the effect on the distribution system will depend on the location of chargers, the speed at which they charge, and consumer behaviour.

Adoption of EVs will be likely concentrated in urban areas in Southern Ontario, where drives are often short. In Ontario, half of all drivers live in the Greater Toronto Area (Scratch 3). At the centre the GTA, Toronto Hydro – an LDC that faces significant renewal needs and increasing demand – reports:

- The load that charging EV uses is like adding another house to a transformer;
- Their distribution system can currently handle 10% market penetration of level 1 and 2 chargers, or less than 4% using level 3 chargers;
- Already constrained stations and feeders may face additional loads, particularly before the completion of the Copeland TS for the downtown core; and,
- The distribution system will be ready to facilitate a maximum of 406,119 EVs by 2022 (*Ontario's Electric Vehicle Program* 14, 16, 36; *Toronto Hydro's Role in EV Infrastructure*

Development 5).

Accordingly, Toronto Hydro alone could absorb most if not all of the electric cars in Ontario if the province reaches its 5% target.

2.6 Smart Grid[1]

In 2009, the *Green Energy and Economy Act, 2009* directed the OEB to implement a smart grid. The Ontario Smart Grid Forum defines a smart grid as:

> "…a modern electric system. It uses sensors, monitoring, communications, automation, and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system. It increases consumer choice by allowing consumers to better control their electricity use in response to prices or other parameters. A smart grid includes diverse and distributed energy resources and accommodates electric vehicle charging. In short, it brings all elements of the electricity system – production, delivery, and consumption – closer together to improve overall system operation for the benefit of consumers and the environment" (Ontario Smart Grid Forum, *Enabling Tomorrow's Electricity System* 1).

The government defines it as:

> "…the advanced information exchange systems and equipment that when utilized together improve the flexibility, security, reliability, efficiency and safety of the integrated power system and distribution systems, particularly for the purposes of,
>
> > (a) enabling the increased use of renewable energy sources and technology, including generation facilities connected to the distribution system;
> > (b) expanding opportunities to provide demand response, price information and load control to electricity customers;
> > (c) accommodating the use of emerging, innovative and energy-saving technologies and system control applications; or
> > (d) supporting other objectives that may be prescribed by regulation" (OEB, *Supplemental Report on Smart Grid* 2).

In 2010 alone, the United States and China invested $7 billion each in smart grid infrastructure and technology (MaRS 5). These investments have an impact on utilities and the economy. For instance, EPB is a utility based in Chattanooga, Tennessee that has invested significantly in new distribution technology. When a storm hit that community on July 5, 2012, the smart grid halved both the number

[1] For a thorough review of the various smart grid programs among Ontario's LDCs, see MaRS. Market Insights. *Ontario Utilities and the Smart Grid: Is There Room for Innovation?* Toronto: MaRS, 2012. Web. 15 Mar. 2014. <http://www.marsdd.com/app/uploads/2012/08/MaRSReport-Ontario-Utilities-and-the-Smart-Grid_2012-1.pdf>. 7-20.

of customers that should have lost power and restoration time for those who did. In 2013, their modern infrastructure prevented 58 million customer-interruption-minutes and $1.4 million in repairs. After a tree brought down three substations, most of the 11,000 customers that should have been affected for hours noticed no outage, while those interrupted regained power in six minutes. Smart technology also saved the utility 260,000 miles of travel, 11,500 gallons of fuel, and was the primary reason behind an upgrade of their bond rating (EPB 15-17, 20).

2.6.1 First Steps: Smart Meters and TOU

In July 2004, the Ministry of Energy tasked the OEB to provide a strategy to implement smart meters for every consumer in Ontario by the end of 2010, with an interim target of 800,000 installations by the end of 2007 (Ontario, *Minister's Directive to the Ontario Energy Board* 2-4). LDC responsibilities included selecting a smart meter system, organizing themselves into procurement groups, installations, service, and reading. The implementation budget for smart meters was $1 billion with ongoing increased operating costs of $50 million per year (OEB, *Monitoring Report: Smart Meter Investment* 1-2; OEB, *Smart Meter Implementation Plan* vi).

The OEB mandated:

- The minimum functionality requirements of a smart meter, while cost recovery on meters that exceeded minimum functionality was privy to Board review;
- From 2006 to 2012, a charge was temporarily added to retail electricity rates to recoup labour and capital costs for the project. LDCs continued this temporary rate adjustment after 2012 until the balance of their costs were paid; and,
- Some LDCs sought cost recovery for the stranded costs associated with traditional meter inventories (OEB, *Guideline: Smart Meter Funding* 5-8, 10-13.)

LDCs generally met the 2010 installation target. Since then, the implementation of time-of-use (TOU) pricing – enabled by smart meters – allows consumers to save on their bills by shifting consumption to off-peak hours. LDCs send smart meter data to the IESO Meter Data Management and Repository (MDM/R), a centralized storage collection facility for validating and producing TOU billing for LDCs (Ontario Smart Grid Forum*, Modernizing Ontario's Electricity System* 14).

In her 2014 Report, the Auditor General of Ontario reviewed the smart meter implementation plan. She argued that "When costs of the Ministry, the OEB and the IESO are included, we noted that total costs relating to implementation of Smart Metering had reached almost $2 billion at the time of our audit," which would be double the initial budget. Further, procurement and MDM/R integration "made it difficult to ensure cost effective implementation of Smart Metering." Finally, the Auditor argues that conservation targets arising from smart metering have not been met, while time-of-use has had little influence on peak demand levels (366-368).

2.6.2 Next steps: Information Technology (IT) and Grid Automation

Smart grids need considerable digital infrastructure to analyze, interpret, and act on system telemetry. Previously the domain of the transmission system, sophisticated IT programs are entering the distribution space (Telvent 1). These new tools will require a significant capital investment:

Navigant Research predicts that utility expenditures on IT will double in the next decade (“Utility Spending on Smart Grid IT Systems”).

Existing systems, such as meter, billing, distribution, outage, and supervisory control and data acquisition (SCADA) systems will begin to converge into one database – Advanced Distribution Management System, ADMS – which will give operators an “unsiloed”, holistic view of the status of their systems. Dispatchers will be able to see system status in real time, including voltage, current, and physical asset conditions. These systems can move quickly to isolate interruptions and minimize the number of customers affected by a failure and can automate the rerouting of power during a fault, creating a “self-healing” grid (*Advanced Distribution Management System*; Telvent 3-5, 9).

Ontario’s LDCs are continuing to install IT infrastructure. Fifteen Ontario LDCs have adopted Guelph Hydro’s Geographic Information System (GIS) software, helping them map and locate infrastructure and track service crews (MaRS 9). As part of its pilot project in Owen Sound, Hydro One has established new infrastructure and implemented new software to create an “Advanced Distribution System” to manage DG at the LDC level (MaRS 11). Burlington Hydro’s Switching Automation System has improved system reliability by 40% and reduced outage durations by 20% (Burlington Hydro). Veridian Connections has recently replaced its SCADA system, which it will integrate into its GIS software and eventual ADMS platform (19-20).

2.6.3 Next steps: Distribution Technology

LDCs have considerable assets to move electricity from generators to customers. Some LDCs are fitting substations and transformers with sensors and grid automation technology. Data from smart meters on transformers are allowing LDCs to observe loads and predict failures. Veridian has developed a smart meter for its pole-top and pad-mounted transformers, which can send data on the health of the asset back to the control room. In addition, by comparing smart meter data from transformers to those loads attached to it, the LDC can locate cases of electricity theft (20).

In addition to supplementing old equipment with IT, advances in engineering are beginning to produce a new generation of distribution assets that will increase the flexibility, reliability, and efficiency of the grid. Consider the transformer: much of Ontario’s stock are traditional "dumb" versions - a step-down box serving approximately eight homes with no feedback capabilities. Advances in semiconductor technology are leading to economically feasible solid-state transformers. These transformers offer many advantages over traditional technologies, including:

- Smaller;
- Can be bidirectional;
- Can input or output both AC and DC power;
- Can alter frequency in addition to voltage and act as a harmonic filter, improving power quality; and,
- Communicate with the LDC much like smart meters, providing signals on system loads or faults and helping to provide efficient electricity routing (Kawa).

2.6.4 Next steps: Micro-grid

Over the next few decades, LDCs will need to accommodate the micro-grid: some parts of the distribution network will move from centralized control to smaller, local grids that work both in tandem and independently of the main network. Features of the micro-grid include:

- Distributed generation (DG): many small, local electrical generation or storage facilities feeding into the distribution system directly;
- Neighbours sharing DG electricity in times of local surplus;
- The ability to integrate, provide, and draw energy from the main grid, when required;
- Disconnection and isolation during interruption events, minimizing the impact of any outages; and,
- The ability to draw power from DG sources during interruptions (World Energy Council 3; Ontario Smart Grid Forum, *Enabling Tomorrow's Electricity System* 23).

2.6.5 Next steps: Conservation, Demand Response and the Smart Home

In the *LTEP*, the Ministry has made clear that it intends to put "conservation first" by "...offset[ting] almost all of the growth in electricity demand to 2032 by using programs and improved codes and standards". Conservation and demand management (CDM) will meet 10% of peak demand by 2025. The *LTEP* also calls for:

- A coordinated approach to conservation amongst LDCs;
- New financing for consumers and incentives for efficient appliances;
- Consideration of social benchmarking – allowing consumers to compare energy consumption to neighbours – to decrease demand; and,
- A new 2015-2021 CDM framework from that should offer more tools and support for LDCs (26-27).

LDCs also have a considerable role to play "behind-the-meter" in shaping electricity demand in homes and businesses. Since 2011, LDCs have the responsibility to meet conservation targets. LDCs have created their own conservation programs, as well promoting province-wide OPA programs, such as rebates for energy efficient heating and air conditioning systems.

CDM should play a significant part in Ontario's electricity future. In the coming years, the Green Button Initiative will provide secure and up-to-date information on a consumer's energy usage, allowing them to adjust consumption. The emergence of the smart home will further help consumers control their demand. A smart home uses a local area network to adjust electricity use according to market price. Increasingly efficient appliances with smart home technology are entering the marketplace; by 2020, the worldwide market for smart appliances will reach $35 billion annually ("Smart Appliance Market to Reach Nearly $35 Billion").

2.6.6 Next steps: Timing

The 2011 *Second Report of the Smart Grid Forum* anticipated smart home technology "embedded in most household appliances and devices" by 2015 (11). It appears that widespread adoption should take a few more years. Nevertheless, by 2030, the Forum anticipates the widespread implementation of the smart grid, including smart homes, appliances, EVs and DG[2].

3.0 New Technology: Implementation, Timelines and Practices

Ontario's distribution networks are facing a period of technologically driven renewal. These technologies offer a myriad of new benefits and costs to LDCs. How (or) will LDCs build the 21st century distribution network, and what will their market look like in the next decades?

3.1 Sharing Knowledge: LDCs as Team Players

There are numerous academic and public sector groups investigating the implications of the smart grid. In Ontario, two are particularly noteworthy. First, the IESO-facilitated Ontario Smart Grid Forum has been meeting since 2008 with the objective to "[a]dvance and leverage the development of the Ontario Smart Grid by focusing on the high-level policy and regulatory aspects of emerging, smart-grid-related issues over a long-term horizon" (*Terms of Reference* 2). It has produced several reports on upcoming smart grid challenges and changes. Concerning technology, it seeks to:

- Maintain a collective understanding of relevant developments in other jurisdictions;
- Promote and support economic development by Ontario industry organizations and corporations and the export of smart grid expertise and knowledge;
- Focus on Ontario, but recognize developments elsewhere and any necessary or opportune linkages;
- Not be an advocacy group for any one particular technology solution or vendor product;
- Foster healthy competition and innovation in the provision of smart grid technologies; and,
- Recognize and respect the interests of organizations participating in the Forum (*Terms of Reference* 2-3).

Second, the OEB commissioned the Smart Grid Advisory Committee in 2013. Membership includes LDCs, Hydro One Networks, the IESO, AMPCO, the Association of Ontario Municipalities, and various private firms. The Committee will provide advice and recommendations to the OEB on:

- Standard data access mechanisms;
- The deployment of smart grid technologies;
- Cyber-security; and,
- Interoperability (*Terms of Reference for the Smart Grid Advisory Committee* 1-5).

A continued focus of these groups is road mapping – determining a critical path with measurable timelines and objectives. There is also emphasis on inter-agency cooperation in both these groups. These procedures reflect international best practice (World Energy Council 19).

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[2] (Modernizing Ontario's Electricity System 37). The Smart Grid Forum provides a comprehensive and well-presented *Ontario Smart Home Roadmap*.

3.2 Renewable and Distributed Generation: LDCs as Networks

Historically, large, centralized generators produced electricity delivered via the transmission system to large consumers directly or via LDCs for residential and commercial customers. Such a system required a robust, large, and reliable transmission system subject to N-1 reliability criterion and processes to ensure that connectivity to large generators was continuous. LDCs remained as a conduit to supply load, and were not subject to this type of reliability standard.

Today, this stands to change as numerous, small generators connect directly into the distribution network. Ontario's experience with FIT and microFIT demonstrates substantial interest in small-scale generation. This change in paradigm is championing use of smart grids to ensure renewable LDC-embedded DG connects to highly reliable distribution networks.

LDCs may evolve from commodity deliverers to quasi-network operators, running their distribution centres as the IESO manages the Ontario grid. LDCs may become a network within a network. Distributors would have to monitor and balance demand and supply to manage network loading, coordinate maintenance outages of generators with their own distribution assets, prepare for and respond to unforeseen failures, and perhaps contract supply in both near and long term.

Together, storage and distributed generation will form the backbone of distributed generation within smart networks and micro-grids. Accordingly, the challenges faced by LDCs include:

- LDCs may require greater human capital, expertise, and operations, maintenance, and administration costs as DG becomes more integrated into systems;
- Although DG providers will have responsibility to mitigate voltage variance and power quality issues, a policy framework is not yet in place to distribute responsibilities. LDCs will nevertheless have to prepare for greater fluctuation in supply quantity and quality in the event of problems at the DG site;
- If the uptake in renewable energy occurs before widespread adoption of new substation and transmission technologies, additional stopgap infrastructure may be required, diverting capital from the implementation of smart grid technology;
- The lack of system capacity can slow adoption of new technology;
- Existing assets may become "stranded" when anticipated loads are displaced by DG and the associated future revenues to finance those assets are lost;
- With more players in the generation field, greater collaboration between LDCs and other regulated entities – particularly the IESO and Hydro One – will be required; and,
- If the distribution system goes the way of a "local network," cooperation between Hydro One and the IESO will be critical to maintaining both local and provincial-wide system reliability.

The New York State Department of Public Services is reviewing the future of its distribution sector. With respect to distributed generation, their staff report expresses the opinion that:

> "incumbent distribution utilities are best situated to [allow for the deployment of distributed generation]. As the entities that planned, designed, built, and have operated existing distribution systems, they are uniquely positioned. Just as importantly, they

> know how existing distribution systems are operated under real world conditions, and engage in frequent contact with the ISO related to system reliability issues. They also know the specific needs of many customers served by such systems…"
>
> "… The incumbent utilities already possess the particular and unique resources needed to transform the grid and realize the [distributed generation] vision. They can begin investigating and planning immediately, and can most efficiently design and construct upgrades to existing distribution systems. In many instances, the upgrades needed to facilitate two-way power flows, automated controls, instantaneous communications and dynamic management of energy sources and loads can and will be designed and engineered to work with existing facilities. The incumbent utilities are best positioned to carry out this work. Their existing resources and capabilities, including an experienced and specialized workforce, will be critical to an informed and efficient rebuilding of the electric grid."

They nevertheless caution about the challenges ahead for distributors:

> "Coordinating and actively managing a wide array of [distributed generation] on a real-time basis, with implications not only for system economy but also for reliability, will require a degree of utility engagement greater than what would be needed at the bulk system level. Although competitive processes are more likely to stimulate innovation in [distributed generation] products for consumers, there may be products that are so closely tied to critical reliability interests that direct utility engagement is needed" (*Reforming the Energy Vision* 25-26).

3.3 New Technology Procurement: LDCs as Buyers

LDCs are accustomed to distributing electricity supplied only from the transmission system. As more DG and renewables come online, distributors will obtain power from a greater range of suppliers through different connection and procurement mechanisms. Innovation is allowing for new, market entrants that will lead to greater interaction between LDCs and the private sector. Further, LDCs may enter the DG market to find cost savings and revenue streams. For instance, PVs on poles reduce line losses, generate electricity, and provide system status feedback (Halton Hills Hydro 3-4).

RESOP, FIT, and microFIT incubated renewable energy in Ontario, while smart meter infrastructure was the first, large-scale procurement process for LDCs building the smart grid. As technology matures, there will be more options available to purchase, finance, and install new generation and the remainder of the smart grid.

Ontario is considering replacing the microFIT program with net metering, which uses a specialized meter to calculate the net electricity consumption from the grid (*LTEP* 6, *Conservation First* 8). For renewable projects over 500kW, the Large Renewable Procurement program will likely replace FIT. In a preliminary set of recommendations, the OPA proposed that applicants would be subject to a tender/request-for-proposal process integrated into regional planning. The OPA intends to follow best practices, including community and municipal engagement, establishing the ability to connect to the grid early in the process, the presence of a sound business case, and using multiple evaluation criteria – not just cost – for each application (OPA 18-20). As LDCs continue to purchase new technology, they can look to the OPA's best practices in procurement for guidance. They include:

- A balance between specificity and flexibility in proposals;
- Maintaining good communication with bidders from one source;
- Third party expert advice;
- A transparent and fair process, independent from politics;
- Attempts to make tenders competitive with many bidders;
- Using price as a deciding factor, while also considering a bidder's history and abilities; and,
- A clear assignment of risks and responsibilities (12).

Other considerations include:

- In reviewing Hydro One's smart meter procurement processes, the 2014 Auditor General's Report recommends that procurement should also consider "retaining adequate documentation to justify vendor selection and evaluation and acquiring enough knowledge about a project's business requirements before issuing a Request for Proposal, to minimize the risks of significant contract-cost increases" (392-393).
- The rate of change in technology has increased exponentially in the last decade. LDCs face a changing landscape much like telecommunications companies have over the last 20 years: for decades, landlines were sufficient. Yet, since 2000, we have moved rapidly from touch-tone telephones to the iPhone, which is essentially a computer in our pockets. This is a precautionary tale for LDCs; new technology can effect rapid change, so capital investment must be flexible and forward-looking to avoid obsolescence and stranded assets; and,
- Appropriate timing for the establishment and timely adoption of standards will ensure that LDCs can leverage economies-of-scale and participate in a North American marketplace. Procurement should come after the adoption of international standards, when possible.

3.4 New Technology: LDCs as Innovators

LDCs also play a role in developing new technology in the supply, delivery, monitoring, control, metering, and use of electricity. LDCs can also be innovative in their business practices to find efficiencies and increase value. The extent to which the government and regulator will allow, expect, or encourage LDCs to take risks and innovate is an important consideration for their future business. Some LDCs have demonstrated a willingness and ability to prototype new infrastructure and processes. They invest in new technology and programs for several reasons:

- The government mandate for continued investments in the smart grid;
- Leveraging the expertise of the private sector, colleges, and universities in pilot programs;
- LDCs are required to reach conservation targets as conditions of licence;
- They can recover prudent investments in smart grid development and CDM; and,
- The OEB rate regime encourages LDCs to find savings though continuous improvement.

Many of these investments are subject to or even driven largely by government mandates or regulatory requirements. For example, the 2011-2014 CDM Framework encouraged innovative ways to promote conservation. This top-down program suffered from several deficiencies. The Ministry of Energy's *Renewed Vision for Energy Conservation in Ontario* acknowledged some problems, including:

- A failure to recognize the varying capacities and needs of different LDCs;
- The limited influence of LDCs on program design and operation;
- No LDC control or input on OPA CDM programming;
- A slow OEB approvals process for LDC CDM initiatives; and,
- Poor response to changing market or customer conditions, such as already reduced demand from a slowing economy (8).

Issues addressed by Electricity Distributors Association include:

- A lack of emphasis on private-sector involvement and market-driven innovation;
- A multitude of participants – the Ministry, OEB, OPA, LDCs, and the Environmental Commissioner –made for a cumbersome policy process;
- Duplication of applications by requiring approval from both the OPA and the OEB for CDM programs;
- That LRAM accounts for local programming should be reimbursed through rate riders;
- Focus should be on customer needs, not system-wide requirements; and,
- The end-date for programming of December 31, 2014 provides no incentive to establish CDM expertise at LDCs (1-3, 17).

The Canadian Electricity Association also notes sector-wide barriers to innovation, like:

- The internal organization of electricity firms;
- Uncertainty of the role of utilities as innovators;
- Excessive regulatory focus on low electricity rates; and,
- The high financing costs of innovation (*Innovating for a Sustainable Future* 9).

In a series of interviews with LDCs, Barrows and others found that:

- The regulatory regimes of the past encourage "extreme risk aversion;"
- LDCs need to focus on forming partnerships to aid in the innovation process; and,
- There is a conflict between investing in innovation, while providing for both rates-of-returns and low rates for their customers (67-70).

In response, the government has proposed that the new 2015-2021 framework include:

- Providing LDCs greater power over programming;
- More efficient oversight procedures;
- Stable, long-run, and predictable funding for CDM programs;
- Greater emphasis on customer engagement and education;
- A recognition of differences between LDCs, both in terms of location and client base; and,

- Cost-effective programs that provide a “fair allocation” of costs and benefits (*Conservation First* 13).

For its part, the OEB has stated “with respect to innovation the Board intends to explore further opportunities to embed the facilitation and recognition of technological innovation into the performance and rate-setting framework for electricity distributors.” The Chair of the Board believes the OEB must “figure out how to encourage that innovation in a monopoly environment... and not discourage it with unnecessary regulation” (Leclair 9).

Investments in new technologies compete with the traditional capital and O&M investments that LDCs need to maintain and expand their systems. As such, LDCs with older infrastructure may have higher proportions of O&M costs and less funding available for forward-looking ventures such as new technologies.

3.5 The Net-Zero Customer: LDCs as Backup

Two decades of CEA research affirms that customers are “especially sensitive to the cost of electricity” (*Smart Grid: A Pragmatic Approach* 15). Customers are already seeking ways to become more energy efficient. A study by Scotia Economics found that household electricity costs as a proportion of family spending has been declining due to appliances that use less electricity, increasing energy efficient homes, and renovations that include energy retrofitting. By 2011:

- 87% used energy-efficient lights, up from 84% in 2007;
- 45% used a programmable thermostat, up from 35% in 2007;
- 60% lowered the overnight temperature in the winter;
- 58% turned off computer monitors when not in use;
- 14% air dried dishes in the dishwasher; and,
- 37% made at least one energy-efficient home improvement from 2008 and 2011 (Warren 1-2).

A common target for net-zero energy consumption standards for new buildings is 2030 (Net-Zero Energy Home Coalition 7, 10, 29). With consumers becoming more energy efficient, new DG, PVs, and the emergence of a smart and net-zero home, the relationship between LDCs and their customers will likely change. The LDC may ultimately become a “customer of the consumer.” Adoption of new technology will force LDCs to anticipate potential reductions in their consumer base. We are likely heading towards a polarization of the customer base: those who require electricity more than ever versus those who use LDCs for backup power.

Consumers that remain fully connected to the grid will incur lower commodity costs, but likely face higher distribution costs. Although they may only draw from the grid on occasion, the cost of the infrastructure to implement the smart grid and maintain the distribution network – particularly bidirectional flow and net metering for those who act as DGs – will likely become a greater part of a consumer’s bill. Thus, bill reductions may not be proportional to lowered consumption in the face of higher tolling charges. Education in this case may be required to mitigate likely negative reactions.

3.6 The Death Spiral: LDCs as Redundant

Long-term planning within a rapidly changing technological landscape is a significant challenge. As fewer consumers bear the cost of an LDC's infrastructure, many will seek their own energy solutions. Widespread disconnection is possible, perhaps sooner than previously thought:

> "Due to the variable nature of [renewables], there is a perception that customers will always need to remain on the grid. While we would expect customers to remain on the grid until a fully viable and economic distributed non-variable resource is available, one can imagine a day when battery storage technology or micro turbines could allow customers to be electric grid independent. To put this into perspective, who would have believed 10 years ago that traditional wire line telephone customers could economically 'cut the cord'" (Kind 5).

This process may iterate to the point where the sector enters "the death spiral," where the shrinking customer base eventually cannot sustain an LDC's asset portfolio. The turning point will likely be when the combination of PVs and storage reaches retail grid parity, where the cost of producing and storing electricity at home or at the office meets or is less than the prevailing regulated market price:

> "The so-called utility death spiral is proving not just a hypothetical threat, but a real, near, and present one. The coming grid parity of solar-plus-battery systems in the foreseeable future, among other factors, signals the eventual demise of traditional utility business models" (Rocky Mountain et. al. 39).

PVs in Hawaii have already reached grid parity and soon so will Los Angeles. Owing to higher electricity prices in the Northeast, Westchester, NY should reach parity within the decade (Rocky Mountain et. al. 28). Battery technology – required to ensure a continuous supply of electricity – should reach parity by the late 2030s in LA and Hawaii, and 2050 in the Northeast. (Rocky Mountain et. al. 30).

A recent study by PricewaterhouseCoopers of utility professionals worldwide found that – owing to the emergence of DG, PV, and ES – 53% "anticipate business model transformation" while 41% see a complete transformation to the power utility business model. Less than 10% of North American professionals see the traditional, centralized industry model to "play the lead role in meeting future demand growth." Accordingly, half of those surveyed felt that the prospect of DG increasing the cost of electricity distribution to be "high" or "very high." LDCs must think hard how to position themselves to address these possibilities (1, 5, 8, 9, 17).

An evolution of the business model could prevent the death spiral. Utility managers remain optimistic: 82% of PricewaterhouseCoopers' participants saw the evolving electricity marketplace as an opportunity rather than a threat (17). Indeed, telecom provides an example of sector transformation: the traditional landline monopoly of Bell Canada has evolved into a lucrative internet, media, and telecommunications conglomerate. In the United States, components of the former AT&T "had the vision to get in front of the trend to wireless and lead the development of non-regulated infrastructure networks and consumer marketing skills. As a result, they now hold large domestic market shares. In fact, they have now further leveraged technology innovation to create new products that expand their customer offerings" (Kind 6).

Peter Kind and the Edison Electric Institute provide several strategies to address the emergence of DG into the main stream:

- Assess appropriateness of depreciation recovery lives based on the economic useful life of the investment, factoring the potential for disruptive loss of customers;
- Consider a stranded cost charge in all states to be paid by [DG] and fully departing customers to recognize the portion of investment deemed stranded as customers depart;
- Consider a customer advance in aid of construction in all states to recover upfront the cost of adding new customers and, thus, mitigate future stranded cost risk;
- Apply more stringent capital expenditure evaluation tools to factor-in potential investment that may be subject to stranded cost risk, including the potential to recover such investment through a customer hook-up charge or over a shorter depreciable life;
- Identify new business models and services that can be provided by electric utilities in all states to customers in order to recover lost margin while providing a valuable customer service—this was a key factor in the survival of the incumbent telephone players post deregulation; and,
- Factor the threat of disruptive forces in the requested cost of capital being sought (18).

3.7 Customer Impact Costs: LDCs as Essential Partners

The 40-year-old homeowner in 2030 will have been born in 1990 and will likely be very comfortable with digital technology. As time progresses, consumers are becoming more:

- Expecting of their LDCs to be socially/environmentally conscious;
- Somewhat responsive to peak shifting via TOU and CDM;
- Willing to pay some premium for green energy;
- Sensitive to increasing rates, but consider the motivations behind rate increases;
- More engaged with their LDCs, but in more passive ways – social media, e-mails, etc.;
- Increasingly sensitive to interruptions of any length; and,
- Reliant on technology for every aspect of their life (IBM 6, 8; Accenture 23-29; Abdullah 3).

Although the academic literature on customer interruption costs (CIC) is scant[3], we assume that CIC is increasing considerably. As home offices, the Internet, and EVs continue to grow in adoption, the loss of electricity to the home of the future will be disabling: drained EVs will leave customers stranded; PVs that cannot produce energy will lead to lost revenues; home businesses and e-commerce will lack Internet connection; and cell phones will not be able to charge. Mitigating these ever-rising costs will require more prominence in rate filings and regulatory considerations. LDCs and

[3] The only Canadian studies on interruption costs that we could find are from the University of Saskatchewan (1982, 1988), cited in Wacker and Billinton, 1989. Michael J. Sullivan has conducted work on this topic in the United States in 1995, 2004 and 2010. See bibliography entries for Sullivan. We explore CIC throughout this series, notably in our paper on reliability.

the OEB must weigh increased investment in capital – and thus increased rates – against a robust measurement of the true cost of interruptions.

With tools like the Green Button Initiative, consumers will have considerable data to help make informed decisions about their energy consumption. The very presence of this data encourages consumers to seek out information and become increasingly energy-savvy. LDCs must be ready to explain to their customers everything from the basics of TOU to the processes for installing PVs.

LDCs will be increasingly interacting with third parties, particularly those behind the meter. Telecommunications companies are selling home monitoring systems that can be adapted for the smart home, while both Google and Apple have acquired smart home technology companies. The provision of behind the meter services could provide LDCs a new revenue opportunity, while offering consumers the opportunity to bundle services – both electricity delivery and in-home services – and realize cost efficiencies. At the same time, entering this market presents new risk for LDCs. Since the OEB will not consider behind-the-meter services in rate submissions, this risk comes with a limited safety net. LDC intervention could also stifle innovation by crowding out the private sector.

When adopting new technology, there is the question of "who leads." In the current market climate, both LDCs and customers can work together to collaboratively integrate new technology. Here, there are incentives on both sides: new technology will help LDCs face aging infrastructure challenges, while customers are eager to lower their bills. Strong management of customer service and sound consultation processes can create such a collaborative environment. That said, the decision must be mutual: LDCs will have to engage in considerable behind-the-meter activities, at the very least providing advice and guidance to the customer. Customers in turn will require a willingness to engage with their LDCs as opposed to the private sector.

3.8 Data Privacy: LDCs as Gatekeepers

Smart grid programs such as Green Button and AMI transmits detailed information about consumption patterns. On one hand, this will allow LDCs to understand electricity requirements, line loads, and transformer stress. On the other, hackers and criminals could use the data to determine customer routines, such as typical working hours or the presence of a security system. The transfer of data to and from the customer is the point of greatest exposure in the system and the most likely source of privacy and security breaches, both with the wireless submission of smart meter data and the provision of consumption information for consumers.

The law requires LDCs to meet certain privacy criteria when installing smart technology: municipally owned LDCs are subject to the *Municipal Freedom of Information and Protection of Privacy Act*, *1990*, while Hydro One is subject the *Freedom of Information and Protection of Privacy Act*, *1990*. The Information and Privacy Commissioner of Ontario provided input during the construction of MDM/R and worked with Hydro One and Toronto Hydro to build security into AMI from the very beginning of their implementation, along with developing *Privacy by Design: Achieving the Gold Standard in Data Protection for the Smart Grid* (26).

In both cases, institutions followed the Commissioner's principles of "Privacy by Design," a set of best practices for privacy concerns across industries. They include:

- *Proactive* not Reactive; *Preventative* not Remedial: Anticipate and mitigate privacy breaches before they occur;
- Privacy as the *Default Setting*: Automatic protection of personal data within IT infrastructure;
- Privacy *Embedded* into Design: Privacy measures are to be treated as an essential part of infrastructure, not as “bonus” functionality;
- Full Functionality – *Positive-Sum*, not Zero-Sum: Privacy, security, and other instructional objectives can co-exist and complement one another;
- End-to-End Security – *Full Lifecycle Protection*: Personal data is protected throughout every stage of its use, from collection to destruction;
- *Visibility* and *Transparency* – Keep it *Open:* That privacy measures are communicated and open to independent verification; and,
- *Respect* for User Privacy – Keep it *User-Centric:* Always keeping the end user in mind, by offering strong privacy defaults and empowering users to understand and adjust their privacy profiles (*Operationalizing Privacy by Design* 12-53).

The current OEB Smart Grid Committee is examining privacy and security. In the meantime, it is unclear what kind of regulatory and audit requirements LDCs will face in the future.

3.9 Notes on Regulation, Policy and Planning

The OEB expects LDCs to incorporate new technology and smart grid infrastructure as part of their planning processes. The regulator no longer distinguishes between smart grid and other capital investments. It recognizes that smart grid investments are incremental; LDCs should mix traditional assets with smart grid technology according to an integrated approach that makes the best business case (*Renewed Regulatory Framework* 48). By encouraging strong capital planning, the OEB seeks to drive the movement towards a smart grid while maintaining the quality of supply and reasonable rates. This is in line with best practices (Litos 27; World Energy Council 19).

The *Renewed Regulatory Framework* makes clear that the OEB focuses on customer value and LDC efficiency. In return, the OEB continues to explore additional revenue decoupling options for LDCs to recoup losses from conservation and reduced energy distribution, which should allow these firms to maintain revenue streams in the face of declining energy intensity (Leclair 6-7). If net-zero is widely adopted, if there are moves towards grid disconnection, and if uptake of EVs is slow, the regulator and the government will need to consider finding additional efficiencies or new revenue streams for LDCs.

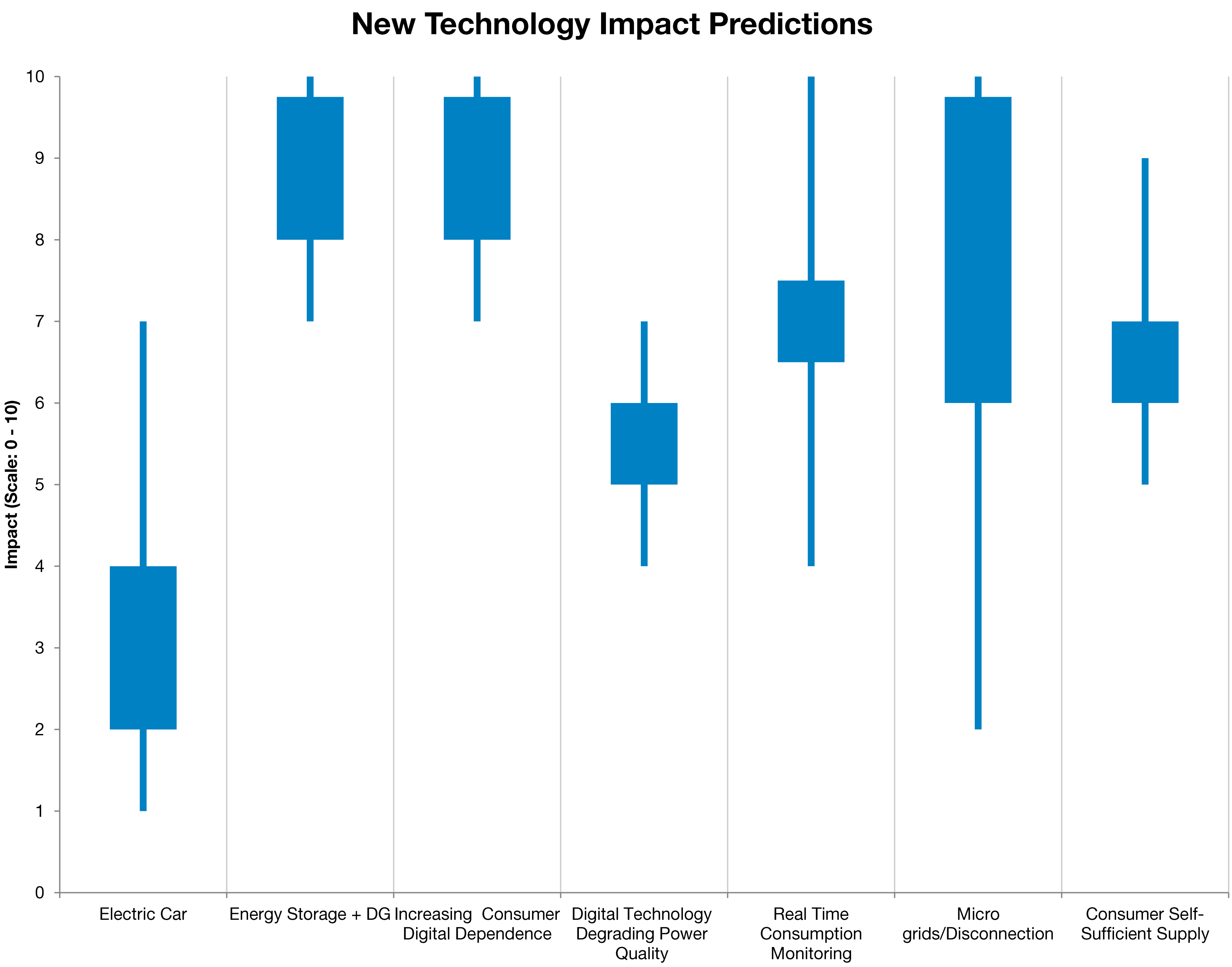
The Future of the Distribution Sector: New Technology

Visual:

An analysis of the potential importance of new technologies on the LDC sector. Projected importance is ranked from one to ten on the vertical axis. Each topic on the horizontal axis includes a “bar and line.” The line represents the possible range of the issue’s importance, while the bar represents our predicted importance.

Observations

- Customers will need increasingly reliable electricity to meet their digital lifestyle;
- Smart grid technology can provide this increased reliability along with improved grid resiliency by providing LDCs with real-time telemetry on their system along with automatic rerouting of power: the self-healing grid;
- This same technology will also enable customer participation and empowerment through increasing consumption monitoring and (CDM) conservation and demand management opportunities;
- The combination of cheap solar panels and storage technology may lead to many consumers becoming self-sufficient or net-zero customers;
- CDM programs, new appliances and changing building practices are making the home and office less electricity intensive. Under the current rate regime, bill reductions will not be proportional to lowered consumption as tolling charges reflect the cost of infrastructure, not delivery. Less than expected savings will encourage more consumers to consider self-sufficiency;
- Communities may elect to form micro-grids, islands within LDC networks; and,
- There is a real possibility of a “perfect storm:” rising prices and cheaper alternatives leading to a mass disconnection from the grid.
- The consumer information collected from the smart grid leads to concerns about privacy and security;
- Third-parties, such as natural gas, cable-telecom, and internet companies have or will likely enter the market, particularly in the provision of consumer technology and information services;
- Regulated LDCs will continue to facilitate technological innovation at current levels by working with industry and academics as test beds for new technology. Further participation in the innovation process will require new regulatory incentives;
- At current pace, the electric car will pose little threat to the integrity of distribution systems provided the uptake is gradual, reasonably well distributed, and LDC’s have knowledge of charging locations. Rapid adoption would require expensive upgrades of LDC assets.



New Technology Impact Predictions
Impact (Scale: 0 - 10)
10
9
8
7
6
5
4
3
2
1
0
Electric Car
Energy Storage + DG
Increasing Consumer Digital Dependence
Digital Technology Degrading Power Quality
Real Time Consumption Monitoring
Micro grids/Disconnection
Consumer Self-Sufficient Supply

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Energizing the Future

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