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Future Drivers and Trends Affecting Energy Development in Ontario

LESSONS LEARNED FROM THE U.S.

Emerging Energy Trends

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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.

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Executive Summary

Mowat Centre's Energy Hub (Mowat) contracted with the National Regulatory Research Institute (NRRI) for a study and report on emerging trends facing the energy sector in the United States, with a particular focus on distributed energy resources (DER) and their potential role in the electric utility of the future. This research focused on four different major portfolios and three future scenarios. The four portfolios are:

(i) The New Energy Consumer;
(ii) Meeting Energy Demand Behind the Meter;
(iii) Grid Modernization and the Utility of the Future; and,
(iv) The Future of Centralized Supply.

The three future scenarios, focusing on the year 2050, are:

(a) "Business As Usual" characterized by only the minimal necessary steps to begin the process of integrating distributed energy resources;
(b) "Focus on Short-Term Cost-Effectiveness" where the role of DER would be limited to fully cost-effective technologies; and,
(c) "Focus on Innovation" modeled as a fully realized, flexible, decentralized energy system, offering a range of options to customers.

As this research shows, a new literature on DER capabilities is just beginning to address all of the industry changes needed to capitalize on all of the values that DER can produce and deliver to customers and to the system as a whole. The essence of emerging research is that the combination of technically and economically available DER is more than capable of producing and delivering essential grid services cost-effectively, compared to the otherwise-required central station power and transmission alternatives, at least in particular grid locations in practically every utility service territory. Some early examples are showing great promise, but extensive work remains before a full transition to a DER-optimized grid might become a practical reality.

Looking at the future for energy consumers, this review shows a major bifurcation between active and passive customers. Active customers are already imposing new demands on utilities, and are demonstrating growing diversity of wants and needs, creating new challenges for utilities and regulators. One possibility is that the future will bring much greater unbundling of services and rates, with customers selecting choices from a broad menu of options, some provided by utilities and others by competitive suppliers. That future will be very different from the long-standing kind of one-size-fits-all utility offerings that basically differentiated only between residential, commercial, and industrial customers offering few if any choices beyond basic service at standard prices. This creates many new challenges for utilities and their regulators, as discussed in Section 2 of this report.

The opportunities for meeting customer demand behind the meter are expanding rapidly as new technologies are starting to change the utility industry: The lines between the utility and customer sides of the meter are already starting to blur. Technological progress in these areas is already substantial and rapid. Every week brings new announcements about progress towards higher efficiency and clean energy production and use, and each new trade show is full of examples of manufactured goods of all kinds that continue to do more and more with less and less material and energy inputs. In the not-too-distant future, zero-energy buildings could become the norm and smart appliances could be capable of interacting with the grid of the future in a dozen new ways, providing combinations of grid services and cost savings for their owners and operators. Solar photovoltaic (PV) systems, in particular, are already poised to disrupt the century-old electric utility industry model, as it is becoming fully cost-effective for larger number of customers to produce at least some of their own energy. In one plausible future, cost-effective DER might prove capable of overwhelming central station power supplies and transmission, so that much if not all new utility investment will take place on the distribution system, gradually supplanting the previous centralized infrastructure. Behind the meter challenges are reviewed in Section 3 of this report.

Utility grid modernization components generally include sensors and controls for the utility system, combined with sensing and monitoring capabilities and advanced communications systems, designed to help optimize operations and control of all major infrastructure components –generation, transmission, and distribution. The primary missions for grid modernization for utility companies include:

- increasing the efficiency of utility operations;
- increasing system reliability and resilience;
- reducing fossil fuel use and emissions; and,
- improving utility planning.

The major components utilities are beginning to incorporate into the electricity grid, in order to achieve those missions, include:

- transmission system enhancements;
- distribution system enhancements, including distributed automation and distribution management systems;
- advanced capabilities for integrating distributed resources;
- advanced meter infrastructure (AMI);
- system-wide communications and information integration; and,
- mechanisms for helping to shape consumer demands to produce system benefits.

Some of the most important challenges with grid modernization that are facing utilities and utility regulators include:

- managing the growing quantities of data that flows from AMI and other grid sensing, monitoring, and controlling technologies;
- determining which smart grid activities are best suited for implementation by monopoly utility companies and which by competitive product and service providers;
- addressing how integrated resource planning can evolve to incorporate novel DER applications;
- learning about all of the behavioral aspects of customer responses to rate designs, education, and energy use information; and,

- addressing how all of those challenges might best be addressed for small utilities, that will be hard-pressed to develop and implement in-house the required suites of new capabilities.

These issues are discussed in Section 4 of this report.

Looking to the future, there are many uncertainties and unknowns about central-station resources. This report briefly reviews current prospects for central station thermal power plants fueled by nuclear, natural gas or oil, concentrating solar power, coal, and biomass, and alternative technologies for hydroelectric and hydrokinetic power, wind power, and solar PV. The report identifies a need for detailed scenario planning that involves all relevant stakeholders and communities in decision making about future utility infrastructure. That discussion is presented in Section 5 of this report.

The report, on the whole, finds that perhaps the best that can be said about U.S. policies towards DER in mid-2016 is that this policy arena is looking like a major work in progress. Several states are actively engaged in proceedings to explore what changes might be necessary for utilities to fully accept cost-effective DER. Demand response and dynamic pricing are making serious inroads in some jurisdictions. Energy storage is starting to find profitable niches in some areas. And, researchers are developing protocols for enabling microgrids, non-wires alternatives, and eventually perhaps transactive-energy. However, there is nothing yet in the U.S. like a coherent single vision of the utility of the future.

For the future, the NRRI research team suggests that Ontario might usefully focus its attention on undertaking all no-regrets policies. Fundamentally, that means using market forces as much as practical with limited taxpayer or ratepayer incentives, to achieve all cost-effective DER. A touchpoint would be to try to identify all the actions that make sense irrespective of likely changes in fuel prices, global energy markets, future environmental regulations, and the like. If guided by sufficiently robust, broadly-inclusive community integrated resource planning modeling, many DER technologies will prove to be fully cost-effective already, and in the coming decades more are sure to become available. Ontario could easily play a leadership role in understanding and applying DER technology. A conscious move towards implementing all cost-effective DER could lead to positive economic growth for Ontario. Ontario, with its large industrial base and several world-class research universities, could easily become a vitally important center of best practices for sustainable energy development.

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1 Introduction

This report was sanctioned by Mowat Centre's Energy Hub (Mowat), who asked the National Regulatory Research Institute (NRRI) to study and report on emerging trends facing the energy sector in the U.S., with a focus on the drivers and potential trajectories of energy transformation, with a special focus on distributed energy resources (DER). The report would focus on short-, medium-, and long-term recommendations to help Mowat prepare policymakers and regulators of Ontario, Canada, to better prepare for Ontario's possible energy futures. This section consists of four parts:

(i) a brief discussion of the purpose of this study;
(ii) a concise review of important background information and relevant information about the current status of Ontario's electricity industry;
(iii) a brief explanation of how this report is organized; and,
(iv) a list of important criteria to be used in evaluating the ideas presented in relation to Ontario's energy future.

1.1 Purpose of this Study

Mowat asked NRRI to address, from the perspective of the United States, a few primary questions about DER:

(i) What have U.S. jurisdictions already done about integrating DER, and what do they plan to do?
(ii) What have been principle obstacles to utilizing DER?
(iii) How might the local and regional utility planning procedures be changed to best accommodate DER?
(iv) What policies and regulatory actions have worked best, and what has not worked as well? And, for those policies and regulatory actions that have not worked well, what is the explanation for why they did not work out??
(v) Have DER resulted in legacy obligations, which are typically called stranded assets in the States, and if those exist, how are they being allocated and recovered?
(vi) What has been the role of net energy metering (NEM), and how might NEM apply in the future?
(vii) What kinds of rate designs are best applied to utility systems that are beginning to accommodate more DER, and are best practices emerging in the U.S. for how fixed charges might be applied?

Perhaps, most important, Mowat asked NRRI to identify both the best ideas about DER policies and regulations from U.S. jurisdictions that Ontario might adopt and not-as-helpful ideas that Ontario might avoid.

1.2 Background and Current Status of Ontario's Energy System

Ontario passed its Green Energy Act (GEA) in 2009, taking a leadership role in all of North America to transform its energy system, particularly its electric utility industry, towards higher energy efficiency and the use of clean and renewable energy (Ontario Ministry of Energy 2016; Turner 2015).

Ontario set a goal of closing its existing coal-burning power plants and ending the use of coal as a fuel for making electricity. The last of its coal-burning power plants closed in 2014 (Turner 2015).

Following the example of Germany, Ontario established the first feed-in-tariff in North America for renewable powered electricity (Fontaine 2013). Ontario started tiered, time-of-use (TOU) pricing for electricity, and made progress towards implementing new smarter-grid technology. By the end of 2014, the GEA was credited with supporting 31,000 jobs, and over 4,000 MW of green electricity had been brought online. Dozens of manufacturers had launched their operations in Ontario, which had started to establish itself as an important business hub for clean energy technologies and innovations (Turner 2015). And, Ontario became one of the leaders in smart meter deployment and is credited with addressing leading-edge issues about consumer data privacy (USDOC 2016).

The GEA was not all positive and success stories, though. Problems appeared. Ontario's domestic content requirement for renewable energy facilities was eventually overturned by the World Trade Organization (WTO 2016). Local siting concerns were raised against proposed renewable energy installations, especially wind farms. At least some consumers blamed electricity price hikes on Ontario's renewable energy feed-in-tariff. And, customers wanting to install their own small renewable energy systems found themselves stuck in long queues awaiting interconnection approvals (Turner 2015).

Now, in 2016, Ontario has taken another major step in energy policies by passing the *Climate Change Mitigation and Low-carbon Economy Act* (Legislative Assembly of Ontario 2016). This law sets targets for reducing greenhouse gas emissions below 1990 levels, by 15 percent by the end of 2020, 37 percent by 2030, and 80 percent by 2050. It further directs Ontario's government to prepare a climate action plan for achieving those targets. Provisions include a greenhouse gas cap-and-trade program, a new Green Bank modeled after the similar program in the State of New York, strengthened building codes, incentives for electric vehicles and lower-carbon standards for vehicle fuels, and a major initiative towards research and development for new clean energy technologies (Morrow and Keenan 2016).

Presently, Mowat identifies six trends that are strongly affecting Ontario electric utilities (Mowat 2016b, pp. 3-7):

(i) Flat consumption demand;
(ii) Specific regional areas of high demand growth;
(iii) Growing numbers of consumers investing in distributed energy resources;
(iv) Challenges because of energy prices, including the rather longstanding price advantage of natural gas compared to electricity (called the "spark spread"), and difficult-to-predict and gradually increasing electricity prices;
(v) The need for utilities to invest in replacing aging infrastructure and adding new infrastructure; and,

(vi) Societal expectations, including both an expressed desire to obtain more energy from cleaner and renewable sources, plus siting concerns for locating new or replacing existing infrastructure.

These trends are easily recognizable from similar U.S. concerns, too. For example, ACSE (2016) reports that U.S. electricity infrastructure will require nearly US$1 trillion of new investment between now and 2040. And, U.S. utilities are also experiencing aging infrastructure, flat or declining sales, and particular areas where the existing grid is being stressed because of rapid growth in demand. In addition, U.S. utilities are facing a suite of stricter environmental controls for both air and water emissions, plus the possibility of action on greenhouse gases (Dietz, Bowen, et al. 2016; Gillis 2016; Stanton 2015a, pp. 5-9).

Another major recent change is the growing insistence on the part of large U.S. national and multi-national corporations, for obtaining much larger portions or even all of their electricity needs from clean and renewable energy resources (Hill 2016; Labrador 2016a and 2016b; Lundin 2016a; WWF et al. 2014). More and more U.S. utilities are being asked to help their largest customers to source power from renewable sources, and regulatory commissions are working on options to enable such purchases. Plus, smaller customers are also enthusiastic about cleaner and renewable energy sources, which is driving growth in on-site and community-shared renewable energy, especially solar photovoltaic (PV) systems. (Stanton 2016, forthcoming, and 2015a).

The essential question, as Patterson (1999) outlined many years ago, is how much of the investments in replacements and new infrastructure will be made in central station power plants and transmission infrastructure, as opposed to the distribution system and DER.

1.3 Organizing the information: Four portfolios and three future scenarios

Mowat required this research report to be organized by four major topics, which it labels as "portfolios":

(i) The New Energy Consumer;
(ii) Meeting Energy Demand Behind the Meter;
(iii) Grid Modernization and the Utility of the Future; and,
(iv) The Future of Centralized Supply.

For each of the four portfolios, Mowat asked for discussions about how technologies and policies, along with "economic, social and market trends," might end up shaping the utility industry by 2050. Mowat asked for those discussions to include the expected "effects on the different energy system participants including energy customers, utilities and existing commercial generators, government, investors and proponents, and new market entrants." Mowat also directed that the research should "consider the role of climate change mitigation and adaptation as well as other macroeconomic effects."

Furthermore, Mowat asked for each portfolio to be reviewed under three different future scenarios. A first scenario, termed "Business as Usual" is based on Ontario's "existing environment… and the minimal necessary steps to begin the process of integrating distributed energy resources." At the other end of the spectrum is a scenario termed "Focus on Innovation." That scenario would be characterized by "a fully realized, flexible, decentralized energy system, offering a range of options to customers predicated on a fully competitive model" (Mowat RFP, p.2). Between those two scenarios would be another called "Focus on Short-Term Cost-Effectiveness." That scenario represents something of a middle ground between the other two, reflecting more changes as necessary to accommodate all new DER as the technologies prove to be fully cost-effective, but presumably changes that would not be as comprehensive as those included in the "Focus in Innovation" scenario.

In addressing the three scenarios as identified by Mowat, the analysis derives from major differences in the both the breadth and depth of changes in both the regulatory environment and industry structure, and in technological improvements and potential leaps in new technology. These are basically differences in degree and not differences in kind: All of the scenarios will see some increases in deployment and utilization of DER, increased efficiency in end-use appliances and in buildings, and progress towards emissions reductions of both hazardous air pollutants and greenhouse gases.

The "Business as Usual" scenario assumes very little, if any, change in regulatory environment and industry structure, reflecting only those changes that are already in the works. "Business as Usual" is already evolving in response to policy and regulatory changes combined with market forces, so some migration towards the increased use of DER already appears inevitable. For purposes of scenario analysis, however, the authors assume that Business as Usual means that no further major changes in the regulatory environment or industry structure will be forthcoming, and that technological change will be modest. Nevertheless, it takes a huge stretch of imagination to think that many changes will not be forthcoming between now and 2050. In many ways, a Pandora's Box of DER has already been opened, and slowing the spread of those resources might prove difficult, even possibly requiring regulatory constraints to restrict what would otherwise prove to be robust markets. Thus, the task of describing a BAU scenario is largely one of imagining what could be the minimum breadth and depth of changes coming to the electric utility industry.

The authors presume the second scenario, "Focus on Short-Term Cost-Effectiveness," involves modest, incremental changes to both regulatory environment and industry structure, with those changes evolving over time to accommodate various DER technologies as they become fully cost-effective. The assumption would be that both regulations and industry structure and technological improvement will change gradually, as needed to enable markets to adjust so that cost-effective technologies and practices will be readily adoptable, rapidly achieving market acceptance in keeping with the principles of diffusion-of-innovations research. Examples of incremental changes underway in many U.S. states are presented.

The "Focus on Innovation Scenario" is based on the idea that comprehensive changes in the regulatory environment and industry structure could take place sooner, so that barriers to widespread DER deployment would be greatly diminished.

Realistically, the most likely path between now and 2050 lies somewhere along the continuum between the second and third scenarios. "Business as Usual" is already adjusting in response to multiple market forces associated with DER, and technology improvements are proceeding rapidly, most notably in solar photovoltaics, energy storage, electric vehicles, and demand management. Emerging trends suggest that utility futures will be very different from the past: DER is ushering in the biggest set of changes to the utility industry in a century.

The previous industry model was predicated on the two major ideas:

(i) That loads were almost entirely inflexible, and needed to be served through the use of firm supply, in the form of both generation and wires capacity; and,

(ii) That generation was subject to economies of scale in construction, so that very large central station power plants connected to load centers by long-distance, high-voltage transmission lines were thought to be the optimum means of providing electricity service.

An industry with a long history of planning from the centralized facilities outward towards the grid edge, is now just beginning to think about how to model and plan starting from the grid edge, backwards towards the transmission and centralized generation components. Instead of thinking about supplies being operated to meet variable demand, DER represents a major new opportunity for demands to be operated as needed to meet variable-output supplies. In a recent survey of utility executives, almost half of the U.S. respondents and nearly two-thirds of those in Europe, say that the traditional model for distribution companies is already, or soon will be, obsolete (Jamison 2016).

A new literature on DER capabilities is just beginning to address all of the industry changes needed to capitalize on all of the values that DER can produce and deliver to customers and to the system as a whole.[1] The essence of all this emerging research is that the combination of technically and economically available DER is more than capable of producing and delivering essential grid services cost-effectively, compared to the otherwise-required central station power and transmission alternatives, at least in particular grid locations in practically every utility service territory. Some early examples are showing great promise, but extensive work remains before a full transition to a DER-optimized grid might become a practical reality.

There are two prominent models of what the utility of the future might become (Accenture 2016, p. 9; Fox-Penner 2014):

- The first model is a "distribution platform optimizer" or "orchestra conductor" where the distribution company itself will be fully engaged in controlling any and all of the resources necessary to match supply and demand in real time. Those different resources might be owned by any combination of the utility, third-party providers, and customers, but it would primarily be the utility's responsibility to blend them together in time and

[1] See, for example, Ackerman and Woychik 2016; Aggarwal and Orvis 2016; Barrager and Cazolet 2014; Callaway et al. 2015; EPRI 2015 and 2014; Fine et al. 2015; Fitzsimons 2014; Hledik et al. 2016; Kushman 2016; Martinot et al. 2015; Pyper 2016b; SolarCity Grid Engineering 2016 and 2015; USDOE 2016j; and Woolf, Whited et al. 2014.

space to meet customer needs. In this model, utilities might become experts in procuring and operating DER (Pyper 2016b).

- The other model is the utility acting as a "platform access provider" where the modern utility grid provides an open system that any and all competitive suppliers can utilize to offer their products and services to end use consumers. In that model, more of the infrastructure will be owned by third-parties and customers, and the utility's role in managing and coordinating the different resources will be much smaller.

At this point, it is not yet clear whether one of these models will win out over the other, or whether some hybrid will emerge. The most likely near-term approach in the U.S. appears to be multiple experiments and pilot projects in multiple jurisdictions that will begin to test the different approaches. Already, regulatory proceedings are underway in several jurisdictions, intended to bring stakeholders together to review proposals for future utility business models and practices, plus legal and regulatory issues, as needed to enable full applications of cost-effective DER. Perhaps the foremost example is New York's "Reforming the Energy Vision" (REV) proceeding, in New York PSC Case No. 14-M-1010.[2] But, similar state regulatory agency proceedings are already underway in California, District of Columbia, Hawaii, Massachusetts, and Minnesota, and recently the Commonwealth Edison Company of Chicago announced its interest in undertaking similar changes in its business model (Bade 2016).

1.4 Criteria to use to evaluate the scenarios

Mowat (2016a) identified some evaluation criteria based on "important and abiding values" that have already been identified in Ontario. Those criteria include:

(i) Efficiency and effectiveness;
(ii) "Deliver[ing] energy with a high degree of reliability to customers at a principle-based cost;"
(iii) "Competition-based pricing for as many system attributes and assets as can be reasonably accommodated;"
(iv) "A commitment to a low-carbon economy; and,
(v) "Enabl[ing] utilities to effectively serve all of their customers confidently and with a reasonable expectation of return on investment."

In addition to those criteria that were provided by Mowat, NRRI researchers proposed that the following will also be considered:

2 Ontario's electric industry structure is similar in many ways to that of the State of New York. New York has a single-state independent transmission system operator (NY-ISO), and restructuring that enables customer choice of generation supplier. In addition, Ontario might consider emulating other fundamental components that are present in New York, such as the New York State Energy Research and Development Authority (NYSERDA), and the New York Clean Energy Fund, with its New York Green Bank and NY-Sun activities, New York Battery & Energy Storage Technology Consortium (NY-BEST), and the sustainability and smart distributed generation hub projects of the City University of New York (Sustainable CUNY and Smart DG Hub).

(i) Equity in treatment for all major customer groups (e.g. residential, including low-income, small and large commercial, small and large industrial);
(ii) Environment, including: hazardous effects on air, water, and land; greenhouse gases; effects on the ability of utilities to support achievement of various important sustainability principles;
(iii) Economy and employment, including all major effects on the local, provincial, and national economies, including both the roles associated with energy self-supply and for related export industries;
(iv) Ekistics (that is, the effects of infrastructures on individuals and society);
(v) Reliability and resilience, including both cyber security and physical security and encompassing fuel and technology diversity;
(vi) Government roles, focusing on the roles of government policies and financial supports or subsidies; and,
(vii) Utility and competitive supplier roles of the various regulated and competitive utility companies that are responsible for electric power generation, transmission, distribution, and customer service, plus natural gas and water and wastewater utilities, and deliverable fuels companies, such as those distributing heating oil, propane, or even wood fuel.

NRRI researchers identified the following basic ideas to be reviewed and included in the scenario descriptions:

- Smarter rates and tariffs – including the eventual possibilities of time-variable rates, real-time rates, and transactive energy tariffs – that provide consumers with real-time or near-real-time pricing, which enables customers, aggregators, and service-providers to make cost-based decisions on an hourly or sub-hourly basis;
- Flexible demand, meaning loads that can be scheduled to follow variabilities in supply, rather than supply always being manipulated to follow loads;
- Set-it-and-forget-it convenience, which relies in part on smarter grid technologies and improved energy management system capabilities and eventually smarter appliance controls;
- On-site and other distributed generation at all scales from single consumers, to neighborhood or community scale systems;
- The potential roles of prosumers, who both produce their own energy and consume energy and other grid services;
- Microgrids, and the related subjects of nano-grids, multiple, nested microgrids, and waste-heat utilization including combined heat and power and district energy systems at all scales;
- Load-defection and grid-defection;
- Roles for government and utilities in experimentation, research, development, and demonstration; and,
- Integrated distribution system planning and operations, including modeling and procurement of non-transmission and non-distribution alternatives.

2 The New Energy Customer

A growing number of electricity customers expect more from their electric utility than in the past, just as consumers in general have placed higher demands on other companies.[3] As expressed in one report,

> *Electricity is no longer just something the utility delivers to consumers. Consumers want more choice and control over their management of electricity. New unregulated entities are entering the market to meet consumer needs with new products and services (*GridWise Alliance 2014, 1).

The quote implies that utilities must find ways to provide value to customers other than traditional reliable service at stable prices; if they do not, they could face death-spiral-type consequences (*See*, for example, Graffy and Kihm 2014).

2.1 Trends and their implications

The heightened customer expectations come in various forms and derive from different sources. Active customers require certain things, such as real-time information, unbundled services and rates, and enabling technologies. Other customers, labeled in this paper as passive customers, generally want reliable service at stable prices.[4] Overall, active customers impose additional demands on utilities.[5] With increased diversity of customer desires and needs, utilities face a greater challenge in accommodating all customers: They must meet disparate customer needs. For regulators, the tough task is to make sure that utilities act in a way that best advances the public interest, which according to the traditional definition is the aggregate, long-term economic welfare of active and passive customers.[6]

A majority of utility customers are currently passive, and many if not most will remain so in the future. A policy question that U.S. utility regulators are asking is: What actions can

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[3] Consumers in general feel more empowered, are less tolerant of poor service, less loyal and more informed. For example, Uber has enhanced consumer expectations for the taxi industry by providing quicker service, lower prices at certain times and a more convenient payment method.

[4] Passive customers tend to have an "information" problem, high switching costs, or are just simply inert (i.e., once they make a decision, they stick with it and tend not to change their behavior, even when it seems they should). Some analysts perceive consumer inertia as the lack of consumer participation in new market opportunities when ample information exists that a consumer would benefit. According to this definition, consumers are irrational in not changing their behavior. One often-used example of consumer inertia is the long distance telephone market, where the penetration of non-AT&T carriers progressed slowly and several years passed before these carriers collectively were able to increase their market share above AT&T's.

[5] Some industry observer define passive customers as requiring only basic service from their utility, while active customers demand enhanced or value-added services. This begs the question of what distinguishes the two kinds of services. One might say that basic service reflects electricity as essentially a commodity, while enhanced services transform electricity into more of a service. Enhanced services, for example, provide more personalize electricity service by increasing their value to an individual customer.

[6] Regulators can also conceptualize the "public interest" by identifying the multiple objectives that comprise the public interest, assigning weights to those objectives, and resolving the trade-offs among them.

utilities take to transform customers from passive to active? While such a pursuit appears sensible, artificially carrying out the transformation through excessive subsidies and other non market-based actions, for example, might jeopardize the public interest. The simple reason is that the cost of the altered behavior might exceed the benefits. The benefits of "forcing" more new technologies may not justify the costs.[7] For example, setting an excessively high feed-in tariff to bolster investments in DG may be ill-advised because of the harmful effect (e.g., higher rates) on core customers.

In any event, the bifurcation of customers presents unique challenges for both utilities and regulators. Historically, utilities have had customers with varying characteristics. Two noteworthy ones are the value customers place on reliable utility service and their responsiveness to price. The new electricity customer may have distinct demands and characteristics compared with traditional (passive) customers. Throughout its history, regulation segmented customers by how much electricity they consume. This criterion for bifurcation established residential, commercial and industrial classes. Clashes occurred over cost allocation between these classes. In the future, we should expect more discord within the residential class between active and passive customers. Some observers label this as the "digital divide" that could become increasingly challenging for both utilities and regulators in the coming years.

2.2 Customer activism

We first need to define active customers and contrast them with passive (i.e., traditional utility) customers. Traditional or passive customers essentially pay little attention to their electricity consumption and bill. They receive their bill and then pay for it without much scrutiny. They are satisfied with their utility service (both in terms of price and reliability) and presumably find spending much time on managing their usage, or seeking the least-cost option, as irrational endeavors relative to the benefits.[8]

Active customers tend to exploit increased competitive conditions, access to more information, new technologies, and market developments. They place greater demands on

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7 Regulators should be leery of rent-seekers who try to push a certain technology that profits them but fails a societal cost-benefit test. Subsidies could potentially put a technology a leg up on its competitors; that is, give the technology an unfair advantage that would be socially undesirable. "Leveling the playing field" among technology alternatives should be the primary regulatory goal. Most economists would support subsidies or favorable treatment to a specific technology *only* under restrictive conditions; namely, the existence of serious market/regulatory failures for which the benefits of their mitigation exceed the costs. What we have observed in U.S. society is a tendency for companies to exploit government for favors. These rent-seeking activities do little to enhance economic welfare for consumers, compared with improving the value of products and services. Companies in the utility space may fall under this umbrella, especially in their dealings with regulators and legislatures.

8 *See* Accenture 2011 for grouping of customers into six categories: Service-centrics, traditionalists, tech-savvys, self-reliants, social independents and cost-sensitives. Another source classifies customers into three broader categories: (a) traditional, (b) active and (c) prosumers [Ontario Energy Board 2016, 12.] Prosumers benefit, for example, from consuming cleaner electricity, reducing their utility bill and receiving payments from their utility for unused power.

utilities to provide (1) a wider array of products and services, and (2) greater opportunities to control their electricity usage and the price they pay for electricity.[9] They tend to want:

(i) Real-time information[10] and pricing so that they can better manage their usage;
(ii) The capability to save on electricity costs via, for example, time-varying pricing, demand charges, demand response and energy-efficiency initiatives;
(iii) Clean energy as they are willing to pay more for electricity when produced from renewable energy;
(iv) Above-average reliable and resilient service (e.g., shorter and less frequent outages),[11] and power quality[12] as they assign greater costs to outages and other service disruptions;[13]
(v) The ability to self-generation (e.g., CHP, micro-generators, rooftop solar) and other distributed energy resources (DER)[14]; and
(vi) Opportunities as "prosumers" to sell unused electricity back to the utility.

Some customers may want all of these things while others demand different combinations. A customer, for example, may select a green tariff that requires him to pay extra for electricity produced from clean energy sources.[15] Another customer may want "fair" rules for self-generation, both in the price the customer pays for standby utility service and the price it receives for selling unused electricity back to its utility. A third customer may just want real-time information to better control her electricity usage. In satisfying all of these diverse demands, a utility would have to unbundle its services and possibly take more drastic actions. Each of these new activities costs money that regulators will have to decide how and from whom the utility will recover them.

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9 An example of where companies have been successful in transforming their product line is the cable industry, which expanded its service offerings and competed in other markets, rather than expending substantial resources to compete with the satellite companies in the old product market. Cable companies went from being television-only providers to providers of internet and phone service, sold both individually and in bundles. In other words, customers can choose between buying separate services or a combination of services.

10 One example is turning "big data" into useful information for customers to make decisions on a real-time basis.

11 Grid resilience has become particularly important in the East since super storm Sandy.

12 A "digital" world has heightened the concern over the serious problems created by momentary disruptions in voltage or frequency.

13 One reason is that households use electricity for a wider range of activities, some of which have substantial value that would be lost with power outages or power-quality problems.

14 The spectrum of DER includes solar, wind, CHP, microgrids, storage, efficiency, demand management, and demand response. DER can benefit customers by making generation more flexible, transmission and distribution more controllable and resilient, allowing customers to become producers and loads more interactive and dynamic. Even though technology will allow customer to become more self-sufficient, for example by installing a rooftop solar system, it is unknown how many of them actually would. Most consumers do not want to produce the product or service that they use, whether it is automobiles, most food items or electronic devices.

15 Some big U.S. corporations have begun to demand that the electricity they purchase from their local utility comes from clean energy sources.

Some customers want additional and better services from their utility than previously, just like they do from other companies. As remarked in one paper, "The last best experience anyone has anywhere becomes the minimum expectation for the experience they want everywhere" (IBM 2016, 4). Customers are becoming increasingly accustomed to more customer-centric service in other industries. The same paper commented that:

> Today's energy and utility customers are asserting more control by choosing particular providers and offerings, actively managing their consumption and making their voices heard directly through social channels, not just through regulators. In some cases, customers are even generating their own power. The utility industry is reaching a point where customers can behave more like partners with their utility, which can lead to new opportunities (IBM 2016, 2).

A fundamental question for policymakers and utilities is: What do electricity customers really want? That is, what value do customers receive from electricity? It is customer-specific, as some customers expect less from their utilities than other customers. While we can safely say that more customers will become active in the years ahead, we can only speculate on the percentage that will.

While almost all customers when asked would like to have highly reliable service, clean energy, and low prices.[16] But if asked what trade-offs they would be willing to make, customers would answer differently. For example, some customers may be willing to pay nothing for cleaner energy, as their preference is for the lowest-priced electricity. Other customers, on the other hand, would pay, say, 10 percent more for their electricity if it came from clean-energy sources. The presumption that all customers are demanding more from their electric utility seems overstated. Electricity customers, like customers of other products and services, are heterogeneous. Many customers want things to remain the same. Others want change and technological developments have given them the opportunities to take more control with additional options. Bifurcation of utility customers based on their expectation for utility service seems like a valid place to start in studying policy alternatives for the future electric industry.

There are many reasons why market observers expect growing customer activism over time. The first is economic: With likely cost reductions for self-generation and information-based technologies, more customers will exploit their benefits. A second reason is the availability of new technologies. We have seen the increased penetration, for example, of smart meters, information/digital technologies, and smart thermostats.[17] These have given customers the tools to automatically manage their electricity usage.[18] Demographics also favor more

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16 One problem with consumer research is the discrepancy between what people say they believe and their actions.

17 Nest thermostats are an example of a technology that has provided customers with a positive experience even though they never expressed a prior demand for it.

18 Smart meters, for example, can provide 2-way communications capabilities and other functionalities that facilitate the ability of customers to better manage their electricity usage. They can also, although rarely in the U.S., allow for time-varying pricing. Such pricing can bolster certain new technologies (e.g., energy

active customers in the future. The millennium and other younger generation are technologically astute and have a reference point that differs from older customers in their expectations for utility service.[19]

When customers have more options to manage their electricity costs and make associated choices, it is likely that they will become increasingly active and set a higher standard for satisfactory utility service. This development has occurred across a wide spectrum of industries, and the electric industry should anticipate the same.

The possibility that customers could never be worse off if they have more choices is axiomatic to many. Consumer sovereignty says that each consumer is the sole judge of her own welfare; she does not have to buy from a specific supplier, and if she has choices she can take her business elsewhere. A number of exceptions exist, such as circumstances in which individuals have incomplete or erroneous information or are unable to process logically the available information. For example, customers can process the information they receive incorrectly or make decisions based on false, misleading, or incomplete information.[20] Customers might have to live with these decisions either on a temporary or a long-term basis.[21] Active customers therefore need good information and act rationally in making decisions that will benefit them.

2.3 Essential elements of customer activism

The features of a well-functioning market, i.e., a market for active customers, should have certain characteristics. The major ones include the following six:

(i) Well-informed customers,
(ii) Price transparency,
(iii) Customer responsiveness to the prices and offerings of different providers,[22]
(iv) Low transaction costs,
(v) Adequate competition among providers, and
(vi) Low entry barriers for new providers.[23]

storage), both inside and outside home. The lack of interest in time-varying pricing probably reflects the preference of customers and regulators for the "hedging" or "stability" aspect of average-cost pricing.

19 The young generation place high demand on hand-held electronic devices. They also may tend to demand real-time information to reduce their energy usage.

20 Many customers fail to fully exploit the available information in making the best choice. Reasons include confusion and bounded rationality.

21 In many markets, customers have incomplete or erroneous information or are unable to process the available information rationally. The relevant question then becomes: Are these problems serious enough to warrant regulatory intervention? In the U.S. the typical response is for government to supplement market forces in protecting consumers from inadequacies of their own judgments. We observe, for example, consumer protection laws, labeling and warnings, mandatory product standardization, and consumer reports. Two prominent features of poorly performing markets are: (1) companies have substantial market power and (2) consumers are ill-informed and inactive in changing companies when it would be in their interest.

22 Providers may not only sell products and services, but technologies as well.

Without these features, customers receive fewer benefits, or even negative benefits, from active participation. Lacking good information, customers are liable to make wrong choices. Customers need to respond to the prices and offerings available from different providers.[24] Search and other transaction costs must be held to a minimum. Finally, customers must have an adequate number of providers from which to choose. This is helped by minimal barriers to entry by new providers. Overall, well-functioning markets require certain features that do not happen by chance. The implication is that necessary market conditions must exist for active utility customers to become better off.

2.3.1 Empowering utility customers

A strategy for engaging customers, or using the popular term empowering customers, should have three broad components: The availability of unbundled products and services, information, and enabling technology. Customer activism depends on several factors, including: (i) choice of value added services; (ii) pricing options; (iii) economical self-generation and demand response; (iv) a variety of electricity sources; and (v) real-time information (*See* New York's Reforming the Energy Vision (REV), 2014).

Consumers make decisions in a complex environment in which uncertainty, confusion, and transaction costs prevail.[25] An apparent rational reason for electricity retail consumers to switch from full-requirements to DG status might conflict with factors that make taking no action more sensible. The latter factors would include small expected benefits, uncertainty over actual savings, and search costs.

A simple rule illustrates the economics of customer activism: *Utility customers will search for better alternative when they expect the gains to exceed the costs*.[26] Gains can arise from lower prices and higher product or service quality; and costs include transaction costs plus any perceived costs (e.g., lower service quality[27]) from switching suppliers. When utility customers feel indifferent about switching because of no discernible gains, they would tend to do nothing. In one sense, the term inertia involves customers remaining in their current

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23 Two schools of thought comprise fundamental perceptions of entry barriers. The first, attributed to the economist Joe Bain, defines a barrier as anything that enables an incumbent firm to charge monopoly prices without attracting new entry. The second school of thought, led by George Stigler, defines a barrier to entry as costs incurred by a new entrant that are not, or have never been, incurred by an incumbent. The Stiglerian definition provides a more stringent test of what constitutes an entry barrier.

24 Assume, for example, a situation in which the current customers of a company are not likely to leave it for another company, no matter the price and service quality they are receiving. With such "captive" customers, the company would be able to charge a higher price without losing customers. In other words, the company would act like a monopolist. It might have an incentive, however, to offer lower prices to attract new customers, thus engaging in price discrimination.

25 "Transaction costs" refer to the costs for customers to search out and negotiate with suppliers of different electric services.

26 This condition assumes that customers are risk-neutral. If they are actually risk averse, then even an expected net gain might not necessarily cause them to change their current situation.

27 One example is a decline in customer service. Customers of non-utilities might have fewer rights to complain because of poor service, relative to the rights they enjoyed as bundled sales customers of their utility.

situation when the expected gains are not sufficient to offset the costs and risks associated with switching to another alternative. This action reflects perfectly rational customer behavior.

Inertia can prevent customers from changing suppliers when they should. The human tendency is toward "inertia", which some people would call laziness. Since contemplating whether to switch to another supplier requires effort and time, the opportunity cost for many customers can exceed their expected benefits. Unless one supplier offers clear advantages (e.g., large cost differences) in view of time constraints, other costs, and uncertainty over benefits, residential customers might not deliberate over the choice of DG or another provider of electric service.[28] In other words, passive customers, although seemingly exhibiting inertia, are acting rationally. A goal of making electricity consumers more active, for example through subsidies, may therefore conflict with the public interest.

2.3.2 Unbundled products and service

Unbundling refers to the offering of separate prices to retail customers for individual components of electric service. For retail customers, these components may include energy, capacity, reliability, transmission, distribution, and ancillary services. Examples of less broad specific value-added services are billing service provided by third parties, enhanced grid management services, emergency operational services, metering services and data, and customer-sited energy storage (*See*, AEE Institute 2015). Retail competition is a form of service unbundling where the utility sells and prices commodity electricity separately from the other components of electric services in demand by retail customers.

Unbundled electric services are complementary in that one service component helps enhance the value of other components. Electric energy, for example, has value to retail customers only if they have access to the delivery system that transports the electricity from the producer. Ancillary unbundled services, such as local reactive support and power system voltage generation and control, may also be essential services in maintaining the stability and reliability of the local electric power system.

At any given time, a utility may offer customers both bundled and unbundled services.[29] Customers would typically benefit if offered the choice between bundled services and unbundled services. Some customers, namely active customers, may opt for purchasing individual components of electric service – for example, enhanced reliability – if they are less

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28 Behavioral economics predict that real-world decision making is often inconsistent with consumer decisions that neoclassical theoretical models would suggest to be optimal or rational. *See*, for example, Frank 2007; and Thaler and Sunstein 2008.

29 Mandatory bundling of a good or service can be a means for a company to exercise market power. In the economics literature, tie-in sales and bundling of services can lead to monopolistic price discrimination. A particular concern is the incentive for monopolists to use tie-in sales and bundling to achieve price discrimination that otherwise would not be possible. Tie-in sales and bundling also preclude potential rivals from offering individual services at a lower cost. *See*, for example, Carlton and Perloff 1990, 841-43.

costly than purchasing bundled service.[30] For other customers like passive customers with higher transaction costs, purchasing the bundled service could be the preferred action. That is, passive customers may be content with their utility offering only basic service while active customers may prefer enhanced services or value-added services.

Overall, the economic pressures for unbundling retail services are robust whenever competitive pressures prevail.[31] As long as DG, for example, can compete with utility bundled service, those economic pressures will likely only grow in the future. One lesson learned from the experiences of other U.S. public utility industries is that when existing regulatory and utility practices depart from market realities, reform becomes inevitable. Reform includes the unbundling of retail services and rational pricing. Simply put, competition creates the stimulus for the unbundling of electric services.

2.3.3 Unbundled rates

One prediction is that unbundling, by accelerating competition, will move prices toward marginal cost or market-based levels. One plausible outcome is a fixed-variable rate design that efficiently signals to customers energy commodity (kWh) rates corresponding to marginal cost. A fixed fee or reservation charge would recover those fixed costs not recovered through the energy commodity rates. The logic behind this prediction presumes that the competitive forces accelerated by retail unbundling will tend to force prices to marginal cost. Real-time pricing is one example of a fixed-variable rate design. Under this methodology, prices are composed of an hourly energy charge and an access charge. The access charge allows the utility to recover its revenue requirements while enabling energy prices to be set at short-run marginal cost. Compatibility with real-time pricing is the differentiation of utility services by quality and time of use.

For unbundled services containing natural-monopoly features, such as some ancillary and distribution services, either cost-of-service pricing or some form of performance-based rates can evolve. Not all unbundled services will, or should, be priced using the same methodology. Utility regulators must determine which unbundled services are competitive and which will still have natural-monopoly traits. As a rule, those which have competitive characteristics should either be deregulated or at least subject to loose regulation. For such services, contracting between parties may be appropriate. Bilateral negotiations have the potential to produce the greatest benefits by allowing the parties to specifically tailor services to their specific demands.

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30 Enhanced reliability on an individualized basis – for example, by installing equipment on the customer's site – may be more economical than if the utility treats reliability as a public good by making large investments to increase reliability for all customers.

31 Unbundling of utility services in the U.S. telecommunications and natural gas industries was initially driven by the economic pressures from consumers who wanted the opportunity to purchase the lowest-priced products and services. In the natural gas industry, unbundled gas transportation was in large part a response to bypass threats by large retail customers and the associated problems of cost- shifting and stranded investments. From the perspective of local gas distribution companies, unbundling could avoid lost profits from customers leaving the distribution system (i.e., from bypass). Gas distributors have generally been agreeable to assuming the role of transporters, since their profits are generally not tied to the amount of purchased gas they procure for their customers. This has not been true for electric utilities.

2.3.4 Good information

One feature of an efficient market is well-informed customers.[32] Such customers know the different products and prices that competing providers offer. These providers will tend to compete more aggressively, since they expect customers to switch to those providers offering the best deal. Overall, knowledgeable consumers tend to shop around, induce price cuts, and undermine market power. When, instead, customers are ill-informed, providers recognize that they could maintain higher prices, not compete as aggressively, and still retain customers.[33] If a provider knows that its customers are not seeking out the prices being offered by other providers, it is able to charge a higher price.[34] Even though other providers would offer a lower price, the incumbent provider recognizes that its customers might not know or care if they did.

Ill-informed consumers are often confused and they tend to stay with their current service, even though they would benefit from switching to another provider or service. This condition again imposes less competitive pressure on providers to offer a lower price. Customer confusion can revolve around price, as well as customer rights and responsibilities.[35] In such a market, adequate customer education becomes critical for well-informed decisions and for mitigating market power.

One topic warranting attention is whether the presence of well-informed consumers in a market protects other consumers who are not well-informed. If companies have to offer competitive prices to well-informed consumers, will not other consumers get the same benefit? Unless companies can discriminate against ill-informed consumers, it seems that they will have to offer the same deals to all consumers. As long as some well-informed consumers exist, it seems that companies will have to act competitively or else lose market share to their rivals.

2.4 Enabling technologies

Customer awareness will be needed, as well as enabling technology that allows most of the day-to-day deployment of the offered products to be automatic (i.e., with low transaction costs for the customer). Limited access to information, high customer acquisition costs, and

32 Some observers contend that engaged utility customers must understand how, how much and when they consume electricity. The absence of such information precludes customers from managing effectively their usage.

33 Less-than-perfect information *per se* does not pose a serious problem since rational customers will expend only limited time and resources to acquire information justified by the benefits. In other words, well-informed customers lack perfect information. *See*, for example, Stigler 1961.

34 In a market where consumers are seeking the best deals, suppliers are under pressure to set price at marginal cost. Even if the number of suppliers is only two or three, the assumption of active consumers would tend to produce competitive prices reflecting marginal cost. This is consistent with what economists call the "Bertrand paradox".

35 As expressed in one report: "There was a fairly widespread feeling that the complexity and range of tariffs offered was not to help the customers by offering them a wide choice, but to confuse the customer and make that choice more difficult." [FDS International, 2011, 1.]

other transactional hurdles are obstacles to customer activism. Enabling technologies can help mitigate these factors and transform customers to become active.[36]

2.5 Three paths for consumer activism

2.5.1 Business-as-usual

Under this scenario, no major changes in public policies and market conditions happen. The world moves along with continuing improvements in information-based and DER technologies. These evolving developments should raise the number of utility customers who are active. This would increase the complexity of utility operations and their challenges to accommodate active customers (through pricing) as well as protect passive customers from cost-shifting and other discriminatory actions.[37]

The narrative on traditional U.S. utility regulation is that it provides utilities with less-than-robust incentives to innovate.[38] Regulatory practices can discourage or stimulate a utility's commitment to new technologies. Whereas regulation tends to reduce a utility's downside risk, it also eliminates its gains from successful new technologies, unless regulatory lag is substantial or special incentives are present. Regulation, in effect, socializes both the risks and benefits of new technologies. Under this scenario, utilities would continue to have weak incentives to innovate themselves. They would also be indifferent or even opposed to customer-oriented innovations developed and marketed by third parties. All of these conditions would be compatible with a business-as-usual scenario.

2.5.2 Short-term optimization

Under this scenario, the policy objective is to undertake least-cost actions or achieve the lowest electricity prices in the short term (e.g., over the next few years). That is, policies would emphasize short-term over long-term effects. Policymakers would show no favoritism toward renewable energy and other clean energy sources. Subsidies would be held to a minimum, even though they could produce long-term benefits.

Under this scenario, new customer-oriented technologies and other innovations would be delayed. One reason is that the de-emphasis on R&D would delay the entry of innovation

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36 As discussed later, new technologies can be both a blessing and a curse for utilities.

37 One way for utilities and regulators to protect core customers is to assure that the prices paid by active customers for unbundled services are compensatory; that is, the incremental costs incurred by a utility for providing unbundled services are fully recovered from active customers. This condition is also compatible with advancing economic efficiency.

38 Traditional rate-of-return (ROR) ratemaking provides utilities with weak incentives for innovation and with disincentives for accommodating DG and other potentially socially desirable actions (e.g., energy efficiency) that would reduce their sales. It also bases utility revenues on past costs rather than on the value to customers from utility actions that underlie the costs. Finally, because traditional ratemaking sets retail prices based on average cost rather than marginal cost, consumers face distorted price signals.

into the utility space.[39] This would consequently slow down the transformation of customers from passive to active status.

2.5.3 Innovative environment

This scenario accounts for new technologies and other innovations just taking off or not yet imagined. Innovations can focus on new products and services that offer active customers convenience, control, value, and participation. New technologies can include (1) energy-efficiency hardware, (2) DG, (3) electric vehicles[40], (4) on-site batteries, (5) set-it-and-forget-it" appliances[41], and (6) internet of things offering controls for not just buildings, but also for individual appliances, light bulbs, control technologies for AC or lighting, programmable controllable thermostats, and building energy management systems.

This scenario enhances the ability of customers to be active because of lower transaction costs, the availability of new software and hardware, and improved economics. Public policy would also stimulate customers to transform from their passive state to one where they become more engaged in managing their electricity usage.

A lesson from history is that new technologies often take decades before they become widely dispersed: Several successful steps must transpire before a new technology-- even when initially promising -- gains wide acceptance. Most new technologies start off in a primitive state, proceeded by a long process of technical improvements and cost reduction, prior to broad market penetration.

Another observation from history is that many if not most major technologies were not projected to have a disruptive effect (think of the airplane, television, the steam engine, the computer, the laser, the mobile phone). It is conceivable that we may see in the years ahead a radically different electric industry than what we can imagine today. One factor in this transformation could be innovations that turn customers into highly engaged participants. This could drastically change the utility business model and the regulatory paradigm.

2.6 Increased demands on utilities

Active customers will almost certainly pose greater challenges for utilities. They include:

(i) Unbundling of services and their pricing;
(ii) Investments for upgrading the grid;[42]

[39] Companies and government view research and development (R&D) as having a long-term return, which under a short-term optimization scenario would be heavily discounted.

[40] Low oil prices have seriously jeopardized the luring of consumers to electric vehicles.

[41] For example, smart appliances automatically respond to price signals.

[42] Grid modernization can benefit utility customers by mitigating cyber and other threats to the security of the electric grid, expanding new products and services, reducing barriers to new technologies and improving overall economic efficiency.

(iii) Better communications with customers (e.g., with social media);
(iv) Customer demand for real-time information;
(v) Investments for greater generation diversity (e.g., clean energy technologies);
(vi) Other investments (e.g., smart meters);
(vii) Higher revenue and profit uncertainty;
(viii) Erosion of monopoly status; and
(ix) Heightened planning uncertainty (e.g., from customers switching from full-requirements to partial-requirements status).

Electric utilities face tougher challenges when customers have more choices and impose additional demands upon them. Pressure on inflating utility costs comes from various sources: increased demand for clean energy, replacement of aging infrastructure, grid modernization, transition costs to accommodate more renewable energy, integration of new technologies, cyber security protection, public demands for improved "superstorm" response, and customers' demands for higher reliability and overall quality of service.

For example, with more customers adopting DG technologies, operation of the distribution network becomes increasingly complex. The distribution network must keep the system in balance and confine voltage and frequency levels within a tolerable band. It must also respect contingency limits, meaning no violation of a line's physical limit if some other line or generator goes out of service unexpectedly. The network carries out these basic functions by purchasing "ancillary services." The operation of an interconnected electric network has to be monitored in real time to assure that: (1) production always matches consumption, and (2) power can flow across the network within established reliability and security constraints. The integration of DG makes these tasks more difficult.[43]

Utilities may also have to become more innovative. Regulators can assist by providing them with stronger incentives to adopt new technologies and undertake R&D. Regulators can also allow utilities more flexibility and leeway in their operations and service offerings. The result is that utilities can better avoid a death-spiral-type[44] outcome from DG penetration and other developments that challenge utilities' financial stability.

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43 A Massachusetts Institute of Technology study (2011) on the future of the electric grid explains that low levels of DG penetration reduce load at the nearby substation, but high DG penetration could create excess load at the substation. The outcome is power flowing from the substation to the transmission grid, creating a reverse power flow that grids might find difficult to handle and causing high voltage swings and other stress on electric equipment. These potential strains on the distribution network will require utilities to make further capital investments in system upgrades, which might include distribution automation, system interoperability, data management and analytics, and cybersecurity to address new network dynamics.

44 A death spiral relates to an existential crisis whereby a utility has limited ability to raise its prices to sustain financial viability in response to adverse events. In a competitive environment by definition, individual companies have no control over the price and will experience financial disaster if they try to raise their price above the market price. In non-competitive industries, companies are able to exercise some control over the price they receive, but even then they can encounter lower profits when they price their product or service too high

2.7 A minority of customers are active today

Utilities will increasingly face a bifurcation of customers. As of today, the vast majority of utility customers are passive and may remain so for the foreseeable future.[45] Because electricity costs are a small percentage of the average customer's income and total spending, it would be unsurprising if many customers remain passive.[46]

Unlike high-tech industries– a prime example is mobile phones– electricity is essentially a commodity with relatively few value-added features. One perception, for example, is that electricity is a commodity derived from the demand for energy services (e.g., air conditioning, water heating, lighting), unlike cell phones and other electronic devices with special features that make then increasingly valuable to consumers over time.[47]

Often in bifurcated markets, companies will price discriminate in favor of active customers, who are more willing to shop around to get the best deal. Because of the inertia reflected in the behavior of passive customers, companies can charge them higher prices while suffering only a minimal loss in sales. Later we will discuss what customer bifurcation means for utilities and regulators in terms of cost allocation, the utility business model, utility planning, and rate design.

2.8 Challenges for policymakers and regulators

This section discusses the specific challenges that the bifurcation of customers poses for policymakers/regulators. Utilities face the task of accommodating active customers while not jeopardizing the welfare of other (e.g., core) customers. The regulator's job is to assure both active and other customers that their utility will treat them fairly. Regulators will have to grapple with new ratemaking issues and revisit the regulatory compact that they have ascribed to over the past several decades. Regulators also have to assure customers that they have access to new technologies, for example, by prohibiting utilities from erecting undue barriers to technology diffusion.[48]

Overall, regulators have the task of making sure that core objectives continue to be fostered. These objectives include fairness to all customers, service reliability and economic

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[45] According to one report, for example:

> The number of electricity customers who use net metering increased exponentially from fewer than 7,000 in 2003 to more than 450,000 in 2013…Growth has continued in 2014, with more than 75,000 additional net metered customers reported through May 2014. However, despite this growth, in 2013 these customers represented only 0.3% of the more than 145 million electricity consumers in the United States. [Heeter et al. 2014, 1.]

[46] The average residential customer spends about 2.7 percent of its before-tax income on electricity. (Bureau of Labor Statistics, *Annual Expenditure Survey*, 2012.) By reducing its electricity bill by 25 percent, for example, the average customer's real income would increase by only 0.675 percent.

[47] Kind 2015, 15.

[48] Delays in the introduction of new technologies and services can deprive customers of potentially large benefits.

efficiency. Fairness requires that utilities do not unduly discriminate against distributed generation providers nor shift costs to core (i.e., full requirement) customers. [49]

2.8.1 Broad concerns

Regulators should ask the following broad questions in a bifurcated-customer environment:

(i) What should we expect of utilities in accommodating new customer demands?
(ii) Who should pay for new required investments, and how?
(iii) What role should third-party[50] (e.g., competitive) providers play in meeting customers' new demands?[51]
(iv) What restrictions and liberties should third-party providers have?
(v) How can regulators guarantee an economically level playing field between utilities and third-party providers?
(vi) What barriers to consumer activism exist today and how can regulators mitigate them?[52]

Proponents of utility transformation have emphasized customer welfare as the paramount objective. Throughout its history, utility regulation has given customers top billing. One difference recently is that technology and other factors have allowed customers to take more control, placing greater demands on utilities. Another difference is that the interests of residential customers have become diverse, requiring regulators to trade-off the welfare of some customers for the benefit of others.

There is a legitimate concern that utilities might favor themselves or an affiliate, which violates the condition of a level playing field. Utilities might also inhibit those innovations that threaten their monopoly status or be indifferent to those innovations that largely have public benefits.[53] Regulators have to be vigilant to make sure that utilities do not erect artificial (i.e.,

[49] The term "fairness" and its derivative, "fair," appear commonly in the regulatory arena. We often hear of a "fair rate of return," "fair and reasonable rates," "fair value," and a "fair process." Because fairness is elusive and enters the domain of philosophy, it becomes difficult to know what is fair and to say that one action is fairer than another is. Since stakeholders' perceptions of fairness differ, the regulator's job is to balance them so as to best advance the public interest.

[50] These non-utility providers can directly serve retail customers or utilities. They provide technologies in addition to products and services. Non-utility providers play a crucial role in meeting the demands of active customers. How utilities interact with them and what rules regulators establish affect what benefits these providers transmit to retail customers.

[51] Experiences in other industries have shown that in a workably competitive environment allowing non-utilities to provide services can produce significant benefits to consumers. The telecom industry is a good example where third-party providers have played a valuable role.

[52] They include limited access to information, high customer acquisition costs and other transactional obstacles. *See*, for example, Energy Industry Working Group 2014.

[53] Public benefits are external to a utility and defined by economists as positive externalities. Examples include clean air and national security, which the country values but individual utilities in terms of their profitability do not. Investments in new technologies that reduce greenhouse gas emissions and lower the risk of harmful climate change, for example, yield benefits for society at large. Absent carbon pricing or similar

undue) barriers to protect their financial interests at the cost of customer welfare. These barriers can reduce the value of the distribution network, thereby hindering the development of innovative value-added services that benefit active customers.

Economists often disagree on whether certain "barriers" are actually anti-competitive or merely normal, pro-competitive market activities. Critics of a liberal definition of entry barriers argue that many of the alleged barriers are no more than market efficiencies that serve to improve consumer welfare. They are therefore often mistaken for obstacles to competition that need to be mitigated. As an example, when motivated by competitive forces, strategic pricing reflects pro-competitive behavior, rather than anti-competitive. By definition, pro-competitive activities benefit both consumers and society-at-large. In contrast, anti-competitive activities violate socially welfare-enhancing market practices by improving the finances of a company, while making consumers worse off.

2.8.2 Ratemaking

Ratemaking has wide-ranging effects. It has the important functions of affecting customer behavior (e.g., how much electricity to consume and whether to self-generate) and the ability of a prudent utility to collect adequate revenues for financial health. It has three general parts:

(i) *Revenue requirements* (e.g., new utility investments dedicated to serving active customers);
(ii) *Cost allocation* (e.g., dividing up incremental costs among active and passive customers); and
(iii) *Rate design* (e.g., method for recovering of fixed costs from DG customers, real-time pricing).

Ratemaking affects the ability of utilities to recover their costs, allocate costs between customer groups and achieve predetermined regulatory/social objectives. These objectives include the financial viability of utilities, the efficient use of electricity and the accelerated penetration of socially desirable, new and emerging customer-oriented technologies.

In the U.S., analysts and others have raised concerns about current ratemaking practices, especially as they relate to industry transformation and customer bifurcation. Some ratemaking practices are driven by self-interest while others have more legitimacy from a public-interest perspective. Even in those jurisdictions not anticipating radical industry reform, utilities along with other stakeholders and their regulators are contemplating changes in ratemaking.

Present ratemaking in the U.S. has triggered several concerns:

(i) Financial harm to utilities from lower sales given the typical rate design of recovering most fixed costs through volumetric charges;

policies, no direct financial compensation associated with those benefits exists, thus driving a wedge between the private returns that a utility can realize from such innovations and the overall social return.

(ii) Inappropriate rates and rate design for DG and full-requirements customers;
(iii) Pricing of surplus power (i.e., the net metering rate) from rooftop solar customers;
(iv) Cost-shifting to full-requirements customers;
(v) Deficient utility compensation to DG customers for the value they contribute to the utility grid;
(vi) Deficient DG customer compensation to the utility for standby and other grid services;
(vii) Uniform prices across all time periods; and
(viii) Underuse of smart technologies for more rational pricing.

We should note a few things about ratemaking in the U.S. First, ratemaking can address many of the challenges facing the electric utility industry. As some observers have remarked, "Set the prices right and good things will happen." In the context of this paper, good pricing can provide customers with the right incentives about how much electricity to consume and from which sources to purchase electricity. From a policy perspective, the behavior of active customers would be socially desirable under efficient pricing. For example, such pricing would prevent uneconomic bypass.

Second, ratemaking is extremely difficult to do right. Changing rate design, for example, would benefit some customers but hurt others; and the information presented to commissions from different stakeholders is fraught with problems (e.g., biasness) and includes non-quantifiable metrics. It is therefore hard for regulators to know which rate design best advances the public interest.

Third, ratemaking has become increasingly complex over time because of expanded public policy objectives and the presence of additional stakeholders in the regulatory process. Conflicts between achieving different objectives have intensified. A current challenge for U.S. utility regulators is how to continue supporting rooftop solar without "giving away the store." A more general problem is how to create an environment where utility customers are more active, but are not encouraged to migrate to other providers because of inefficient pricing.

Fourth, U.S. regulators generally do adapt to a changed market and political environment, although cautiously, when the public interest would otherwise suffer. State utility regulators tend to undertake major reforms, including changed ratemaking practices, only when continuation of the *status quo* would bring disastrous results that disrupt the political equilibrium. These results can include: (1) utilities losing customers to competitors and suffering serious financial problems and (2) the suppression of a social objective (e.g., advancing energy efficiency) for which a regulator gives high priority.

Fifth, ratemaking comes down to the relative importance that regulators and stakeholders place on different objectives. In other words, ratemaking is an art as well as a science. With bifurcated utility customers, regulators will have to decide how far they will go to protect passive customers or advance the interests of active customers as they demand more services from their utilities.

Sixth, reaching agreement on rate issues (i.e., a political equilibrium) requires a balancing of interests, where each stakeholder has to give up its preferred choice for the public good. Stakeholders in many states have not yet reached agreement on things like (1) compensation by the utility for surplus rooftop solar power, (2) compensation to the utility for grid services provided to DG customers, and (3) the optimal use of smart meters for pricing. The last action might include time-varying pricing and demand charges for residential customers.[54]

2.8.3 Utility obligations

A radical regulatory response presumes a transformed electric industry in which utilities have adopted a new business model that defines their new role, objectives and strategies. The regulatory compact between a utility and its regulators might also undergo a major change.[55] The utility, for example, may have less retail monopoly power, disrupting its geographical franchise, and the regulator might allow the utility's rate of return to vary within a larger range, based on the utility's performance in accommodating active customers.

Even with a new compact, utilities would still have to adhere to certain restrictions and conditions. "Just and reasonable" rates will continue to be a regulatory criterion with the following features: (1) the provision of affordable service to utility customers, (2) rates reflecting only the prudent costs of a utility, (3) rates aligned with the utility's cost of serving different groups of customers and providing different services, (4) sufficient utility revenues to attract new capital and satisfy minimum financial standards, (5) prohibition of undue discrimination against any customer class or service (e.g., rates should never fall below short-run marginal cost), and (6) in competitive markets, approval of any price voluntarily transacted between a buyer and a seller. But the utility in a transformed industry would likely have different functions and obligations, including the separate treatment of active and passive customers.

One modified obligation of utilities would be to accommodate active electricity customers without compromising core regulatory objectives. For example, regulators should require utilities to facilitate the dissemination of the latest technologies to maximize their value to retail customers. The capability of the utility distribution system should satisfy the distinctly different customers' demands. Utilities would assume the function of coordinating the flow of electricity on their systems so as to accommodate power flowing through multiple paths and

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[54] The topic of residential rate design for distribution services is getting increased attention all across the U.S. Filings have been made in a number of jurisdictions to change the design for residential customers to improve recovery of fixed costs. And there are now many papers, articles and whole conferences devoted to this topic.

There are many different ways to design a demand charge. A major choice that must be made is whether to base it on a coincident peak (CP) demand or a non-coincident peak (NCP) demand. The CP demand measures the individual customer's demand at the time of some system peak. This could be the system peak for the electric utility or the peak for the independent system operator. The hour of the system peak is identified and the kW demands of each customer during that hour are measured.

[55] The oft-cited "regulatory compact" connotes an implied agreement between the utility and the regulator: The utility will provide affordable, reliable, universal service in exchange for the exclusive right to serve customers in a geographic territory at an authorized rate of return.

maximize customer value. New technologies can help achieve this outcome more economically. In this transformed industry, innovations that create new products and services offering customers greater convenience, control, value, and participation will be in demand. The emphasis on consumer empowerment will entail new, value-added services, new pricing options, self-generation, choice of electricity sources, and real-time information. The question then turns to, how can innovation foster these developments?[56]

Another obligation of utilities, which regulators would have to monitor, is to assure third-party providers that utilities will not erect undue obstacles. These obstacles, which disproportionally harm active customers, can include restricted access to the utility distribution system, excessive interconnection costs to third-party service providers and undue discriminatory pricing.

To promote the public good, regulators need to distinguish between artificial obstacles and natural obstacles. For example, a natural obstacle is a customer's rational response to risk and customer uncertainty over the future economics of DG. An artificial obstacle could include regulatory rules that unduly discourage utilities from accommodating DG, entry barriers to DG providers, or distorted price signals to consumers that make DG less economically attractive. Regulators should always try to mitigate artificial obstacles, which by definition derive from market imperfections or flawed regulatory practices and policies, as long as the benefits exceed the costs of mitigation. Mitigating natural obstacles, on the other hand, would invariably fail a cost-benefit test. In the U.S., stakeholders often plead to eliminate obstacles that allegedly disfavor their preferred technology or source of energy. Frequently, these obstacles are simply normal market conditions whose elimination would involve a cost (e.g., via subsidies) greater than the benefits. One example is overpaying DG customers for electricity they sell back to their utility. Although stimulating development, such a practice would result in overinvestment in DG as well as higher rates to non-DG customers.

2.9 The primary objectives

Regulatory actions require adherence to core regulatory objectives, irrespective of how the electric industry evolves. According to many observers, the ultimate objective of regulation is to maximize the long-term welfare of all customers collectively. Violating these objectives would jeopardize the public interest. Whereas in the past, regulators emphasized customer protection, in the future the focus will ostensibly shift to assure customers that they receive the highest possible benefits from new technologies and that passive customers are protected from undue discriminatory practices. This means that utilities refrain from erecting excessive barriers to third-party providers and that they invest in those technologies that efficiently accommodate the desires of active customers.

[56] Some observers see as inevitable the transformation of the electric industry from a rigid, unidirectional centralized system to a more flexible, networked system. *See*, for example, AEE Institute 2015; and Electric Foundation Institute for Electric Innovation 2015. While this transformation may occur, its timing and scope will vary by state and utility. Some states, like California, Hawaii and New York, will be leaders while others will follow; at least that is what we observe today in the U.S.

Core regulatory principles applied for decades in the U.S. are as follows:

(i) *Maximization of aggregate customer welfare:* for example, maximizing the value of new technologies to all utility customers, active and passive; or maximizing what economists call consumer surplus;[57]
(ii) *No cross-subsidization funded by passive customers:* for example, no cost shifting as a result of utility non-recovery of fixed costs from active (e.g., DG) customers;
(iii) *Rates include only prudent utility costs:* for example, economical investments for serving active customers[58]; and
(iv) *Reasonable utility returns from accommodating active customers:* for example, aligning utility returns with risk; this may require performance-based regulation (PBR).[59]

2.10 Options for accommodating active customers

This section addresses in more detail the options that utilities have to best accommodate active customers while at the same time protecting other customers. It covers such topics as the role of utilities versus third-party providers, ratemaking, and service unbundling. Utilities may need to evaluate their current business model as well, in addition to revamping their distribution system to function as a platform that facilitates 2-way electricity flows between large numbers of market participants. Regulators may want to consider giving utilities stronger incentives for the development of new technologies and their dissemination to customers.[60] What is important in an active-customer world is that utilities facilitate the dissemination of new technologies marketed by third parties to retail customers. Regulators should view barriers to economical decisions by utility customers to control their electricity usage and their source of electricity as artificial (as defined previously) and antithetical to the public interest.

2.10.1 The regulatory principle of balancing

U.S. regulators apply uniform generic approaches to decision-making. First, they ascribe to what analysts and practitioners referred to as the "balancing act" of regulation.[61]

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57 Consumer surplus measures the value customers received from a product or service minus the monetary and nonmonetary (e.g., search costs) outlays. With new technologies, for example, consumer surplus, conceivably, could increase because of (a) reduced prices, (b) the availability of additional services (e.g., value-added services) and (c) an increase in the quality of service.

58 That is, investments satisfy a cost-benefit test.

59 A results-based regulatory model shifts the emphasis of regulation from the reasonableness of historically incurred costs to the pursuit of long-term customer value. Regulatory incentive plans allow for shifting the focus from inputs to outputs. Especially appealing is the notion that a primary criterion for utility revenues is its relationship to the value that customers receive from utility service. Implementing such regulation to produce desirable outcomes poses serious challenges for regulators. *See*, for example, Costello 2010.

60 Traditional regulation provides less-than-robust incentives for utilities to adopt new technologies and other innovations.

61 In the U.S. state utility regulators attempt to balance the rights of utilities and their customers by considering three major factors: (a) *legal constraints*—for example, utilities have a right to be given a reasonable opportunity to be financially viable, and customers have a right to just and reasonable prices; (b) *the*

Regulators attempt to balance the interests of the different stakeholders with the overall objective of promoting the general good.[62] At least, that is the premise behind the public-interest theory of regulation.[63] Terms like "fairness" and "just and reasonable prices" have subjective connotations that challenge regulators to balance the dual objectives of fairness and economic efficiency and other objectives. Regulatory actions, according to the traditional version of the balancing act, try to assure customers that they receive safe and reliable service at just and reasonable rates.

In today's environment, balancing has become more complex, taking into account (1) utility competitors (e.g., DG providers) wanting a "level playing field" (or an unlevel field favoring them), (2) customers wanting lower prices and reliable service, (3) utilities wanting rates that allow them to be financially healthy, (4) environmentalists and some customers wanting clean energy and energy efficiency, and (5) some customers wanting more control over their electricity usage and the price they pay for electricity.[64] Trying to accommodate these diverse and, in some instances, inherently conflicting objectives poses a tough task for regulators. Historically, regulators have tended to emphasize the longer-term consequences of their actions, rather than trying to appease the immediate demands of stakeholders. In the U.S., this has become more difficult over time as stakeholders have increased in number and placed added pressures on regulators to favor their agenda.

U.S. regulators have struggled with trying to advance both core (i.e., traditional) and new objectives. Core objectives include fairness, economic efficiency, service reliability and safety, and financially healthy utilities. New regulatory objectives, related to energy efficiency, clean energy, active customers, renewable energy and affordable utility service, in addition to an expanded regulatory agenda, have made ratemaking more complicated. This is especially true in trying to continue satisfying the core objectives underlying "just and reasonable" rates. Regulators must make additional tradeoffs, as new objectives often conflict with the core objectives.

U.S. regulators implicitly make decisions by weighing different objectives to advance the public interest. Utility regulation has always involved compromising different objectives. For example, to improve economic efficiency via marginal-cost pricing, how much would rates increase for certain customers? Is the outcome fair to those customers and in the public interest? How much would economic efficiency have to increase to compensate for the higher

regulator's perception of fairness; and (c) *compatibility with a broader interest.* Regulators try to balance the interests of the different stakeholders with the overall objective of promoting the general good.

62 In other words, regulators show no undue favoritism or discrimination toward any stakeholder.

63 This paper assumes that good regulation requires utility regulators to make decisions that are in the public interest. It performs no analysis on whether regulators actually attempt to pursue this objective. The economic literature is replete with theoretical and empirical studies showing that utility regulators may lean more toward serving politically powerful interest groups than the general public. The author leaves it up to reader to judge the validity of these studies.

64 The "balancing act", with the goal of trading-off stakeholder interests or objectives, resists a "corner solution" where regulators completely ignore certain objectives at the expense of the general public.

rates?[65] No single rate mechanism is superior, for example, to other mechanisms in advancing all of the regulatory objectives. Regulators therefore need to prioritize the objectives, and implicitly assign weights to these objectives in their decision-making. For DG, the salient conflict is between fostering a clean energy source via a subsidy and being fair to core customers who have no desire to produce their own electricity. Other conflicts arise when regulator try to balance the interests of active and passive customers.

Finally, as emphasized in this paper, regulators need to make trade-offs when advancing different objectives. Regulators also need to process the information they receive from different stakeholders in a logical way, as well as interpret the information correctly, to arrive at a good decision. They have to account for the inevitable tradeoffs in addition to assessing the public-interest effect of individual rate mechanisms. A regulator's decision is akin to purchasing a car, where a person must balance power, safety, fuel economy, appearance, maintenance costs, purchase price, reliability, and other features to reach a decision that gives her the greatest satisfaction.

Similarly, the regulator needs to make decisions that account for multiple objectives, some of which are conflicting and non-quantifiable.[66] This task is admittedly difficult, requiring a combination of unbiased information and good judgment to reach sound decisions in the public interest.

Finally, regulators face the uncertainty of outcomes. Different stakeholders present to them ostensibly biased information favoring their interests. Regulators must distinguish biased information from unbiased information.[67]

2.10.2 Radical versus incremental approach

Ontario is stressing incremental action in electric-industry transformation that seems to coincide to date with the posture of most U.S. states. This position reflects (1) hesitancy toward making major changes in a world of high uncertainty and (2) the willingness to learn (or the preference for learning) from the experiences of so-called leading jurisdictions. Utilities and states/provinces do not have to be leaders in supporting new technologies and business innovations, especially those whose future values are in doubt. As free riders, they can learn from the experiences, both positive and negative, of so-called leading jurisdictions. The followers can view activities in states like California and New York as a public good. This posture seems rational in view of the highly uncertain future of most new technologies and the state of the electric industry.

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65 As another example, how much would rates have to increase to general ratepayers to make utility service more affordable to low-income households? Would the increased rates more than offset the benefits of lower-priced utility service to needy households? From a cost-effective perspective, the relevant question is: How can regulators make electricity affordable to low-income households in the least costly way? *See*, for example, Costello 2009.

66 A regulator's decision is more difficult than the prospective car owner in that the latter has more precise quantifiable information that is less conjectural.

67 Even when the information presented is unbiased, almost all predictions have inherent uncertainty (i.e., are susceptible to error).

The favored position in the U.S. as of today is that the utility of the future will have a radically different role and business model than what exists today. If that is true, then state utility regulation will have to align its policies and practices with this vision. A contrarian position is that it is presumptuous to say for sure that the industry will change dramatically, notwithstanding the trend toward so-called game changers in the form of renewable and distributed energy, energy storage, and the inexorable movement toward clean energy. This position has credibility as we have learned from the past that expected events, for various reasons, often fail to transpire. A transformed industry, as we have seen for U.S. electric-industry restructuring that was initiated in the 1990s, may happen in some states but not in others.

2.10.3 Functions of utilities versus third parties

Utilities can assume different functions in growing DG. They could provide services to both their core (i.e., full-requirements) customers and DG customers. The services for DG and other active customers will include enhanced services that utilities did not provide previously. Regulators have discretion over what products and services utilities can sell. Their decision rests on what functions they envision utilities to performing. Three alternatives are "platform" facilitator and operator ("traffic cop"), service provider,[68] and "wires" provider.[69]

One middle-of-the-road option is for utilities to interact with DG customers as a partner with third parties. In this role, utilities primarily act as a facilitator of new technologies and service offerings by exploiting their engineering and other expertise. An example of a partnership is the utility entering into a commercial arrangement with a third-party, who would develop and build a DG facility. The utility could then sign a long-term lease or operating agreement with the third party. A second example would relegate the utility's role to working with a vendor or customer to facilitate the application of a DG technology.

Utilities could also invest themselves in DG facilities and electric-vehicle recharging stations, for example, and rate-base them to earn a profit.[70] One concern with this approach is that all utility customers would pay for the investments even though the benefits may flow to a relatively small number of customers (e.g., active customers). Alternatively, utility shareholders could initially fund these investments and recover the costs from DG customers over time. A third option is for utilities to form an affiliate that provides DG services.

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68 Some utilities have already invested in solar PV to improve their earnings. Others are considering additional services to offer their DG customers.

69 *See*, for example, Aspen Institute 2013; Bipartisan Policy Center 2013; Lehr 2013; New York State Department of Public Service 2014; and Rocky Mountain Institute 2013.

70 One rationale for utility investments in electric-vehicle recharging stations, for example, is market failure; that is, the private sector, for whatever reasons, would under-invest in recharging stations. In a more facilitative role, a utility could help stimulate electric vehicles by expediting permitting and installation, in addition to offering time-of-use rates for electric-vehicle charging. The market-failure argument would seem to hold less for the DG market, which has attracted a large number of vendors, installers and other market providers.

2.10.4 Ratemaking reforms

One topic under vigorous discussion in the U.S. relates to cost recovery and funding for expensive new investments, some of which are directed at active utility customers. There are five aspects of cost recovery (e.g., rate-basing capital expense): timing of recovery, method of recovery, customers responsible for recovery, criteria for recovery, and the accounting treatment of costs. Each of these aspects affects the willingness of utilities to invest in technologies and services targeted at active customers.

Two main questions for regulators are: Who should pay for new investments benefiting active customers, and how should utilities recover their costs? When a new technology benefits only a portion of a utility's customers, the regulator should consider what the responsibilities are for separate customer classes. Should all residential customers bear the risk of a new technology that benefits only active customers? As a rule, customer groups who benefit the most should pay more of the costs. In some U.S. jurisdictions, utilities recover the costs of new smart meters through the customers' distribution charges. Complaints have come from some customers who see little benefit from these meters.

One issue related to utility incentives to adopt and invest in new technologies involves the recovery of stranded assets. The typical book-depreciation practice in the U.S. tends to discourage utilities from replacing existing physical assets with new technologies because of stranded costs. When depreciation rates are set too low, the depreciation period can extend beyond the economic life of an asset. In such an instance, the utility encounters technology risk by suffering a financial loss if it were to replace the asset at the end of its economic life (*See* Kahn 1991). One response to this problem is to allow the utility to use accelerated depreciation. This would improve the utility's cash flow in the early years of an asset's life, which can help finance new technology. Accelerated depreciation, though, increases the burden on customers by increasing their rates in the short term. This may be one reason why U.S. regulators have not looked favorably upon accelerated depreciation, along with the fact that it shifts risk to customers.

2.10.5 Exploiting differences in customer preferences

Utilities can exploit customer differentiation of demands on utilities, for example, through smart technologies by offering individualized value-added services at a profit. They can behave like airlines, in other words, in differentiating their services to earn higher profit margins from their customers. Although reflecting discriminatory pricing, this action can enhance the utility's incentive to provide additional services that active customers may be willing to purchase.

As an illustration, *priority service* is a form of product differentiation in which the market segments into different groupings. Those customers willing to pay higher prices gain higher priority in receiving the product or service. Priority service is a rationing scheme for curtailing excess demand in the event of deficient supply, where both efficiency and equity are factors. The theory of efficient rationing suggests that allocation should be according to customers' valuations of service.

2.10.6 Access to the utilities' distribution system

One option to foster active consumerism is to transform the utility distribution system into a platform. This option is being seriously discussed in several states. "Platform" refers to a system that supports interactions among multiple parties, and establishes a set of rules that facilitates transactions among multiple parties. A platform can increase innovation and competition by: (1) reducing transaction costs, (2) increasing transparency, and (3) enabling the enhancement of integration benefits that will grow as additional diverse suppliers and new technologies (e.g., storage, plug-in electric vehicles) enter the market. Industry observers label this role of utilities as a smart integrator, facilitator, or orchestra leader (*See* Rocky Mountain Institute 2013).

2.11 A new utility business model

2.11.1 Rationale for a new business model

Regulators might want to advance a new utility business model. The new model can allow utilities, for example, to profit from offering distributed generation services or owning PV solar systems, while maintaining a competitive marketplace that precludes them from having an unfair advantage.

The recent dialogue in the U.S. on the electric utility of the future has focused on whether the existing business model is sustainable, given the prospects for the rapid development of solar PV and other DG technologies.[71] A threat to utilities can start with sales losses to DG and, subsequently, an inexorable struggle to recover fixed costs from fewer customers. Price increases aggravate utilities' problem of yet more customers switching to DG. The prevailing business model in use today derives from market, consumer, and technological attributes of the electric industry that may not exist in the future.[72]

2.11.2 Attributes of a good business model

The late management guru Peter Drucker (1954) commented that a business model answers the following questions: Who is your customer, what does the customer value, and how do you deliver value at an appropriate cost and at an acceptable profit? A business model therefore concerns how a company (i) creates value for its customers through its operations,

[71] We observe in the U.S. that some utilities would prefer, at least initially, to take a defensive stance by erecting barriers to DG development and advocating for ratemaking reforms that assure their financial viability. The latter action could include charging DG customers a special fee, implementing revenue decoupling, and shifting recovery of fixed costs to the customer or demand charge.

[72] These attributes include one-way power flow, utility profitability tied to electricity sales and rate basing, exclusively passive customers, economies of scale and scope in utility operations, and limited integration of third-parties providers into the planning and operation of the distribution grid.

products and services, and (ii) generates sustainable operating and financial performance.[73] A business model focuses on the utility's products and services, their value relative to their cost, and how efficiently and effectively the utility creates, produces, delivers, and supports those products and services in their franchised area. The utility business model should have three qualities. First, it should adapt to new technological and market developments. For example, utilities as "platform" operators should accommodate DG that technological changes have made economical to utility customers.

Second, a business model should support traditional regulatory objectives including: cost-based rates, fairness across different customer groups, highly reliable service, and just and reasonable rates. Notwithstanding major changes that might evolve in the electric utility sector, long-held regulatory goals will still hold a high standing.

Third, the business model should satisfy predetermined broad social objectives (e.g., affordable electricity to low-income households, clean energy). For example, changed conditions might require a different business model in which utilities would have more opportunities to exploit the benefits for themselves and society from the improved economics of DG and other technologies. A utility can then take a more proactive role, rather than a defensive posture where they see new technologies as a threat to their long-term financial viability.

The prime rule behind selecting the appropriate business model is that it should help to enhance utility performance to conform with society's demands reflected through public policies, market conditions, current technologies, and customer behavior and preferences. For example, one desirable outcome may be to maximize competition in the delivery of efficient energy services over a newly formed (i.e., revamped) distribution-grid platform.

A last point is that regulators should consider aligning their policies with the selected business model.[74] The regulator together with the utility and other stakeholders could concur on the preferred business model. The connection between policy objectives, utility strategies, and regulatory practices should follow a logical order: Objectives lay the foundation for how a utility plans and operates, and the regulator provides incentives, imposes mandates, and oversees utility activities. The ideal outcome is a regulatory solution that best promotes the public interest and achieves the objectives set out by regulators and other policymakers. One of these objectives should be the maximization of the aggregate economic welfare of active and passive customers.

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73 Drucker advised that in reviewing whether to change their business model or other aspects of their business, companies should start by asking five basic questions: "What is our mission? Who is our customer? What does the customer value? What are our results? What is our plan?" Electric utilities, in addition to satisfying their customers and shareholders, must also appease policymakers who prescribe their broader social responsibility. In the context of this paper, the question relates to what business model would best maximize the long-term interests of active and passive customers collectively.

74 When regulatory policies fail to align with the business model, the utility may deviate from its strategy to achieve the predetermined objectives. One example is a business model that accommodates DG but regulation gives no incentive other than to penalize a utility if it falls short of expected performance. A second example is an attempt to achieve fair competition for DG in the absence of any code of conduct rules that would prohibit a utility from favoring affiliates over third-party DG providers.

2.12 Technology advances and R&D

2.12.1 A digression on R&D

The main benefit of R&D is to advance the current state of technology. R&D can play a critical role in nurturing new technologies during their initial stages of commercial application so that they become more prominent in the future. When a new technology becomes commercial, it can still benefit from further R&D to hasten its diffusion in the marketplace. For example, additional R&D and technology improvements will be needed for solar power to become mainstream by mid-century.

In the public utility sector, technological change has the additional value of fostering policy objectives. For some industry observers, the absence of breakthroughs in energy technology will preclude major strides toward attacking global warming in an affordable way (*See* Sivaram and Norris, 2016). R&D can also spawn new technologies that will particularly benefit those customers who want more choices, and control over their electricity usage and the price they pay for electricity.

2.12.2 The effect of public utility regulation

Various features of public utility regulation affect how much and how utilities make R&D/innovation investments. They include the tightness of regulation, regulatory commitment, degree of information symmetry, cost recovery, allocation of the benefits, and risk incidence. For example, depreciation policy can help ensure recovery of invested funds over the economic life of the physical capital. When depreciation rates are too low, with depreciation stretched out over too many years, a utility may find it uneconomical to replace old equipment will new equipment. The costs would be particularly high in a dynamic environment in which new technologies promise large benefits to society. Allowed deprecation rates can therefore have a large effect on R&D and technological progress.

As another example, a regulatory practice of splitting the benefits of a new technology between utility customers and shareholders can booster the efforts of utilities to invest in R&D. Otherwise the benefits to utilities may be deficient relative to the risks they would bear. A third example is the regulatory commitment to R&D, reflected in guidelines, rules, or individual rate-case decisions, can lower the risk to the utility, thereby making R&D more attractive.

The economics literature has devoted relatively little attention to regulated firms' incentive to engage in R&D, and develop and adopt new technologies.[75] Nevertheless, the standard narrative is that regulation tends to make utilities cautious about innovating and taking risks. The common thinking is therefore that utilities fall short in their R&D activities and deployment of new technologies. Utilities tend to underinvest in R&D and new technologies that have public benefits or threaten their monopoly status. Especially for the latter reason, regulators need to be vigilant that utilities do not "squash" those technologies that threaten their

[75] Two publications do offer analysis on this topic: Bailey 1974; and Berg and Tschirhart 1988.

financial health but are in the interest of their customers. The consequences can be particularly harmful for active customers who could benefit the most from those technologies.

2.12.3 Regulatory tools

Regulators have access to a number of tools to bolster R&D/innovation. In advancing the interests of active customers, innovation becomes imperative. Utilities can be either creators or users of innovations.[76] An increasingly important function of public utilities will be to act as a conduit for filtering the benefits of innovations developed by third parties to retail customers. After all, most innovations that benefit utility customers had their beginnings outside the utility space. Utilities' ability and willingness to play the role of "innovation" adopter depend on regulators creating a favorable risk-reward environment.[77] If utilities believe that innovations will not improve their financial condition, they will be less inclined to deploy them for the benefit of their customers.

As a cardinal rule, any utility, or any company for that matter, will find R&D/innovation financially attractive when it expects profits to compensate it for the risk it bears.[78] One guide is to ensure that the risk-reward relationship aligns rewards with utility risks.

Although the net effect of regulation on R&D/innovation is difficult to assess, the consensus among industry observers leans toward the negative. The conditions required for non-regulated firms to innovate seem to be lacking for utilities. For example, why should a utility make an extra effort to innovate when most of the benefits will go to customers or society?

The major regulatory tools to bolster R&D/innovations either try to increase the expected returns to utilities or reduce their risk. The following is a list of tools that regulators can consider:

(i) Variations of Rate of Return (ROR) regulation such as economic depreciation[79] and risk-adjusted returns[80]

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76 Companies are often users of new technologies rather than creators. For example, they tailor new technologies created by others to their specific needs and situation. Public utilities, historically, have not been prolific inventors of new technologies. Instead, they commonly integrate into their network new technologies developed by third parties.

77 As an adopter, utilities do not have to be the creator of a new technology; they can simply acquire and use the technology for the benefit of their customers.

78 The inherent features of R&D pose challenges for a private for-profit company. It is expensive, for example, with costs commonly incurred several years before a company can reap profits or other benefits. R&D by nature is risky and success is difficult to predict. Innovations starting with R&D often require long lead times between basic science and commercial deployment. External parties can also appropriate the benefits. New knowledge is especially appropriable, unless one has acquired patent protection. These features of R&D imply two things. First, companies are unlikely to innovate unless the payoff from successful innovation is substantial. Second, the market may under-allocate resources to R&D, providing a rationale for government funding.

79 *Economic depreciation* = d - i + a, where d = wear-and-tear or physical depreciation rate (e.g., number of units of output from a machine declining at a rate "d" over time), i = inflation rate, and a = technological change. Under

(ii) Price caps[81]
(iii) Focused incentives (e.g., financial reward for successful innovations)[82]
(iv) Profit or benefit sharing (e.g., utilities retain benefits of a new technology for 5 years)
(v) Regulatory lag[83]
(vi) Limited retrospective reviews[84]
(vii) Planning (prospective) process[85]
(viii) Regulatory commitment[86]

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traditional ROR regulation, utilities lack incentive to retire old capital and replace it with new capital incorporating the latest technology. They are susceptible to stranded costs when the allowed depreciation rate is below economic depreciation. One reason is that ROR regulation under-depreciates certain assets by ignoring technological progress.

80 Regulators can allow higher returns for investments, like new technologies, with higher risks.

81 In its purest form, a price-cap scheme regulates a utility's prices but not its profits. Price caps generally allow utilities to earn higher profits. Compared to ROR regulation, a price-cap scheme also imposes higher risk on the utility. The focus shifts from "inputs" to "output," which in theory should improve the utility's interest in deploying innovation to serve customers.

Price cap regulation typically permits revenues to diverge from realized costs for a specified period of time (e.g., four years), but does not promise specific long-term returns on investment. Although such a scheme is able to provide strong incentive for short-term innovation and cost reduction, it may provide limited incentive for long-term infrastructure investment. The choice between ROR regulation and price cap regulation will therefore depend in part on the type of investment being considered.

82 Incentive-based regulation puts some risk on the utility, but it also allows the utility to benefit from "successful" outcomes. Designing a properly structured incentive mechanism is challenging but important to avoid distortive outcomes. *See*, for example, McDermott et al. 1992. The authors make the observation that "an incentive may be necessary to encourage adoption of a new technology at the same time another incentive is needed to maintain cost control of the innovative project." [at 27]

83 Regulatory lag has a similar effect that patents do, by allowing a company to retain the benefits from innovation over some reasonably long period. It is defined as the delay between an event that changes a utility's costs or revenues and the utility's subsequent change to its rates. Regulatory lag has a mixed effect on utilities' willingness to innovate: Lengthening the time allotted for utilities to recover their costs increases their financial risk; but lengthening the time allotted for utilities to retain the benefits improves their financial condition. ROR regulation, like "cost-plus" contracts and other similar transactions, typically provides limited incentive for innovation and cost control.

84 Retrospective reviews probably have caused utilities to favor low-risk investments, especially if they face bounded opportunities to earn high profits. Limited retrospective reviews mean scrutinizing the prudence of utility decisions leading up to an outcome but no second-guessing based on outcomes alone.

85 Regulators might consider, for example, evaluating new technologies in the context of integrated resource planning (IRP). Several states require both electric and gas utilities periodically to submit integrated resource plans. As a prospective review, IRP allows the regulator and non-utility shareholders to compare new technologies, before the utility commits to them, with other options on a so-called "level playing field." IRP has particularly bolstered energy efficiency and DG because it requires utilities to review, on an equal basis, these options along with traditional supply-side technologies.

86 Regulatory commitment can be full, partial or none. Partial may involve, for example, the regulator pre-approving a project. Any imprudence in utility decision-making affecting completion of the project is still subject to disallowance. Completely eliminating the risk to utility shareholders would tend to overly blunt utilities' incentive to contain the costs of "innovation" projects and carefully evaluate their economics. In general,

(ix) Explicit rules (e.g., a utility should recover all prudent costs for pilot projects even if they are unsuccessful[87])

(x) Policy guidance (e.g., guidelines on pilot programs; commission policy on utility innovation)[88]

Elimination of undue barriers to third-party providers would also help bolster R&D/innovation. The utility's presence in the DG market, for example, can discourage the entry of third-parties. The utility might have cost advantages because of economies of scale or scope, or, instead, have a contrived foothold from erecting barriers to third-party participation. Two examples of the latter condition are overcharging DG customers for utility grid services and discriminatory actions toward third-party DG entities. Regulators should ask themselves: How can we guarantee an economic level playing field between utility-owned and third-party DG facilities? Utility ownership (or via affiliate) would require regulatory rules to ensure non-discriminatory access by third parties wanting to enter the DG market in the utility's service territory and compete with the utility. Cost-shifting and other problems can emerge that regulators will have to address in rules.[89] On the other hand, imposing undue restrictions on the utility or its affiliate can prevent them from investing in DG even when they are the preferred provider from customers' perspective.[90]

The debate over utility involvement entails three basic questions that regulators will need to answer. First, what are the criteria for determining whether a utility or its affiliate can participate in a market that is workably competitive? Second, if the regulator approves utility participation, what limitations should the regulator place on the utility to compete? Third, should utility core customers pay for any of the utility investments in the non-regulated market or should utility shareholders fund the investments? Answers to these questions affect the welfare of both active and passive utility customers. Active customers benefit from more competition, and passive customers from prohibitions against cost-shifting.

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regulators satisfy their duty to protect customers from excessive costs through substantial oversight of "innovation" programs and the traditional regulatory prerogative to examine a utility's books and management and potentially disallow imprudently incurred costs.

The U.K.'s approach under its "innovation" stimulus program requires shareholders to bear a portion of project costs, with refunds based on meeting predefined success criteria. Italy also has incentive-based regulation by offering higher returns on invested capital for competitively selected "innovation" projects.

87 For example, regulators should require utilities to assume reasonable risks, but encourage them to innovate by willing to pass at least some costs of failures on to their customers.

88 One study (Concentric Energy Advisors 2014, 1) identifies what seems like a reasonable policy statement: "Utility regulators should provide crucial guidance and oversight and establish evaluation criteria (e.g., clear standards) that include customer benefits from innovative investments."

89 Cost shifting is not necessarily anticompetitive. It always has the effect, however, of raising the prices of regulated services. Yet it might have minimal effect on the unregulated or workably competitive market: It can simply allow the utility to increase its profits by cost manipulation, rather than predation or other strategies giving its affiliate an unfair advantage over competitors.

90 By serving DG customers, for example, a utility might lower its average cost for information technology activities, general personnel, billing, and metering. The result is a lowering of the utility's average cost, which benefits all customers, both core and DG customers.

2.13 Lessons from the U.S.

One important topic in the U.S. is the role of utilities versus third-party providers. Two other hot topics, which we previously discussed, are ratemaking and the unbundling of utility services and products. As we discussed, utilities may also need to evaluate their current business model and modify their distribution system to function as a platform that facilitates two-way electricity flows between large numbers of market players.

This section summarizes the evidence and experiences in the U.S. that relate to the success of utilities and regulators trying to balance the interests of different stakeholders in accommodating active customers. In the U.S., for example, some customers have available time-varying and other rates that allow them to better manage their electricity usage. Some customers also have access to third-party retail providers and have installed distributed generation (Morey and Kirsch, 2016). This section also identifies the major obstacles erected by utilities and regulators that have hampered customer activism. Regulators need to distinguish between those undue obstacles and obstacles that reflect normal market dynamics. The policy implications are fundamentally different.

2.14 U.S. experience to date

One professed benefit of a transformed electric industry is that it would empower utility customers to become more active participants in the marketplace. Do customers, especially residential customers, desire to be more engaged, or do they just want reliable service at reasonable rates? We know from the U.S. experience that transaction costs would have to be minimal for small customers to switch electricity supplies, including to DG, or to manage their usage.

Ontario can learn from the experiences of both electric and natural gas retail competition where the vast majority of eligible residential customers have decided to continue receiving their total service from the local utility (Morey and Kirsch, 2016). Also, for both electricity and natural gas in the U.S., there is little interest to expand retail competition to other states. Drawing from these experiences, the typical residential electricity consumer may have little interest in DG: The average cost savings are small relative to income, so we can infer that few residential customers would expend the time and effort required to make a well-informed decision on DG. Besides, most households, as they do with most of the products and services they consume, would seem to prefer to buy electricity rather than producing it themselves.

2.14.1 Diversity of positions across states

The growing consensus is that the U.S. electric industry will be undergoing a transformation over the next several years. Major developments in technology and energy policy point to potentially dramatic changes in the electric industry. While even this favored policy narrative among experts is no guarantee of the future, it is dictating the ongoing dialogue across the country about possible new actions at both the state and federal levels.

Some U.S. states have aggressively foster DER and smart grid technologies[91] while others view them as having little or even negative benefits.[92] We observe dissimilar stances among various states on the prospects for a transformed electric industry. It seems reasonable to predict that a few electric utilities will undergo a major facelift over the next few years, while others will see only incremental change. Each state faces unique economic and political conditions that would rationally lead them to pursue a different path for their electric utilities.

A reasonable approach is for regulators and other policymakers to hedge their decisions to account for uncertainty. A rational decision-maker would tend to respond to future unknowns by hesitating to taking major actions today. To the extent that waiting reduces uncertainty, utilities may enjoy an "option value" from an investment delay owing to this uncertainty. And so they might prefer waiting for new information that could reduce the risk of any decision.

A good example of diverse state responses is the electric industry restructuring that occurred during the 1990s. Many observers believed that restructuring throughout the country was inevitable. But we found that in restructured states, a major obstacle was the divergent visions that interest groups held about the electric industry's future. There was no solidarity of views about the industry's future. For the other states, restructuring was not even a topic of discussion or stakeholders reached a consensus of "no change." The present situation parallels that era: The dialogue over the utility of the future involves several interest groups with dissimilar views about the future path of the electric industry. Political and economic conditions also make it rational for states to make dissimilar decisions on the future of the electric industry. Some states may rightly prefer cautious action; their status as so-called laggard states can allow them to learn from the mistakes of leading states.

While a few states, such as California and New York, are proceeding boldly, most states have exhibited more caution. Many questions still remain before we can say with certainty that the electric industry will see a transformation over the next five to ten years. There is no denying that the prospect for big changes is a real possibility. Whether these changes will infiltrate the industry in a profound way across the majority of states remains to be seen. After all, many who are projecting change either have an ideological (even bordering on a quasi-religious mission), or monetary interests in promoting such a path. Regulators should therefore not accept these optimistic[93] or rent-seeking[94] claims for new technologies on face value but act

91 The smart grid represents an information- and communications-based technology that gives utility customers the opportunity to better manage their electricity usage and more actively participate in the management and operation of the grid. *See*, for example, Joskow 2012.

92 States taking the most proactive positions to date are California, Hawaii, Massachusetts, Minnesota and New York.

93 One area of optimism is that a massive number of residential customers will invest in solar PV systems. It is plausible that only a small minority of households care enough about lowering their electricity bills to spend a large amount of dollars upfront or even allow a third party to make the investment and install a system on their rooftop. After all, the average residential customer spends only about 2.7 percent of its before-tax income on electricity. (Bureau of Labor Statistics, *Annual Expenditure Survey*, 2012.) Experiences with retail choice, as discussed earlier, has also shown that the vast majority of residential customers would prefer staying with their current utility rather than switching to a third party even at the lost opportunity to lower their electricity bill.

accordingly to a future that may, but not with certainty, turn out much differently than what the consensus predicts today. This posture has implications for what course of action regulators should take today and in the immediate future versus waiting to see what evolves over the next few years.

The overall question for state utility regulators is what actions they should pursue in view of these prospects for dramatic change in the electric industry.[95] Should they take the lead in proposing changes in utility operations and the business model, and in how they regulate? Should they, instead, wait longer to see what transpires in technology development, and regulatory and energy/environmental policies in other states and at the federal level? What are the costs of staying with the current utility business model and regulatory practices if radical changes occur? At the other extreme, what are the costs of reshaping regulation and the utility business model when the expected changes fail to transpire? Will an explosion in distributed generation be confined to a few geographical areas, or will it permeate across most states?

2.14.2 The job of protecting passive customers

Throughout its history, U.S. regulation has given special attention to vulnerable customers when competition creeps into the retail market. A major regulatory concern that consumer advocates will constantly remind regulators about is that passive customers should not bear any of the costs of new technologies that do not directly benefit them. That is, a major regulatory objective should be to hold passive customers harmless when utilities make investments and incur other costs to accommodate active customers.

2.14.3 Balancing utility, DG and core customer interests

Reaching agreement on ratemaking issues (i.e., a political equilibrium) requires a balancing of interests, where each stakeholder has to compromise on its preferred choice for the public good. Stakeholders in many states are struggling with things like (1) compensation from the utility for surplus rooftop solar PV power, (2) compensation to the utility for grid services provided to DG customers, and (3) the optimal use of smart meters for pricing. These matters are complex partially because of their "fairness" implications and their potential to radically change ratemaking practices.

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94 Some analysts contend that the same condition accounts for both the recent push for distributed generation and support for retail competition in the 1990s; namely, that average cost exceeds marginal cost in both periods, meaning that utility customers benefit from bypassing utility service (priced at average cost) and switching to another source (priced at marginal cost). Because of this pricing discrepancy, it is difficult to know whether bypass improves net economic welfare (i.e., economic efficiency). The effect is cost-shifting between electricity customers, rather than real cost savings. Lost utility revenues, when exceeding avoided costs, typically pass through to remaining core customers in the form of increased rates. This contention basically says that customers want to avoid utilities' sunk costs by having the right to choose another supplier. The logical remedy is to set utility retail rates based on marginal or incremental cost. *See*, for example, Borenstein and Bushnell 2014.

95 States differ on the authority of the state utility commissions to initiate changes that would transform the electric industry. In several states, commissions see their role as narrow, restricted to enforcing any policy changes or other mandates established by the legislature.

The most serious obstacles, at least in theory, to accommodating active customers are utilities' unwillingness to fully exploit new technologies, discriminatory pricing practices (e.g., fixed rates) and onerous utility restrictions.[96] The defensive posture of some utilities to protect their short-term profits may temporarily avert short-term financial distress but not long-term problems. As one article warns, while in the short run these actions can insulate the utility from solar PV competition, they may create "substantial medium- and long-term risks, including those of customer backlash, deferral of adaption, and stimulation of enhanced competition" (Graffy and Kihm 2014, 60.).

As an illustration, utilities can adopt different pricing strategies to protect their financial interest. One strategy is what economists call "myopic pricing," where the utility attempts to maximize short-term profits or minimize short-term losses but at the risk of suffering lower market share over time. Another strategy called "limit pricing" would involve the utility setting a price that is low enough to discourage fringe suppliers or new entrants. In the first strategy, the utility would tend to recoup its losses from customers departing to DG by charging higher prices to core customers. The risk is that the higher prices will lead some of those customers to invest in DG. Limit pricing, while discouraging some customers to invest in DG in the short term, may produce large losses to the utility over an extended period. One way around the latter problem is for the utility to first identify those customers who are most inclined to invest in DG, and then to offer them a special or discounted rate. Other customers could pick up the revenue losses from the discounted rates. Regulators may, however, frown upon such discriminatory pricing.

The evidence to date on retail customers choosing third-party suppliers and responding to time-varying and other non-traditional pricing reveals a highly passive market (Morey and Kirsch, 2016).[97] Small retail customers exhibit inertia in their preference toward bundled utility service and flat rates. Unlike Ontario, no U.S. jurisdiction requires utilities to offer residential customers time-varying rates as the default option.[98]

2.14.4 Regulatory vigilance on new technologies

New technologies may be disruptive by eroding the monopoly status of utilities. A big challenge for regulators is to identify those new technologies that are in the interest of utility customers but contrary to the utility's financial interest.[99] As mentioned before, utilities have incentives to impede the development of new technologies that threaten their monopoly status.

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[96] Restrictions on the ability of network operators (i.e., utilities) to realize the full value of their investments also limit their incentive to innovate.

[97] Real-time pricing will incent customers to manage their energy usage and electric bills, stimulating innovation and new products that will further enhance customer opportunities and benefits. Such rate designs should consider the effect on customers (i.e., passive customers) that are least able or willing to change behavior and respond to price signals, and recognize that customers differ in their tolerance for price variability.

[98] Consistent with behavioral economics, studies have shown that when time-varying rates are the default option, the enrollment rate for residential customers is much higher. *See*, for example, Faruqui 2015.

[99] This is a reason why regulators should be proactive and not just accept utilities' proposals that one would expect to exclude those any new technologies that would harm their financial health.

New technologies providing an alternative to utility services, for example, can reduce scale economies, making entry feasible and thus limiting the market power of the utility.

2.15 What Ontario can learn from the U.S. experience

2.15.1 The good and the bad

The cautionary approach taken by most U.S. states for electric industry transformation seems sensible in light of the great uncertainty over where the industry is heading. Some states got burned in the 1990s when electric industry restructuring was in vogue. California was an example of a state that pursued bold reform but met with disaster as unexpected problems arose. Although innovators can receive great benefits, they also incur risk that can lead to regretful outcomes.

Some analysts contend that the same condition accounts for both the recent push for DG and support for retail competition in the 1990s; namely, that average cost exceeds marginal cost in both periods, meaning that utility customers benefit from bypassing utility service (priced at average cost) and switching to another source (priced at marginal cost). Because of this pricing discrepancy, it is difficult to know whether bypass improves net economic welfare (i.e., economic efficiency). The effect is cost-shifting between electricity customers, rather than real cost savings. In both transformations, lost utility revenues typically pass through to remaining core customers in the form of increased rates. This argument basically says that customers wanted to avoid utilities' sunk costs by having the right to choose another supplier. The result, if true, is that customer activism has been a zero-sum or even a negative-sum game.

2.15.2 Evaluating options from a regulatory perspective

The balancing-of-interests criterion has served U.S. regulators well throughout their history. They attempt to balance the interests of different stakeholders, given their legal mandates and the political environment to advance the public interest.[100] Regulators implicitly identify the objectives of ratemaking, weigh those objectives, and make the inevitable tradeoffs.

Today's contention by many if not most analysts that net energy metering unduly favors rooftop solar customers at the expense of core customers is under great scrutiny in many states. Also under review is the cost-shifting to core customers at the benefit of solar or other DG customers.

U.S. regulators are struggling with rate structures and other ratemaking issues. To date, they have yet to come up with a satisfying solution that meets with both utilities' financial needs and acceptance by customers and other stakeholders. Part of this challenge owes to the desires of some utility customers to self-generate and maintain more control of their electricity usage.

[100] Balancing can involve regulatory objectives rather than stakeholder interests, although both tend to overlap.

2.16 The preferred options for further review

2.16.1 Market-based versus regulatory approaches

Some new technologies may not survive in the absence of subsidies. That explains why their advocates will lobby hard to avoid ending them. The trouble with subsidies is that as long as they are in place, policymakers are unable to determine whether a new technology is net beneficial to society. Subsidies, most often, reflect an inefficient ratepayer or taxpayer-funded giveaway to narrow interest groups, rather than a remedy to a genuine market failure.

U.S. policymakers seem to slight the capability of the marketplace to achieve social objectives. Markets function best when private firms receive the returns and bear the risk from investments and other activities. Moral hazard[101] and socialization of risk are absent, as firms have the right incentive to invest and take other actions. Taxpayer/ratepayer subsidies (i.e., favorable treatment to certain technologies or market participants) should require rigorous cost-benefit tests.[102] For example, subsidies for specific technologies, should continue only under special conditions; subsidies generally have negative side effects that are often non-transparent. Uneven subsidies across energy sources violate the condition of a level playing field where no technology or market participant has an unfair advantage.

Policies that are technology neutral are more likely to lead to the most socially desirable investments. Clean energy technologies, for example, should be competing with each other and the technologies they seek to replace in the marketplace, not in the government arena. Well-functioning markets require consumer empowerment, robust incentives for innovation, and economically sound pricing.[103] Regulators should distinguish between normal market barriers and artificial barriers (i.e., market/regulatory failures). This distinction has definite policy implications.[104]

2.16.2 Tweaking or reforming the utility business model

Pursuing a new business model that offers little benefits could be costly and futile. Adapting the current business model to new conditions might suffice for achieving the objectives set out by the utility, its regulator, and other policymakers. As long as the utility

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101 A "moral hazard" problem occurs when a party faces little accountability for its actions, thus tending to act indifferently to the outcome.

102 Subsidies for an energy source can distort energy and capacity markets by giving false price signals.

103 Other features of an efficient market are well-informed customers, price transparency, customer responsiveness to price changes, low transaction costs, robust competition among suppliers and low entry barriers.

104 Market/regulatory failures are defined here as a barrier when (a) they produce uneconomic and socially-damaging outcomes and (b) their mitigation passes a cost-benefit test and, thus, their amenability to policy intervention. In contrast, normal market barriers derive from natural market forces and would, most surely, fail a cost-benefit test to mitigate. For example, their mitigation might involve a high cost that, on net, would inevitably make matters worse.

could satisfy the needs of its customers at a profit and with current resources and processes, it can avoid the high transition cost of developing and executing a new business model.

A misjudgment or error in selecting a business model is more likely with greater uncertainty of the future. The public policy discourse so far has focused more on not doing enough than on going too far in reshaping the utility business model. Utilities and their regulators should consider the risks associated with both over-reacting and under-reacting to the expected changes for the electric industry.[105] One suggestion for regulators and utilities is to evaluate the benefits and risks associated with their existing policies and practices (e.g., ratemaking, the scope of utility functions) in a transformed electric market.

Decision making under uncertain conditions can easily lead to regrettable outcomes. For example, assume that the utility radically changes its business model to accommodate a high continuous growth in DG. If the actual growth falls far short of expectations, the costs of the transformation to the utility could be excessive and fail a cost-benefit test. Disappointing outcomes come from policies that assume a different state of affairs than what actually transpired. In other words, a mismatch can occur between policies and actual conditions for which utility customers might bear the brunt. These policies relate to the utility business model, ratemaking, rules for fair competition, and financial incentives for DG technologies. Regulatory practices and public policies can therefore fail not only because they move too slowly relative to technological and market developments, but also because they advance prematurely. The latter condition can occur when unfounded optimism about radical changes leads to investments and other costly actions that turn out to be extraneous.

2.16.3 Ratemaking reforms

In the U.S., ratemaking changes are in order as the new environment, especially with DG, becoming more prominent. The disequilibrium condition discussed earlier means that the status quo is no longer sustainable as new ratemaking practices are inevitable. A primary concern of state utility regulators is to keep utility prices from increasing radically (Joskow, 1989). Regulators might therefore impose limits on protecting utilities from competitive technologies that require large short-term rate increases to compensate for transition costs and lost revenues.[106]

Regulatory protection of utilities during an onslaught of competition is a double-edge sword. Regulators will be as intent on avoiding financial disaster for a utility as they have been

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[105] Decision making under uncertainty often accounts for what analysts call *Type I* and *Type II* errors. (Type I and II errors are frequently applied by economists and other analysts in situations where the policymaker evaluates the risks associated with a particular decision given that his projections of the future and other assumptions turned out to be wrong.) These errors stem from policies that assume a specific state of affairs rather than what actually transpired. In other words, a mismatch exists between policies and actual conditions. In the context of electric-industry transformation, utility customers can suffer losses from the wrong policy. Policies might involve the utility business model, ratemaking, rules for fair competition, and financial incentives for clean technologies.

[106] To "conceal" the rate increases by avoiding general rate cases, regulators may consider allowing utilities to recover these costs through trackers or surcharges.

in the past.[107] Most U.S. regulators view a financially distressed utility as not serving the general public. Utility financial burdens can translate into long-term harm to customers: If a utility expects not to recover its full costs for an economical investment, it will tend not to voluntarily offer to make the investment.[108]

On the other hand, regulators may decide not to protect utilities for political or public interest reasons. The public may view traditional regulatory solutions to insulate utilities from competition as exemplifying a one-sided approach that harms the long-term interests of customers and society at large. Some analysts would even argue such an approach increases the utilities' risk where a more proactive strategy would improve the position of utilities by replacing risk with opportunities to benefit from change.[109]

Regulators can approve new ratemaking practices to mitigate financial challenges for utilities. For example, they might strive to end cross-subsidies that motivate certain customers to uneconomically bypass the utility system.[110] While ratemaking reforms by themselves may not fully head off all future financial problems, regulators should consider them a good place to start.[111]

Examples of reformed rates that are under discussion in a number of states are straight fixed-variable-type rates (e.g., three-part tariffs that include a demand charge for residential customers), real-time pricing,[112] multi-year rate plans (e.g., price caps), surcharges for innovations, creation of a separate rate class for DG customers, cost-based standby rates,[113] and

107 From experience, regulators seek to minimize extreme financial outcomes for utilities. Besides, they are subject to legal constraints imposed by legislatures and the courts.

108 A breakeven constraint (i.e., total revenues equal total costs) is a necessary condition for assurance of adequate service utility service in the long run.

109 One good example is cable companies that exploited new technologies to expand their services and bundle them profitably. *See*, for example, Graffy and Kihm 2014.

110 Bypass could have a more serious effect on the utility as the former customer would no longer pay fixed charges. If instead, the customer merely cuts back on electricity usage but remains on the utility as a full-requirements customer the utility would still recover some of its fixed costs. One mitigating factor is that the utility could still recover at least a portion of the fixed charge by providing standby service or other service to the bypassed customer. At least over the next few years, storage will unlikely be cost-effective for DG customers to completely bypass the utility system. Even if it is, DG customers placing a high value on reliability may still be hesitant to wean themselves off the utility grid.

111 One article expressed the view that "the current rate design cannot economically or politically support a large cross subsidy from non-DG to DG customers" (Felder and Athawale 2014, 14).

112 While studies on real-time pricing generally show that the benefits outweigh the costs, most of the benefits go to a small number of consumers who are relatively price-responsive. Thus, although some customers will likely benefit from such pricing, other customers will see higher bills. The fear of a large number of losers is a political obstacle to widespread adoption of real-time pricing.

113 Most DG systems require backup, supplemental or maintenance service from a utility. FThe rates charged for these services can affect the economics of a DG project. Standby rates have been contentious in state regulatory proceedings since the 1980s. One outcome of appropriate standby rates is that they do not discourage economical DG while avoiding a subsidy from full-requirements customers: Less-than-full cost recovery by the utility requires funding by other customers; more-than-full cost recovery results in excessive payment by DG customers making DG less economically attractive. In sum, a good standby rate would result

performance-based rates for utilities (Blank and Gegax, 2014).[114] As DG become more prominent, regulators will ultimately have to address how utilities should recover their energy, capacity and grid costs. Excessive reliance on the volumetric component of utility rates to recover both of these distinct costs will become increasingly contentious over time.[115]

2.16.4 A new regulatory paradigm?

Regulators should ask whether and how they should change their present policies and practices to better serve active customers and protect passive customers. Does regulation need to reinvent itself, adopt a new ratemaking paradigm, or just make modest changes? Examples are: multiyear rate plans, new rate designs, and the requirement of a new utility role. For some states, new rate design and economically rational ratemaking may suffice given the circumstances they face. Regulators can also reward utilities for efficient integration of disparate resources (e.g., DG) and achieving targeted social goals, rather than for growing their rate base through new assets that may not be economical and socially desirable (New York State Department of Public Service, 2014).

One radical approach would be to scrap ROR regulation and replace it with a more incentive-driven and flexible regulatory regime. One such regime is Revenue set to deliver strong Incentives, Innovation and Outputs (RIIO), created by the Office of Gas and Electricity Markets (Ofgem), which is the electricity and natural gas regulator in Great Britain. The RIIO model contains the following features: (1) A detailed set of outputs expected of the utility based on a comprehensive business plan, (2) an 8-year rate plan, (3) explicit incentives for achieving certain performance targets, (4) extensive stakeholder involvement, (5) external benchmarking of costs, (6) a total expenditure concept, and (7) uncertainty mechanisms (Fox-Penner et al. 2013; and Ofgem 2010).

RIIO represents a radically different ratemaking paradigm than what U.S. regulators apply to their electric utilities. It focuses less on the utility's earned rate of return and more on the utility's performance. RIIO uses the mantra "value for money."[116] It incorporates an

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in no subsidy, be fair to DG customers and full-requirements utility customers, and not discourage good DG projects or encourage bad DG projects.F

[114] In a general context, performance-based rates would ask: Are customers getting value for their money? Evaluation of utility revenues would consider outputs (e.g., reliability, penetration of DG, energy-efficiency savings) that benefit customers and society as a whole. The question then becomes, given utility outputs, what revenues should regulators allow utilities to earn? In this regard, performance-based rates are similar to RIIO. Performance-based rates can involve formal incentive mechanisms or simply rate adjustments by regulators based on their judgment of whether a utility performed exceptionally well or poorly. The latter approach is problematic if the regulators' decision is done after-the-fact in an ad hoc fashion, rather than by applying upfront rules and criteria to the utility.

[115] One reason is that utility rates to core (or full-requirements) customers would rise faster as more customers migrate to DG.

[116] As noted by one U.S. regulation expert: Regulation needs to shift from its backward-looking focus on costs, to a forward-looking emphasis on value and desired societal outcomes. In this regard, the "value for money" regulatory model in the United Kingdom, with its emphasis on incentives and outcomes, might profitably be adapted for use in the United States. [Ron Binz 2014.]

incentive system with rewards and penalties to encourage operational efficiencies, as well as funding for innovation and opportunities for utilities to include third parties in the delivery of energy services. Regulators can use the RIIO framework to monitor a utility's performance in serving both active and passive customers. If the evidence shows subpar performance, for example, the regulator could impose a penalty. Likewise, the utility could receive rewards for exceptionally good performance in meeting the needs of its customers.[117] For example, the utility may support a platform that accommodates DG and provide real-time information to customers.

Whether RIIO is feasible for the U.S. is highly doubtful at this time. Would state regulators be willing to accept a radically new approach to utility regulation, like the U.K. has?[118] U.S. regulators typically make changes incrementally rather than boldly. Even if not adopted in the U.S., RIIO contains some commendable ideas that state regulators might want to consider in any new ratemaking approach that they adopt. Especially attractive is the notion that a primary criterion for utility revenue is its correlation with the value that customers receive from utility service.[119] Benchmarking, which U.S. regulators rarely do, rightly shifts the focus from inputs to outputs and holds utilities accountable for subpar performance.[120] In the context of this paper, benchmarking can help regulators monitor whether utilities are meeting the demands of active customers while protecting passive customers from cost-shifting and other discriminatory actions.

2.16.5 The utility role

Traditionally, regulators presume that the physical delivery of electricity across a service area is a natural monopoly. One vision of the future would shift the focus of the natural monopoly from pure physical delivery to utility management of an increasingly complex distribution network because of the smart grid and DG, with the core goals of maintaining reliability and serving active customers. As an Electric Power Research Institute (EPRI) (2014) paper points out, the value of the grid would increase with the integration of the DG with grid operation, rather than just a connection of DG to the grid. The paper identifies four essential components of an integrated grid: (1) Grid modernization, (2) communication standards and interconnection rules, (3) integrated planning and operations, and (4) informed policy and regulation.

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117 Interpreting performance metrics is tricky for regulators. Separating out the effect of external factors from management competence requires sophisticated analysis that often falls short of a definite outcome. A less ambitious application of performance evaluation is to monitor a utility's performance and detect any "red flags" that warrant a more thorough investigation.

118 Back in the 1990s when the electric industry went through dramatic restructuring, many experts believed that traditional ratemaking would not survive. They thought that price caps or more flexible ratemaking mechanisms would replace it, but this did not happen. One reason was that regulators were not willing to give up ROR regulation, although willing to modify it around the edges.

119 This pricing strategy is similar to what Peter Drucker refers to as market-based pricing inducing "price-led costing." This concept places a limit on a company's costs at the price level that consumers are willing to pay for a service. (Note how this differs from cost-of-service regulation, where the company's actual or reported costs determine the price.) [Drucker 1995.]

120 Symmetrically, benchmarking can also reward utilities for exceptionally good performance.

One role for distribution utilities would be to function as orchestra leaders or traffic cops managing a multidirectional flow of power. For example, utilities would coordinate distribution of electricity produced by multiple small entities (e.g., control points) and flowing in all directions. Basically, the role of utilities would change from power supplier and deliverer to system integrator and network operator. Utilities would act as regulated platforms for selling energy services.[121] The ultimate beneficiary should be active customers, who are most willing to exploit the benefits from the latest technologies and market developments.

2.17 Summary

The benefits from customer activism are a major motive for transformation of the U.S. electric industry. The combination of technology, public policies, and economics has made this possible, although the jury is still out on how fast customer activism in retail electricity markets will grow in the coming years. To date, the vast majority of residential customers have shown much inertia, whether it is participating in retail competition programs or a new pricing scheme like time-varying pricing. Even with hype over rooftop solar, only an extremely small percentage of U.S. households have taken advantage of this technology to date. Overall, the attention given to the new electricity customer seems to overlook the fact that electricity is basically a commodity, and the average residential customer may be satisfied with their electric service and the price they pay. Transformation in customer behavior requires electric service to be viewed more as a value-added rather than a pure commodity. We also point out that because the average amount customers spend on electricity is a small portion of their income, devoting additional effort to lowering their electricity bill could easily exceed the expected benefits.

The trend toward more customer activism in the future should trigger action by both electric utilities and their regulators. The availability of unbundled products and services, and enabling technologies along with better information will all contribute to the growth of customer activism. Utilities will increasingly operate in an environment where a distinct line is drawn between active and passive customers. The likelihood of having distinct customers (passive and active) means that the dialogue over whether utilities should operate under a centralized *or* distributed business model is off-mark. Both models can coexist and perhaps benefit from synergy.

Customer bifurcation poses challenges for determining what role utilities should play, and the appropriate ratemaking and business models under which utilities should operate. In the U.S., ratemaking is under review in several states partially because of the conflicting interests of DG and core customers. Regulators must decide how much they are willing to benefit DG customers at the expense of other customers. Some states, including Hawaii[122] and Nevada,

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121 Some observers may consider the platform as a natural monopoly that is economically non-replicable. They define the "platform" as a system that supports value-based interactions among multiple parties and a set of rules that standardizes and facilitates transactions among multiple parties.

122 Last year, the Hawaii Public Utilities Commission concluded that simple retail rate net metering credit is driving uncontrolled, undirected growth, and raising serious questions about cost shifting to non-solar customers. The Hawaiian Electric programs were capped at existing levels as of the release of the October 12 decision, and lower buy-back rates were put into place for new rooftop solar systems on each of

have already reached a triggering point where their recent actions have swung the pendulum away from rooftop solar to core customers. Other states are likely to follow suit in the future.

Regulators will have to expand their interpretation of the "balancing act" to consider the separate interests of passive and active customers. They will likely emphasize the protection of passive customers from cost-shifting and other utility activities targeted at active customers. By definition, active customers are more sensitive to price and the quality of utility service, so the natural inclination of utilities is to accommodate them by discriminating against passive customers. Consequently, utilities may have an incentive to discourage more of their customer from becoming active. Regulators would therefore have the task of making sure that those customers who want to become engaged are not being unduly impeded by their utility. Regulators should have as their objective the maximization of the aggregate economic well-being of all utility customers. This means that they should simultaneously protect passive customers and allow active customers to take advantage of opportunities that they desire to pursue, within certain parameters, of course.

In enhancing the benefits from customer activism, regulators and other policymakers should provide utilities with better incentives to innovate and conduct R&D. They should also make sure that utilities are not blocking innovations from reaching retail customers. Many of the new technologies that can benefit customers have their beginnings in the non-utility sector. If utilities erect barriers to their dissemination, customer activism would experience a setback.

The U.S. experience to date is one where states have taken varying positions on electric industry transformation, of which customer activism is a feature. This diversity exemplifies the adage that states are "laboratories of democracy." Those states that remain hesitant are acting in line with options theory, which says that decision-makers should proceed incrementally in an environment of uncertainty. Although some observers would disagree, sub-federal regulation has its merits in allowing different jurisdictions to decide what is best for them.

the state's islands. Systems with existing retail rate net metering deals will be able to keep them for the life of their contracts. Another interpretation of the Commission action is that it reflects its belief that solar has become competitive enough to require no additional assistance. *See* Dyson and Morris 2015.

3 Meeting Customer Demand Behind the Meter

3.1 Introduction

"Behind the meter" is often also called "on the customer-side of the meter" (SmartGrid.gov 2016). Historically, the distinction was drawn between the utility side of the meter, where a monopoly utility owned and operated all of the equipment from the electric generators, through long-distance and high-voltage transmission lines, then through a substation that transformed the power voltage down to distribution voltage, and finally on to the distribution wires, smaller transformers, and the service lines that led to each revenue meter, where the customer was connected to the grid. On the customer side of the meter was all of the customer-owned and operated equipment that used electricity. In recent years, however, the electric power industry has been undergoing major changes that are challenging this duality in many ways: The lines between the utility and customer sides of the meter are already blurring.

The future of electricity demand, behind the utility meter, is undergoing continuous change. Three major dimensions of that change are:

- (i) increasing efficiency of building design and construction, lighting technology, and all kinds of end-use appliances, any and all of which are increasingly capable of delivering more and better quality customer service while using less electricity and less total energy;
- (ii) growing numbers of customers generating at least part of the power they use, especially with on-site solar photovoltaics (PV); and
- (iii) modernizing utility infrastructure, often grouped under the major categories of automated metering infrastructure (AMI) and smart grid capabilities.

All of these are starting to deliver new capabilities for monitoring and ultimately controlling energy using equipment on both sides of the meter. The big picture trend is that electric power is still being applied to more and more different end uses. But traditional high-energy-use manufacturing has moved off-shore and electricity use efficiency continues to improve at a rate equal to or even faster than further electrification, such that electricity sales growth has slowed remarkably, and forecasts for at least some service territories anticipate negative sales growth in the coming decade. Nation-wide, the U.S. Department of Energy (USDOE 2015c, p. 1-8) presently forecasts less than one percent annual growth in electricity usage from 2011 through 2040.

The following paragraphs introduce three major topics for thinking about service behind-the-meter: (1) increasing efficiency and other DER capabilities; (2) self-generation; and (3) flexible demand. Modern-grid capabilities serve various roles in enabling each of these. After general discussions of each of those major themes, more specific ideas about behind-the-meter functions and usage are discussed in the context of the three different scenarios by 2050.

3.1.1. Continuous improvements in end-use efficiency and other DER capabilities

This general trend is supported by three major factors: (1) gradually increasing efficiency codes and standards, both for buildings and for many types of manufactured appliances and lighting; (2) progress in achieving so-called zero-energy building design and operations; and (3) an ongoing profusion of inventive vigor and entrepreneurial dynamism, focused on all varieties of opportunities for achieving a clean energy future.

In the first instance, dozens of energy end uses are gradually being transformed by increases in minimum building codes and standards and minimum efficiency standards for lighting and many kinds of energy using appliances. These are gradual trends, but the trajectory is clearly pointed towards continuous efficiency improvement. (USDOE 2016b and 2016d; York, Nadel, et al. 2015)

These codes and standards are generally developed by national or international groups, through a process of consensus development amongst interested parties. They tend to follow the principle that the minimum efficiency levels required for buildings and appliances will be subject to continuous improvement, and that each new increment of efficiency will be achieved cost-effectively. Fundamentally, that means that the construction or manufacturing techniques needed to reach each new minimum efficiency level are already practical when the standard is passed. (For example, see IEC 2016; USDOE 2016c and 2016d).

Such standards set an efficiency floor, not a ceiling: They effectively remove from production only the least-efficient examples of each affected type of building or appliance.[123] Given the long useful life of buildings (up to a century or more in some cases) and many large appliances (lasting an average of 10 or 20 years or more, depending on product type), new standards are slow to generate efficiency improvements. Plus, the process of securing official government approval for each new standard leads to further delays, unevenly applied across different jurisdictions. On the other hand, once they are officially adopted and enforced, new standards do achieve widespread compliance, so they ultimately produce an almost failsafe mechanism for improving performance.[124] Part of the art of utility load forecasting is anticipating how loads will change as new codes and standards take effect.

At the same time that mandatory standards are increasing, even stronger voluntary standards that approach the efficiency ceilings achievable through modern technology are also fairly common. It is not uncommon for some jurisdictions to adopt more than minimum standards or for at least some customers to demand better performance for their purchases. For example, buyers of any stripe can require higher efficiency in their purchasing and leading firms can offer higher efficiency as a means of attracting customers. In appliance manufacturing, this tendency is often reflected in premium features and higher efficiencies offered in more

[123] Hawken, Lovins, and Lovins (1999, p. 275) report that in Britain, minimum construction standards are sometimes referred to by the disparaging acronym CATNAP, which stands for “Cheapest Available Technology Narrowly Avoiding Prosecution.”

[124] The recent examples of automotive manufacturers cheating on fuel-economy and emissions standards tests, notably Volkswagon but also other companies, demonstrates that effective oversight and verification is needed, even for mandatory codes and standards. See Ewing 2016; Soble 2016.

expensive products, while entry-level products are more likely to meet only the minimum standards.

In the realm of buildings, the American Institute of Architects 2030 Commitment (AIA 2015; Architecture 2030 2015) is a prime example of a progressive, voluntary standard: In response to growing concerns about global climate destabilization, the Architecture 2030 program prescribes a zero-energy standard for all new architect-designed buildings constructed after 2030, and offers a set of design principles for achieving that goal, termed the "2030 pallet."[125] In a related effort, the Passive House Institute US is developing and spreading practices for building extremely energy efficient homes for low- and moderate-income markets (Dentz, Alaigh, and Dadia 2016; PHIUS 2016; USDOE 2016d).

Remarkable changes, too many to mention, are coming to both of these major realms, buildings and appliances. Every week brings new announcements about progress towards higher efficiency and clean energy production and use, and each new trade show is full of examples of manufactured goods of all kinds that continue to do more and more with less and less material and energy inputs. Society has grown used to the idea of continuous progress in all kinds of electronic equipment, where something like Moore's Law continues to produce better and better performance-to-cost ratios.[126] Similarly, major energy using appliances such as refrigerator-freezers, air conditioners, washers and dryers, and lighting are all undergoing gradual improvements whereby energy and water usage are tending to decrease while the built-in capabilities for intelligent control are increasing. Another prominent example is progress towards building integrated photovoltaics (BIP), where there is good reason to expect that in the not-too-distant future, roofs, walls, and windows will all be capable of generating some electricity at competitive prices. Such products have already existed for several years, and they are already achieving some market acceptance in locations with combinations of high energy prices and substantial subsidies (Strong 2011).

3.1.2. Growing interest and participation in behind-the-meter generation and storage

A second major factor affecting many U.S. utilities and regulators is the rapid influx of behind-the-meter generation, especially in net metering applications and especially using solar photovoltaic (PV) systems (Inskeep, Wright et al. 2016; Stanton 2015a). The overriding situation in the past few years is that PV systems got much cheaper and their production capabilities improved. Meanwhile solar company business models evolved so that solar installations became attractive to much larger potential markets. One of the most popular business models turned out to be arrangements that customers could enter into, with no money down and a long term agreement to purchase the output from solar panels installed on the customer's property. Currently, just over half of all the states allow these arrangements, at least within certain jurisdictions, eight states explicitly disallow any entity other than a utility to sell

[125] A broader set of concepts that identifies a few dozen community-level practices for long-term sustainability is called "Reliable Prosperity" (2016).

[126] For Moore's Law, see Nagy, Farmer, et al. 2013. In a similar vein, "Swanson's Law" states that for every doubling in the cumulative capacity of global solar module shipments, the module price falls by 20% (Stanton et al. 2014, p. 16).

electricity to a customer, and in the rest of the states the status of such arrangements is still uncertain (DSIRE 2016a).

In any case, growth in PV installations has been running in the range of 50% per year, meaning that installed capacity is doubling every couple of years. As a result, many U.S. utilities are asking for regulatory relief of what might be considered "growing pains" (Stanton 2015a, pp. 3-9). As one observer says, PV is already "[c]heap enough that with continued progress, but no breakthroughs, it might alter the global outlook for energy supply within a decade" (Keith 2016).

In a similar vein, batteries are improving in capability while costs decline, plug-in electric vehicles are coming forth with vehicle-to-grid (V2G) capabilities, and manufacturers are well on the way towards developing stationary battery systems that will provide a "second life" for used automotive batteries (Bronski, Creyts et al. 2015; Brown 2016). These factors are combining to create fast-growing interest in behind-the-meter storage at every scale, from residential up through utility scale. Several large U.S. solar installation companies have already adjusted their offerings to include combined solar plus storage (Pyper 2016a; Stanton 2015a, p. 7), and one U.S. utility is already offering on-site storage as a service to its customers (Lundin 2016b).

Other small-scale generating technologies – such as small-wind, micro-hydro and hydro-kinetic, fuel cells, and micro-turbines – are presently cost-effective in only a few particular instances, but some are already achieving early market successes in higher-cost countries like Japan and some EU countries, and all such technologies appear to be subject to combinations of product improvements, cost reductions associated with learning curves in manufacturing, and reductions in soft-costs (Stanton et al. 2014, pp. 15-19). Today, the total costs of most of these technologies is still high enough that in lower-cost jurisdictions all but the most dedicated, innovators are dissuaded from installing them.[127] But, sales are already growing in jurisdictions where the systems can be fully cost-competitive under existing utility rate designs combined with local, state, and federal financial incentives. One example is home- or neighborhood-scale combined-heat-and-power (CHP) appliances that are starting to gain market share in some markets. There is recent substantial growth in U.S. CHP in multifamily buildings, hospitality industry facilities, hospitals and healthcare buildings, and office buildings. (Decentralized Energy 2016; Embury et al. 2015; Shibata 2016; Staffell et al. 2015). The prospects for continued cost reductions and equipment performance increases appear robust enough that growing markets for behind-the-meter production and storage must be considered as a very real possibility for utilities during the time period under consideration for this report. Plus, wealthier customers in jurisdictions with less-reliable electricity are also an important and growing market: Customers who seek more reliable power and have the means to purchase and install their own on-site generation are an important market in places where grid-power is less reliable.

The U.S. has a long history of enabling small-scale distributed generation (DG) through net metering and net billing practices. The initial impetus for net metering was to provide an

[127] In diffusion of innovations theory, the first users to try out any new product or service are called innovators. That group is followed by early adopters. Together, innovators and early adopters might typically represent only a few percent of a potential market. See Stanton and Phelan, 2013, pp. 27-28.

administratively simple mechanism to enable innovators to install on-site generation intended to meet their own electricity needs. Net metering was never meant to support merchant power plants operated to make profits from the generation and sale of electricity. Instead, the initial idea was that net metering would allow a nascent self-generation industry to get started, using a policy mechanism that was: (a) relatively simple to administer; (b) representing a reasonable, "rough justice" mechanism for allocating benefits and costs between participants, non-participants, and utility companies; and (c) would be relatively non-disruptive. The programs had important differences in different jurisdictions, but they were generally similar in allowing customers to deliver excess power to utility grid when available, and then absorb power from the grid when needed, with that exchange taking place at retail prices, at least up to the point where the customers' total utility bill during any given billing period would reach the minimum charge. Outside of that basic structure, there were many differences in the programs, but more than half of all the states established program limits for the total percentage of load that could participate. About a dozen states capped net metering at no more than one percent of load, or less, which effectively limited the total amount of any possible transfers of benefits and costs between different customer groups or between customers and shareholders. (Durkay 2014; Stanton and Phelan 2013, pp. 9-21).

Support for the early development of DER in general, and specifically for distributed solar PV, also came from many federal and state financial incentives. The combined effects of support policies such as tax and financial incentives, along with utility rate offerings like net metering, created fertile grounds for distributed solar PV in some particular states and utility service territories (Bird, Reger, and Heeter 2012; DSIRE 2016b; Stanton 2015a; Stanton and Phelan 2013). Over time, however, the number of net metering customers grew. In at least some locales the innovator audience might have been saturated and early adopters started participating. In several jurisdictions, program caps were approached or even exceeded. In the past couple of years, many utilities and a few state regulatory commissions have raised concerns that net metering programs are becoming disruptive. (Kind 2013; Inskeep, Wright, et al. 2016; Stanton 2015a, pp. 3-5).

In response to specific policies requiring a review of net metering policies as the program caps near, and as concerns grow that net metering might be causing unwarranted cross-subsidies from non-participants or utility shareholders to participants, there have been many recent efforts to change net metering policies or re-imagine net metering practices with the general goal of more accurately reflecting benefits and costs (EEI/NRDC 2014; Eid, Guillén, et al. 2014; Inskeep, Wright, et al. 2016; Stanton 2015a, p. 13; Stanton and Phelan 2013, pp. 2-3). Since 2010, over 20 states have initiated procedures to re-examine net metering, and half a dozen of those have recently adopted such changes (Stanton 2016 forthcoming). Generally, these actions are directed at solving perceived problems with net metering and coming up with replacement policies that will more accurately assign benefits and costs, based on the cost-causation principle.[128]

Since 2014, many US utilities have actively sought changes in net metering rates, and sometimes in all rates for small customers (Muro and Saha 2016). Those legislative and

[128] In network utility regulation, cost causation means assigning costs in proportion to the entity that caused a certain project to be built. This is the opposite of socializing costs across all customers.

regulatory proposals, initiated in part by a report published by the Edison Electric Institute (Kind 2013), are documented in a series of reports from North Carolina State University, Clean Energy Technology Center, entitled *The 50 States of Solar* (NCSU 2014-2016). In 2015 alone, over 100 related legislative and regulatory actions took place in more than 40 states (Inskeep, Wright, et al. 2016; Stanton 2015a). These actions include dozens of utility proposals for changes in rate designs. A report from Rocky Mountain Institute analyzes existing experience with some of the rate design concepts, and recommends ongoing research needed to assess best-practices (Chitkara, Cross-Call, et al. 2016).

In this context, the tax treatment of net metering deserves special note. In the U.S., tax experts view net metering as a simple exchange of energy, non-taxable for income tax purposes. In comparison, any other payment mechanism such as a buy-all, sell-all arrangement or feed-in tariff, and even cash payments for net-excess generation, could be treated as gross income, subjecting customer-generators to more complicated tax treatment and potentially changing the economics of self-generation. (Clean Coalition 2015; Trabish 2013).

In addition to several states that are actively studying replacements or successors for net metering, other states more generally studying utility business model changes for adapting to DER. Broad "revisioning" efforts are underway, under the auspices of state regulatory commissions in California, District of Columbia, Hawaii, Massachusetts, Minnesota, and New York (Stanton 2016, forthcoming). In Chicago, an investor owned utility has announced its intention of revisioning (Bade 2016). And, other similar efforts are underway, on the part of America's Power Plan (2015b), the University of Washington's Clean Energy Institute (2015), the 51st State Project of the Solar Electric Power Association (Bade 2015a), and GTM Research (Propper 2015).[129] And, regional transmission organizations are changing practices to enable DER aggregation for participation in wholesale markets and possibly for developing DER resources to provide non-transmission alternatives (NTAs) (St. John 2016; Stanton 2015b).

As reported in Stanton (2015a, pp. 3-9), seven related factors have combined to bring these proposals to the fore:

- (i) aging utility infrastructure in need of replacement;
- (ii) further tightening of federal environmental protections and the likelihood of greenhouse gas regulations;
- (iii) requirements for grid modernization;
- (iv) flat or declining loads and load factors;
- (v) declining costs and rapidly growing markets for distributed energy resources and self-generation, particularly solar photovoltaics (PV) and battery storage;
- (vi) state and utility NEM programs nearing or exceeding existing caps, thus triggering policy reviews; and
- (vii) strong interest on the part of growing numbers of large corporate and institutional buyers in taking more control of energy purchases and obtaining more or all of

[129] The Solar Electric Power Association, SEPA, recently changed its name to Smart Electric Power Alliance (SEPA 2016).

their electricity from renewable, low-emissions energy resources.

3.1.3. Modernizing utility infrastructure for behind-the-meter operations

Modern grid infrastructure on the utility side of the meter is discussed in the next portfolio. Here, the focus is on how modern-grid technologies are beginning to affect usage on the customer's side of the meter.

There is uneven progress across the U.S. towards integrating more intelligent sensors and controls throughout the electric grid (Brooks 2016). Advanced utility meters are installed already for almost half of all U.S. customers, but there is still a long way to go before achieving what most observers envision to be a fully modern, 21st Century electric grid. The prognosis is for smarter-grid infrastructure to enable two major changes on the customer side of the meter: (i) enhancing customer choice; and (ii) inducing customers to produce utility system benefits by modifying usage patterns (Stanton 2011, pp. 5, 21-28). Some of the big picture ideas are that smart-meters with two-way communications capabilities and greatly improved distribution systems capabilities will enable more customer options, such as multiple different rate offerings, on-site or cloud-based energy management systems, smart appliances, and integrating on-site generation and plug-in electric vehicles. In addition, it is thought that rate designs that convey information about time-differentiated system costs, combined with smarter appliances and ample customer education and regular feedback about usage will result in reduced on-peak usage and improved load factors. As Mowat explains (2016b), Ontario has already embarked on these changes by introducing smart meters and time-of-use rates.

Many U.S. experimental and pilot programs point towards successes in some of these areas already, such as consumer behavioral responses to various peak-time rates along with information about how usage might be reduced. For other areas, though, like smart-appliances and energy management systems for small energy users, the progress has been much slower. For example, only a small fraction of known smart-appliance capabilities are readily available in current models, while other capabilities are awaiting future implementation because appliance makers do not yet perceive ample markets to justify the additional manufacturing costs. This is something of a cart-before-the-horse situation, where appliance makers are waiting for smarter grid capabilities to be manifested before the smarter appliances will be manufactured, but at the same time utilities and their regulators might hesitate to invest in the related utility grid infrastructure improvements and more time-differentiated rates until they know that the resulting changes in customer usage will generate ample savings to provide a reasonable excess of benefits minus costs. Another example is so-called "smart inverters" designed to enable on-site generators to operate in ways that reduce problems for grid integration and enable aggregations of small on-site generation to produce and deliver valuable grid services (USDOE 2015a).

Another major concept for integrating DER is enabling flexible demand, where many types of end-use equipment can be operated so that peak demands are lowered, and eventually so that myriad end-use devices can produce and deliver valuable grid-services on demand. Already, U.S. wholesale markets are incorporating significant quantities of demand-response, including demand response provided by aggregated small customer loads (Kolo 2016). Walton

(2016) reports on one successful program operated by a third-party administrator. This could eventually encompass automated demand response (DR) made possible by smart-inverters, and smart grid-enabled appliances and thermostats, all playing along with smart-rates designed to motivate widespread participation by product and service aggregators and by individual customers. Jamison (2016) explains, "Success will hinge on highly localized demand response solutions using targeted delivery through a digitally enabled grid." Far from being science fiction set in the distant future, Clancy (2016) reports a "Living Grid" program in the U.K. is already demonstrating load-management software that is capable of achieving the goal of coordinating use by multiple electricity customers to achieve "flexible capacity."

Early reports suggest that a large fraction of all electricity demands could be subject to modest time-shifting, such that in the foreseeable future demands might be shaped at least in part to follow supplies, rather than grid operators always adjusting supplies to follow demands. In fact, recent estimates suggest as much as 40 percent of all electrical loads might be amenable to at least some time-shifting. (Bronski, Dyson, et al. 2015; Lazar 2016). That does not necessarily mean there could be big daily or even hourly shifts, but even sub-hourly shifts, if coordinated across hundreds or thousands of end-use devices could result in large cost savings in the capital and operating costs associated with meeting peak demands. Load shifting could also prove very important for managing electric grids that incorporate larger percentages of variable-output power, such as wind and solar: Flexible demands could absorb excess wind and solar when desired, especially noteworthy in the realms of battery-storage and thermal energy storage in devices such as water heaters, space heaters, refrigerators and freezers, and other demands could be reduced rapidly in response to hourly or sub-hourly forecasts of reductions in wind or solar output. (Hledick et al. 2016).

Lastly, cybersecurity is a most important concern that will only grow in importance as more and more devices are added to the electric grid on the customer side of the meter. Some might be added by utilities, but many more could be added by third parties that are not subject to the same regulatory procedures as utilities. Thus, standards are going to be needed to protect consumers and protect all of the equipment on both sides of the utility meter (Phelan 2014).

The trends identified above are well underway and appear irreversible, so the question for the three behind-the-meter scenarios is how much of each will be implemented, how quickly, and how much of the existing industry model will remain more or less undisturbed as the transition to much larger contributions from DER plays out.

3.2 Business As Usual Scenario

A business as usual (BAU) scenario will be characterized by minimal changes in industry structure and gradual, smaller changes taking place behind the meter. But, even in a BAU scenario, some progress in DER should be expected.

Early evaluations are demonstrating a potential for load shifting and demand response, but some important questions remain about the best rate designs, consumer education, and ongoing consumer information needed to achieve important elements of ongoing system benefits. Plus, there are remaining questions about the duration of customer interest in and intensity of focus on personally managing energy use on a daily basis. (Cappers et al. 2016; Cappers, Hans and Scheer 2015; Chitkara, Cross-Call, et al. 2016; Lyderson 2016b). With ample education, many observers believe that customers will gradually take more advantage of time-varying rates to reduce their energy bills, especially as new appliances start to come equipped with features that readily accommodate time delays or pre-scheduling. There is some evidence that more customers will take advantage of automatic time-of-use scheduling, as compared to making manual adjustments. (CSIS 2016).

The markets for distributed generation and distributed storage are also evolving rapidly. Already, some utilities are involved in direct sales of utility-owned rooftop solar, and some solar companies are bundling PV systems with storage. One U.S. utility is already offering customers behind the meter storage, and one competitive electricity supplier is offering on-site solar (Seltzer 2016).

Meeting Ontario's climate action goals will necessitate major efficiency improvements, along with continuing increases in renewable power generation at all scales, including behind-the-meter. And, Ontario's climate goals call for further electrification, with different sources replacing natural gas for heating and hot water and for the addition of more electrified transportation systems. (Legislative Assembly of Ontario 2016; Morrow and Keenan 2016). Reaching those goals will necessitate much more attention on high-efficiency building practices, combined heat and power, and other DER. The government will play an important role in supporting necessary research, development, and demonstrations, and significant attention will need to be focused on the roles for both utilities and competitive suppliers, on utility business models and rate-setting methods to enable utilities to earn reasonable returns on investment, on modernizing rates and tariffs, and on distribution system integrated resources planning.

3.3 Focus on Short-Term Cost-Effectiveness Scenario

Actions in this scenario will be selected based on the findings of benefit-cost tests used to determine cost-effectiveness, which means the different attributes that get counted as benefits and costs, and how they get accurately modeled, are crucially important. Standardized benefit-cost tests are already under review to make certain that analysis can be expanded to account for locational attributes, time of use, and important non-energy benefits (ACEEE 2015, Session 4B; Anderson and Woychik 2016; Bronski, Creyts, et al. 2015; Fitzsimons 2014; Keyes and Rabago 2013; Kiesling 2015; Martinot et al. 2015; NESP 2016; Russell 2015; SolarCity Grid Engineering 2016 and 2015; and Woolf, Whited, et al. 2014).

In this context, one critically important piece of the puzzle for utilities and regulators is that customers are continually investing in all kinds of buildings and equipment that uses electricity. Customers are regularly applying their own financial resources to obtain both energy and non-energy benefits (NEBs), and the sum total of those investments affects utility system needs. When utilities do support specific energy efficiency measures or other DER, the model most often used for marketing those measures to customers has been for the utility to offer some kind of financial incentive. Such incentives are used to help focus customer attention on taking specific actions, but those actions also typically rely on supplemental investments made by the customer themselves.

One way or another, getting customers to take any kinds of actions to use energy more efficiently requires some assistance from an entity that can become the customer's trusted advisor on energy, and maintain that status over time (Bade 2016; Fox-Penner 2014; Navigant 2016). That function could be fulfilled by a utility, by a special purpose agency, or by a competitive supplier, but it does appear that the presence of some trusted advisor will be necessary in order to help motivate customers to take the many actions needed to fully apply all cost-effective behind-the-meter DER. Several U.S. states have addressed this function, in part, by establishing new single-purpose entities, generically known as "conservation utilities" or "energy efficiency utilities" that manage and deliver energy efficiency programming under state oversight. The concept is that those agencies will wholeheartedly support energy efficiency and self-generation, without facing the kind of financial disincentives that might negatively affect traditional utility company interest. Examples, in various forms, include Delaware, the District of Columbia, Hawaii, Maine, Michigan, New Jersey, Nova Scotia, Vermont, and Wisconsin (Efficiency United 2016; Scudder and Heussy 2013, p. 12; WECC 2016).

In a similar manner, the Pay-As-You-Save™ financing model, or PAYS®, provides pre-screening for DER contractors. To gain access for customers to PAYS® financing, and benefit from PAYS® marketing, contractors agree to abide by consumer protection principles and work with a PAYS® ombudsman to resolve any problems. This inherent quality assurance and quality control function helps to break down obstacles that customers face in trying to arrange their own contractor services. (Clean Energy Works 2016).

A valuable role for utilities or third party agents can be in facilitating group purchasing, helping customers to identify cost-effective opportunities and matching interested customers with certified contractors. This role is similar to a concierge, finding the best opportunities and communicating them to customers. Group purchasing can leverage better prices by reducing marketing and acquisition costs for vendors and through lower prices for multiple systems purchased simultaneously. A prominent U.S. example is group purchasing for rooftop solar systems (Community Power Network 2016).

However, there are real concerns that utility support for cost-effective technologies depends fundamentally on utility financial incentives, which have traditionally rewarded utility capital expenditures and increasing sales. The theory goes, as long as utility revenues vary in response to sales throughput, and rates are adjusted upwards to reflect newly invested capital, utilities might not be sufficiently supportive of energy efficiency and customer- or third party-owned generation that might, cumulatively, flatten sales and lower the need for utility capital investment. That general situation can even apply to municipal and cooperative utilities: Though not directly influenced by a fiduciary relationship with shareholders, the managers of city-owned and member-owned utilities often act in generally the same way as their counterparts at investor-owned utilities, not fully supporting or even resisting efforts to maximize efficiency and distributed generation. As Hirsh (1989) explains, the cause could be found in the institutional culture and inertia inside utilities.

Proposed solutions include ideas about either replacing traditional rate of return regulation or supplementing it with performance based regulation, in remaking utility business models, or both (Kihm, Lehr, et al. 2015; King, Lewin, et al. 2016; Mandel 2015; Molena and Kushler 2015; Muhr 2016; Navigant Research 2016; Propper 2015; Whited et al. 2015; Woolf and Lowry 2016). As DER markets progress from BAU towards full innovation, serious attention needs to be focused on these issues.

Generally speaking, utility integrated resource planning (IRP) has been the technique used to screen potential investments to determine cost-effectiveness, but IRP has tended to concentrate on central station power generation linked to loads by long-distance, high-voltage transmission systems. Although renewable power resources and combined heat and power are regularly included in IRP analyses, they have usually been modeled in an overly simplified manner, based on a calculated levelized cost of energy (LCOE) and then compared with other central station power supply options. (See Stanton et al. 2014). Similarly, demand-side management options were typically modeled as customer-class, system wide, demand reductions, with little if any attention to differential effects based on grid location and only general ideas about how load shapes might be affected by efficiency measures, based on high-level assumptions about times of use. Inside utilities, those responsible for IRP analysis had little interaction with distribution system planners: It is the distribution system planners who are most likely to develop their plans based on locational and time of use analysis.

Tester, Drake, et al. (2012, p. 957) call for a transition away from the traditional modeling approach. From this point of view, cost-effectiveness analysis must include assessment of deferrable or avoidable traditional utility infrastructure investments, in generation, transmission, and distribution. If enough distributed energy resources can be deployed in particular geographic areas to defer or avoid more costly traditional investments, the DER options are variously referred to as non-transmission alternatives (NTAs), non-wires alternatives, or market-based alternatives. In the U.S., FERC Orders 890 and 1000 direct regional transmission organizations to offer planning processes “which are open, transparent, and coordinated, and which provide opportunities to review NTAs on a comparable basis to transmission infrastructure” (Stanton 2015b, p. iv).

Though there are not many examples yet where NTAs are being implemented, the few that are being completed are demonstrating that cost-saving opportunities exist. Depending on the utility service territory, such investments can displace transmission, distribution, or both (Delurey 2016). There is a growing literature about how locational values can be incorporated into utility planning and how utilities or other parties might engage in prospecting throughout a system, to identify specific locations that would be most amenable to developing such non-wires alternatives (See, for example: Callaway, Fowlie, and McCormick 2015; Kushman 2016). Some examples are identified in an NRRI report on NTAs (Stanton 2015b, pp. 9-13). Another current example is New York State Electric & Gas Company, requesting “proposals for innovative alternatives to necessary upgrades” at one of its substations (NYSEG 2016). Though more and better modeling techniques are being developed, they are not yet widely incorporated into IRP methods. Thus, improving distribution IRP methods and modeling is one very promising area for achieving cost-effective DER.

One mechanism for securing NTA or NDA resources is to have groups of resources that can be managed as one or more microgrids (Meyers 2016; NJ-BPU 2014b; Stanton 2012a). The Clean Coalition (2016) is working on multiple installations that will serve that function, and the Booth Bay Harbor Project in Maine is another example (Stanton 2015a, p. 11). An important question that needs to be addressed is the utility role, versus the role of competitive suppliers, in establishing and controlling all of the components of non-wires or market-based alternatives. The facilities might include all varieties of energy efficiency, load management and demand response, distributed generation, flexible loads, and storage. Some of those resources could end up under individual customer control, while others could be operated by either a utility or a third-party (O'Boyle 2015). For example, utilities or third-party agents could aggregate multiple small customers, to participate in wholesale markets (Hledik et al. 2016; Kolo 2016; Walton 2016).

As DER applications increase, there will be a need to consider how best to bridge the possible gap between competitive suppliers that have worked with customers irrespective of or with only passing attention directed to geographic location, versus the grid's potential needs for managing loads based on geographic proximity, in order to have NTA and NDA resources succeed. The Booth Bay Harbor pilot project in Maine helps to solve that problem by having the regulator appoint a locational resource manager. As O'Boyle explains (2015, pp. i-ii):

> [D]ifferent models of ownership and operation can optimize the system, so long as they take an adaptive approach that prioritizes fair compensation, fosters innovation and competition, and provides transparency for all market participants. It is likely that each ownership model has its place, and what is appropriate depends largely on the policy priorities of each region. … [A]ny of these models can work so long as the value proposition to each actor aligns with the public interest.

Community energy systems, particularly community-shared solar and other community-shared resources, are also poised to be important components in a scenario that selects all cost-effective resources. Such systems in the U.S. have many different ownership structures and program designs, but the general principle is for distributed generation to be installed in locations wherever the combined values delivered by DG can make the systems good investments (Bland, Goodman, and Palazzi 2016. See also: Chwastyk and Sterling 2015; Community Storage Initiative 2016; Dennis 2016; Durkay 2014; Feldman, Brockway, et al. 2015; Funkhouser, Blackburn, et al. 2015; SEIA 2016; Shaffer 2016; Stanton 2016 forthcoming; Tweed 2016). For many such community-based systems, customers are participating either as part owners or subscribers, making personal investments that reflect their preferences for renewable resources. Having access to the most detailed data available about their own service territory, utilities are in an advantageous position to help developers understand priorities for grid locations that can readily accommodate interconnections for community-based systems, while producing the most value through avoided costs for transmission and distribution. (Stanton 2016, forthcoming).

One vitally important aspect of cost-effectiveness is how it relates to progress towards global climate change concerns. The Center for Climate Strategies (2016b) has already helped to support consensus based climate action plans for 30 U.S. states. Michigan's experience with creating a climate action plan is exemplary (Center for Climate Strategies 2016a, 2010). The essence of the Michigan analysis is the finding that as much as 25 percent of all greenhouse gas emissions can be avoided through fully cost-effective practices that save money, by reducing wasted energy. That means technology already exists to achieve large emissions reductions that simultaneously generate valuable cost savings. As the Michigan analysis shows, much of those savings are readily available through traditional public utility energy efficiency programs for residential, commercial, and industrial customers. (Center for Climate Strategies 2010). In fact, the Michigan analysis shows that if the savings from fully cost-effective measures were reinvested in the next set of measures that cost a bit more, Michigan could achieve nearly 40 percent reductions in greenhouse gases at a total net cost of close to zero. Of course, these findings are based on known energy technologies readily available in 2010. With each passing year, more and better technologies are enabling even more cost-effective greenhouse gas reductions, so the prognosis for today would likely be even better, and there is every reason to expect even more improvements by 2050.

One particularly relevant consideration for Ontario combined heat and power (CHP) technologies, both for individual customers and in neighborhood and community scales. Central station power plants convert only half or less of the energy in useful fuel to electricity, and then another fraction of the electricity is lost in the long-distance transmission and distribution wires used to reach the eventual end users. Estimates of the total efficiency from power plant to electrical outlet indicate that anywhere from one-half to two-thirds or even three-quarters of the energy inherent in the fuel is lost in conversion, transmission, and distribution. Then, ironically, many of the uses for that electricity function on low-voltage direct current (DC) power, so there are even more losses as the alternating current (AC) at the plug gets transformed once again into low-voltage DC, before it can be put to use. (ACEEE 2016a; CHP Association 2016; USDOE 2016e; USEPA 2016).

All that inefficiency means that there can be important opportunities for reducing wasted energy, if CHP can replace other forms of thermal electric generation. One of the primary mechanisms is to capture and use as much as practical of the otherwise-wasted thermal energy. Central station power plants produce waste thermal energy in such huge quantities and often at such long distances from loads that it is seldom practical to utilize more than a small fraction of their waste heat. Smaller power plants, located near loads, can more easily accommodate waste heat utilization in the form of co-generation (usually electricity and heat) or tri-generation (usually electricity, heating, and cooling). Many individual utility customers will be good candidates for CHP applications, but utility rates and tariffs might also need to be redesigned in order to remove existing barriers to more widespread adoption. Plus, applications that share either electric power or thermal energy or both among multiple customers are often blocked by existing laws and rules. If so, then those regulations need revisions in order to realize the technical and economic potential for cost-effective CHP. (ACEEE 2016a).

In the past, CHP analyses have often tried to identify ideal candidate facilities that could utilize as much as possible of both thermal and electrical energy, in the appropriate ratio produced by particular CHP systems. That type of analysis misses large amounts of all the technical potential, though, by first assuming that the existing regulatory structures cannot be changed to better accommodate CHP and second by assuming that neither thermal energy nor electricity can readily be shared among multiple customers. A new kind of analysis is needed, first to identify all of the technical potential for CHP, location by location throughout a utility's service territory, identifying all practical thermal and electrical uses and then asking what portion of them might be served by CHP facilities (See UK Department of Energy & Climate Change 2016 and Shibata 2016 for preliminary examples). Once that potential is analyzed, then further economic analysis can determine how much of the CHP potential can be realized, given possible regulatory changes. That kind of analysis needs to be completed for different kinds of areas on the grid, for example chiefly residential, commercial, industrial, agricultural, and institutional areas, and mixtures of those basic types. Only then will utility planners start to understand how much savings might be achieved by purposefully removing the barriers to widespread CHP adoption. Other countries are already proving that such approaches can be practical. Denmark is most notable, with about 50 percent of all power production from CHP plants, but a few other northern European countries reach 30 percent or more. That compares with only about eight percent in the US and slightly less in Canada. (Thornton 2010, pp. 14-22).

Importantly, once hot water or steam loops are present in any cluster of buildings or neighborhood, then those thermal needs can be supplied from any available source. In that way, redundant systems can be installed to offer greater reliability and resilience in the face of different kinds of disturbances. Depending on the technologies used, some thermal energy could be provided by a CHP power source, which could then also be supplemented by geothermal, solar, or other resources.

In addition, the EMerge Alliance (2016b) is an open, membership-based industry association working on standards for DC power distribution and use in commercial buildings. EMerge Alliance already includes several of the world's biggest manufacturers of electric and electronic equipment, including Bosch, GE Critical Power, Osram Sylvania, and Philips. The major objective of the Alliance is to develop DC standards and a hybrid AC-DC platform that can reduce the inefficiencies inherent in multiple power transformations and enable the safe and efficient operations of DC microgrids. EMerge already has a presence in Ontario, including two demonstration centers in Toronto (EMerge Alliance 2016a).

3.4 Focus on Innovation Scenario

The essence of this scenario would be applying DER, as much as practical, to gradually replace the pre-existing utility infrastructure: As central station generators age and face retirement, DER would be tapped to replace that power and energy. Under this scenario, needs for new central station and transmission resources would be greatly reduced. It remains to be seen, but if it becomes clear that ample DER are available to replace the otherwise-required centralized infrastructure, it could even be possible that some selected transmission assets could also be retired.

Ontario already engages in long term energy planning (LTEP). The 2013 LTEP (Ontario Ministry of Energy 2013) includes major provisions for:

- energy conservation targets using both programs and codes and standards;
- demand response, for meeting 10% of capacity needs by 2025;
- new consumer-oriented financing tools, including on-bill financing;

- continuing additions of wind, solar, bioenergy, and hydroelectricity;
- "innovative partnerships and transformative initiatives" for local distribution companies (LDCs);
- enhanced regional planning and additional "work with municipal partners to ensure early and meaningful involvement in energy planning;" and,
- innovations in smart grid and energy storage.

These are all important steps in the direction towards increased use of DER. Changes in DER capabilities are coming fast and furious right now, which makes it difficult for long-term planning procedures and institutions to keep up with the possibilities. There is no single solution for this dilemma, all interested parties will just have to keep working together to revise forecasts as new, cost-effective options come to fruition.

As the 2013 LTEP (Ontario Ministry of Energy 2013) already explains:

> Communities must… take a more central role when implementing provincial policy objectives. The opportunity for communities to participate in energy infrastructure must be balanced with their responsibility to take ownership of local decisions.

Ontario could be well advised to focus on the goals of continuous improvement and opening the LTEP process to deeply involve its communities. Fully engaging communities in energy planning is not a simple matter of asking for input: Asking is necessary, but by no means sufficient. In fact, the pace of technology change with respect to energy technologies and DER technologies in particular is so rapid that simply asking citizens what they want can prove frustrating to everyone involved. This is particularly true for infrastructure decisions that can have lasting effects for a half-century or more. Research techniques such as deliberative polling and participatory modeling will need to be systematically applied to provide citizens with an adequate knowledge base to understand the decisions that are coming, before anyone can expect meaningful input. (Grönlund, Bächtiger, and Setälä 2014; Iwaniec, Childers, et al. 2014). Communities that have a century of experience generally accepting utility plans with little public oversight have a lot to learn before they can properly function in their new role as full participants in decision making. Utilities might be in a position to provide meaningful assistance to communities beginning to grapple with the many changes that a more distributed energy future will bring (Xcel 2016).

3.5 Summary

A half-dozen U.S. states are already involved in major regulatory proceedings intended to provide a framework for decision making on these issues. New York's process might be the most comprehensive, and most well publicized, but other states are working on related parts of the same puzzle. California is engaged in multiple regulatory proceedings with the intent of fully integrating DER and establishing frameworks for distribution service implementation plans (DSIP). Hawaii is sometimes called "ground zero" in the transition to DER, because so many of its customers are engaging in self-generation and the utilities are scrambling to accommodate so much variable output generation. (Akiba 2015; Cardwell 2015).

Massachusetts Department of Public Utilities (in is 12 June 2014 Order in Docket 12-76B) directed its utilities to file 10-year grid modernization plans, and Minnesota Public Utilities Commission has an ongoing grid modernization docket (CI-15-556). Washington DC's Public Service Commission is hosting, in Case No. 1130, a process for "Modernizing the Energy Delivery System for Increased Sustainability (MEDSIS)." The purpose is to review ideas about modernizing the District's energy systems and understand whether and what modifications might be needed to the existing legal and regulatory framework to accomplish the District's goals.

At present, there might be more consensus about the physical, technical, and engineering aspects of future DER and behind-the-meter capabilities than there is about the regulatory and institutional accommodations necessary to support a future with a fast growing, major dependence on DER. (See, for example: ASE 2013; Bade 2015a and 2015b; Fine et al 2015; Lovins et al. 2002; MIT Energy Initiative 2015; MN-PUC Staff 2016; Patterson 1999; Rifkin 2011; SEPA 2015).

In essence, the generally accepted visions are based on optimizing DER and taking advantage of flexible demand to end up with a grid that is highly reliable and resilient, with ever decreasing negative externalities and more customer choices in terms of service offerings and rate plans. Though there is plenty of variation in some of the details, the big picture visions are rather similar. What is much less certain at this stage is possible roles for regulated utility companies, unregulated product and service providers, and how regulations can best protect the public interest and most vulnerable customers.

Ontario's electric utility structure has much less variation compared to the U.S. as a whole, or even compared to individual states. Ontario is in a great position to watch and learn from all the other experiments going on in the states and other countries, while conducting multiple conscious trials in Ontario, to develop its own path towards the desired end state.

4 Grid Modernization and the Utility of the Future

4.1 Introduction

Predicting the future of grid modernization is proving exceptionally difficult, even looking just a few years into the future, let alone all the way out to 2050. Among the most important uncertainties are: (a) what new hardware and software technologies will become commercially available, and when;[130] what roles might be accomplished by regulated utility companies, versus competitive product and service providers; (b) how appliance and energy management systems manufacturers will enable automated or manual controls;

It would be ideal if grid modernization plans could be segmented and partial steps towards full grid modernization could be made sequentially, with each new investment generating savings in excess of its costs. In practice, however, utility regulators "are being pressed…to make decisions about utility smart grid investments based on imperfect information about benefits and costs" (Stanton 2011, p. 1). In the experience to date, U.S. Department of Energy provided matching funds to dozens of utility projects, "to catalyze and accelerate grid modernization." Roughly $7 billion in funding through the federal American Recovery and Reinvestment Act of 2009 was used to support about 100 projects for over 225 U.S. utilities. Part of the intention was to gather experience and information that could be used to provide proofs of concepts and start to quantify grid modernization benefits. Included were projects supporting transmission and distribution systems equipment, automated metering infrastructure (AMI), and consumer-side time-of-use rates, some combined with customer information services and control devices including smart thermostats and home energy management systems. The general intent was "to prove technical, operational, and business-model feasibility." Data from these projects is helping to demonstrate that well-conceived projects are likely to have benefits that exceed costs. Cost savings are shown coming from: (a) reduced utility capital expenditures and more efficient utilization of assets; (b) reduced utility operations and maintenance expenditures; (c) reliability improvements; (d) reduced pollution; (e) enhanced system flexibility; and (f) energy use reductions as a result of both utility operational controls and changes in consumer usage. (Paladino 2014).

Utility grid modernization components generally include sensors and controls for the utility system, combined with sensing and monitoring capabilities and advanced communications systems, designed to help optimize operations and control of all major infrastructure components –generation, transmission, and distribution. The primary missions for grid modernization for utility companies include: (a) increasing the efficiency of utility operations; (b) increasing system reliability and resilience; (c) reducing fossil fuel use and emissions; and (d) improving utility planning. The major components utilities are beginning to incorporate into the electricity grid, in order to achieve those missions, include: (a) transmission system enhancements; (b) distribution system enhancements, including distributed automation and distribution management systems; (c) advanced capabilities for integrating distributed resources; (d) advanced meter infrastructure (AMI); (e) system-wide communications and information integration; and (f) mechanisms for helping to shape

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130 See NETL 2010 for an early inventory of technologies.

consumer demands to produce system benefits. All of these changes also require education and training for utility system personnel, who need to learn how best to manage these new capabilities for achieving maximum cost savings and consumer benefits. (New York State Smart Grid Consortium 2013, 2010; Stanton 2011).

Some of the most important challenges with grid modernization that are facing utilities and utility regulators include: (a) managing the growing quantities of data that flows from AMI and other grid sensing, monitoring, and controlling technologies; (b) determining which smart grid activities are best suited for implementation by monopoly utility companies and which by competitive product and service providers; (c) addressing how integrated resource planning can evolve to incorporate novel DER applications; (d) learning about all of the behavioral aspects of customer responses to rate designs, education, and energy use information (Lacey 2016); and (e) addressing how all of those challenges might best be addressed for small utilities, that will be hard-pressed to develop and implement in-house the required suites of new capabilities.

Ontario would do well to recognize that the same general kinds of changes that are coming to the electric utility industry, built on the basic platform of implementing intelligent sensors and controls throughout the network, is also coming to other realms. Such changes will eventually affect cities through what are generally referred to as "smart cities" initiatives (Journal of Smart Cities 2016; Smart Cities Council 2016), agriculture through "precision agriculture" intended to optimize outputs while avoiding the waste of all inputs (Precision Agriculture Journal 2016); to new modes of industrial ecology where multiple processes get integrated so that the waste product or residue from any one process is a useful input to another (LeBlanc, Tranchant, et al. 2016); to reimagining transportation systems and infrastructure (International Journal of Sustainable Transportation 2016). As the world begins to address climate change, it is becoming clear that actions will be needed in practically every aspect of the modern world, to approach more sustainable operations.

As Tester, Drake, et al., explain that:

> In considering energy choices for the future, it is essential to look carefully at interactions that extend beyond the energy sector. Energy practitioners will develop better choices for the energy sector if they cooperate across professional lines with those concerned with water supplies, land use and agriculture, waste management, and other sustainability issues (2012, p. 334).

They further point out that energy futures planners must treat energy as a precious resource while attending "to topics that may seem to be outside the direct pathways of energy use, but which are in fact critical elements in a holistic systems approach to sustainability… [such as] climate change, water availability, land and ocean productivity, institutional stability, preservation of habitats and biodiversity, and many other environmental issues (2012, p. 366).

Some of these challenges could prove difficult for small utilities. As Mowat reports (2016b, p. 12), Ontario has several dozen small utilities. An important question is whether and how certain specific services might be provided by single-purpose entities that serve multiple small municipal utilities. The U.S. faces the same kinds of issues with small municipal and cooperative utilities. Sometimes, numbers of these small utilities group together to contract for services from a single-purpose service provider, or often distribution system cooperatives have formed new cooperative entities to provide specific services, such as billing and call center operations. There are many such roles that could be managed by province-wide agencies or competitive suppiers, such as distribution system modeling, community aggregation, and cyber and physical security. (Kolo 2016). For these kinds of functions, Ontario might find that the Provincial government, province-wide agencies, or public-private partnerships can play an important role in developing and sharing service standards and best practices.

In the context of smart-grid deployment, cybersecurity issues are also a major concern. But, in this instance, more of the deployment will be facilitated by or actually under the control of utilities, subject to both national cybersecurity standards and regulatory oversight. For small utilities, staffing to provide adequate cybersecurity oversight and controls will be a serious challenge (Phelan 2014).

4.2 Business As Usual Scenario

Jamison (2016) explains that a "clear model is emerging for the distributor of the future: a digitally-enabled network business that uses data analytics-powered demand response, dynamic storage, and sophisticated, responsive pricing to keep costs low, maintain reliability and smooth… peaks in demand."

Local Distribution Companies, in this image of the future, will be acting as either platform access providers or as platform optimizers, as previously discussed. The focus in this portfolio is much more on the utility itself, and how grid modernization affects the utility, as opposed to the consumer. The behind-the-meter portfolio looks at the same general themes as it affects the consumer. Here, BAU means the utility will implement a set of modern grid technologies to enable more efficient utility operations (Stanton 2011). For example, utilities will use new sensors, controls, and communications systems to:

- improve voltage control and power quality;
- monitor equipment to improve maintenance and reduce down-time, utilizing assets more efficiently;
- improve outage management and restore service faster in the event of outages;
- improve customer service and reduce the total costs of customer service;
- reduce the use of fossil fuels and fossil fuel emissions;
- enhance physical and cyber security; and
- improve utility planning.

Eventually, many of these functions will be at least partly automated, so that decisions previously made by utility personnel will increasingly be made by intelligent control systems, that are pre-programmed to implement routine functions.

The major issue for regulators and policy makers is not so much whether such changes should happen, but rather how best to sequence investments so that total system costs can stay level or even possibly go down as the investments in modern grid technologies gradually supplement and replace some of the previous infrastructure and squeeze greater efficiency out of the system as a whole. Every step of the way, decisions need to be made under conditions with multiple uncertainties, and no one yet has a clear or complete vision of all of the dimensions of change that are coming. This augurs for smaller scale experimental projects, followed by somewhat larger pilot programs, and then gradualism and incrementalism as technologies are deployed throughout the whole infrastructure.

4.3 Focus on Short-Term Cost-Effectiveness Scenario

In this scenario, grid modernization is expected to take place at a faster rate, with more investment happening sooner. An important watchword will be flexibility, as each new investment should make it easier for the grid to adapt to more changes (Aggarwal and Orvis 2016).

In this scenario, non-transmission alternatives and non-distribution alternatives could dominate investments in traditional central station and transmission resources. Neighborhood and community-scale systems of generation, storage, and related DER would be analyzed each time that modeling would otherwise suggest the need for centralized power and transmission, and whenever the non-wires or market-based alternatives prove cost effective, they would be selected. That future might use microgrids in particular areas, effectively functioning as load limiters for groups of customers, to ensure that the distribution and transmission assets are not overloaded. Community-shared resources might be widely deployed (USDOE 2016j; Community Storage Initiative 2016).

Remote microgrids might be practical for areas with widely dispersed populations, rather than building out extensive transmission grids to reach rather modest loads (Gamesa 2016; Kessler 2016). This model should at least be considered and some remote microgrids established to prove the concepts; they can always be interconnected to a larger macrogrid at some time in the future if that turns out to be a cost-efficient option. The U.S. is establishing a hybrid-microgrid program for remote communities (Backhaus, Swift, et al. 2015; USDOE 2015b).

In addition, public purpose microgrids might be considered for any and all kinds of facilities that are important to keep running during any outage of the macrogrid. In the U.S. many Department of Defense facilities are already incorporating microgrids to insure, as much as possible, uninterruptible power supplies. In addition, several U.S. states have started programs to enable microgrids for serving critical infrastructure facilities and first-responders. These include, for example, Connecticut (CT-DEEP 2014), Maryland (Maryland Energy Administration 2014), New Jersey (NJ-BPU 2014a and 2014b), and Minnesota (Burr, Zimmer et al. 2013).

4.4 Focus on Innovation

In this scenario, utilities will complete a major transformation between now and 2050 (Barrager and Cazolet 2014; Muhr 2016). Students of a fully transformed public utility sector point to new cooperative relationships with customers, new business models incorporating major revisions in utility ratemaking based on the value of service as opposed to returns on investment based on embedded costs. Utilities might function as beneficent energy consultants, continuously mining usage data and investigating improved energy technologies, to advise customers about how to maximize the value of energy services while minimizing costs. This model is one of the utility as a learning-organization, holding as its primary focus the interests of individual customers and of society as a whole.

In this scenario, utilities need to become experts in new kinds of roles. While traditional utilities might have been experts at raising capital for making massive investments, and possibly for coordinating gigantic construction projects, utilities of the future need to manage multiple kinds of customer relationships, using an expanding set of communications channels (Stanton and Kline 2016). Utilities of the future need to engage with communities in energy futures planning (Xcel Energy 2015). Utilities of the future need to become experts at mining the massively increased flow of data, to identify options for improving service and lowering cost for consumers (Hoare 2016; Pecan Street, Inc. 2016; Schneider Electric 2016).

One of the big challenges with this type of future is how to change rate designs to accurately reflect benefits and costs of many different DER, and to support partial requirements customers, flexible loads, CHP, and nested microgrids. A great deal of work remains to rationalize such changes.

4.5 Summary

To paraphrase a remark attributed to Sen. Robert F. Kennedy, everyone paying attention to the future of the electric utility industry might say, “Like it or not, we live in interesting times.” It is fair to say that never in the century-old history of this industry have so many changes come so fast, creating so much uncertainty. There are at least some models from other industries of customer interest in innovative technologies and what are called enticing technologies (Milbrath 1989, Chapter 13). There is more uncertainty about how utility companies might best respond to the potentially disruptive changes that new DER technology might bring (Christensen 2016; Sampere 2016).

5 The Future of Centralized Supply

5.1 Introduction

Ontario's current capacity mix is roughly one-third nuclear, a bit less than one-third gas and oil, a shade less than one-quarter hydro, 10 percent wind, and one percent each from biofuel and solar (IESO 2016b). IESO reports that most solar generation resources are interconnected to the distribution system, rather than transmission.

Ontario's transmission system is interconnected to Manitoba and Minnesota, to the West and North. Ontario has four interconnections with Quebec, to the North and East. Plus, Ontario has two interconnections with New York. One is between Lake Erie and Lake Ontario near Niagara, and the other connects to the St. Lawrence area of New York, past the eastern end of Lake Ontario. There are also interconnections to Michigan, at Sarnia and Windsor. These interconnections provide both economic benefits and reliability benefits. For reliability, the interconnections can provide for power imports in response to anticipated or unanticipated needs in Ontario. Similarly, the interconnected systems might also be able to draw power from Ontario when that is beneficial for their own reliability needs. For economic benefits, Ontario is often able to export some of its power into higher cost regions, thus better utilizing Ontario facilities while generating revenue to help cover fixed costs. Since 2005, Ontario power exports have exceeded imports, reducing Ontario consumers' costs by about $300 million in one 12-month period in 2013-14. (IESO and Ontario Power Authority 2014).

As part of its LTEP process, Ontario models the operational flexibility that the interconnections provide, for both economic and reliability reasons, plus possible upgrades to interconnections that would enable larger firm contracts for clean-power imports. Such modeling has to take into account both the physical capabilities of each interconnection to accommodate imports and exports, plus the current and likely future supplies and demands in Ontario and in each interconnected region. Each interconnection has its own capacity limits, and each transmission planning region is engaged in its own modeling and planning, which includes all of its interconnections, to Ontario and other jurisdictions. At present, Ontario exchanges much smaller quantities of power with Manitoba and Minnesota, and larger quantities with Michigan, New York, and Quebec. Exports far exceed imports to both Michigan and New York. Exchanges with Quebec fluctuate more between imports and exports, with the total exchange being close to equal. (IESO and Ontario Power Authority 2014).

Looking to the future, there are many uncertainties and unknowns about central-station resources. This report briefly reviews information about each of the major types of central station power plants and fossil fuel sources, and then discusses each of the three future scenarios Mowat has identified.

In thinking about central station power plants, too often the different points of view get distilled into overly simplistic sound bites that do not convey anything near complete information about choices. Deciding on the appropriate future supply mix requires comprehensive multiple-criteria decision analysis (MCDA) with continually updated input data to reflect the best available, up-to-date information about engineering, economic, and environmental aspects, to help guide decisions. This is especially critical for all long-lived investments, like central station power plants and transmission lines, with expected useful lives measured in decades. All power choices have both positive and negative characteristics: The best anyone can hope for is decisions based on comprehensive integrated resource planning that includes the viewpoints of all important stakeholder groups and reflects all important uncertainties. There is a lot of available research about best practices in such decision analysis, that can guide IRP processes. There needs to be a conscious and conscientious effort to ensure that best practices are used. Not all stakeholder groups are already fully apprised of the nature of choices and potential benefits and costs associated with energy futures alternatives: Significant outreach and education efforts will be needed if provincial and sub-regional planning is to include consideration of all major viewpoints. Ontario has already initiated important efforts to ensure that its communities can be fully engaged in the planning process (IESO 2016a).

In the far distant future, all fossil fuels will be exhausted, even the current types of nuclear fuel. No one knows for certain how long the economically recoverable reserves of fossil fuels will remain available, but irrespective of whether that time frame is measured in decades or centuries, there is a need to begin considering continuously-renewable alternatives and what it will mean to build a bridge from today's dependence on finite fossil fuel reserves to a fully renewable future. Added to that concern must be some accommodations for global climate change policies. No matter what opinions any individuals hold about the veracity of the current scientific consensus, or lack thereof, about climate change, it is clear that world policies are gradually taking shape around the idea that climate change does need to be addressed, which could imply combinations of abandoning the use of fossil fuels while some known quantities remain in the ground plus using carbon capture and storage technologies to prevent greenhouse gas emissions from fossil fueled power plants that do continue to operate. At a minimum, some kind of tax on greenhouse gas emissions might eventually be imposed, which would change the economics of fossil-fueled power plants. Both of these are important contingencies that need to be considered when modeling future power supplies.

5.2 Thermal power plants

All of these central-station power plant options basically boil water (or some other working fluid) to raise steam, and then use the steam to drive turbines that generate electricity. The basic technologies for nuclear, gas/oil, and coal have remained essentially the same for the past 50 years or more, with only modest changes to increase efficiency. Concentrating solar power (CSP) is a newcomer, but that option is showing promise in areas with the most intense solar radiation, like the desert southwest U.S. (USDOE 2016g).

A major source of information about central power plants is the U.S. Energy Information Administration's National Energy Modeling System (NEMS), which is updated regularly with new information (USEIA 2016a). The NEMS model incorporates information about each power plant's typical capacity (in MW), lead time for construction (in years), overnight construction cost (that is, construction cost without financing charges, measured in $/kW), variable operations and maintenance (O&M) and fixed O&M, and heat rate.

5.2.1 Nuclear

For nuclear, the USEIA (2015, p. 105) considers both "conventional" and "advanced light water reactor" plant types. "Conventional" means essentially the existing nuclear fleet. "Advanced" nuclear is modeled as plants on the order of 2,200 MW in size, with a predicted overnight construction cost upwards of $5,300 per kW.[131] Nuclear is one of the highest-cost options for building new central station power plants, but nuclear power is a low carbon resource and, as long as reserves of uranium for the nuclear fuel cycle remain accessible in ample quantities, nuclear plants have low operating costs. Barua, Keogh, and Phelan (2015, p. iv) explain:

> While there are concerns about the management of spent nuclear fuel, nuclear power does provide carbon-free baseload generation, is a reliable and dispatchable resource, contributes to fuel diversity, and is an economic stimulus to local areas. Because the operating cost of a nuclear plant is only minimally affected by the cost of fuel, it is, for the most part… more immune to fuel price volatility than other energy resources.

In the U.S., the recent track record for nuclear power is quite positive, with high reliability and no major accidents. (Rogers 2013). The Fukushima disaster in Japan resulted in heightened attention to nuclear plant risks from natural or human-caused failures, with an emphasis on safety and emergency response capabilities in the event of floods, earthquakes, and loss-of-power (National Academies of Sciences, Engineering, and Medicine 2016; Rogers 2013, pp. 4-5).

The best advice for nuclear, for the time being, is that research and development should continue, working towards a smaller modular plant design that does not generate bomb-grade material (Kessides 2012; USDOE 2016k). Until that happens, building a new nuclear plant will mean locking into a multi-billion-dollar obligation that will bind consumers far into the future. For now, nuclear is a very expensive way to make electricity and a very expensive way to reduce greenhouse gas emissions. Because of its long lead times for construction, it is also a relatively slow means of reducing greenhouse gases. If and when an inexpensive, safe, reliable nuclear plant option becomes available, then regulators can think again about risking ratepayer money on constructing new nuclear plants.

5.2.2 Natural Gas/Oil

Over the past decade, natural gas-fired generation rose significantly from 17 percent to around 33 percent of U.S. power generation and is now, along with coal, the largest fuel source for generation capacity.[132] Gas use is expected to continue to increase in the future, both in absolute terms and as a share of total power generation and capacity.

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131 Only three power plant types included in NEMS are modeled as costing more than an advanced nuclear plant. They are 520MW integrated coal-gasification combined cycle (IGCC) plants with carbon sequestration at an estimated $6,492/kW; 10MW fuel cells at $6,798/kW, and 50MW municipal solid waste plants at $8,271/kW.

132 Since 1995, the consumption of natural gas for electric generation has more than doubled.

The combination of evolving environmental regulations limiting reliance on coal generation and low gas prices has led to a significant increase in the amount of gas-fired generation in the United States. Low gas prices and major financial hurdles are limiting the prospects for new nuclear plants. Renewable energy, which is growing rapidly but generally comprises a small share of fuel sources for electric generation, requires quick response grid support that gas-fired generation is able to provide . Overall, natural gas will play a crucial role in the future generation of electricity in the U.S.

Demand for natural gas is expected to grow in other sectors (e.g., transportation, exports, and manufacturing), placing upward pressure on price. A high enough price rise could adversely affect the economics of natural gas for electric generation. Forecasts call for natural gas to play a growing role in offsetting the variability and uncertainty associated with renewable resources.

Unlike coal and fuel oil, natural gas is not easily stored on-site. The reliability of gas-fired generation is therefore heavily dependent on the delivery system, especially in transporting gas from long distances. Gas-fired generation also faces the risk of curtailments when other uses of gas (e.g., residential consumption for space heating during the winter months) have greater priority during periods of supply and delivery bottlenecks. For example, many gas-fired plants operate year round, posing potential delivery problems during the winter months when traditional gas customers consume much more natural gas. There is a need for increasing pipeline capacity to serve new customers and reroute gas flows from new production areas. Studies have calculated a high social cost from inadequate gas pipeline capacity.[133]

Contracts for firm natural gas supply and transportation affect the risk profile of a power plant. Demand growth of gas use in electric generation, especially during critical periods of extreme weather or fuel shortages, can cause operational problems for both regional power systems and gas pipelines.

Gas-fired generation poses unique challenges for the delivery system. For example, pipelines often have to provide capacity to power generators on short notice, especially during periods of peak electricity demand. In organized electricity markets, the scheduling of electricity by the regional operator may occur one day, one hour, or even as little as five minutes prior to actual generation. Pipelines also have to adapt to the frequent and highly fluctuating changes in gas flow by power generators.

Gas-fired facilities have several attractive features as a fuel source for electric generation. They include:

(i) They can be sited and built with reasonable certainty;
(ii) They can cycle more quickly than base-load coal or nuclear generation – for example, compared to coal units, natural gas units are relatively quicker and easier to ramp up and down;

[133] See, for example, ICF International, *New England Energy Market Outlook: Demand for Natural Gas Capacity and Impact of the Northeast Energy Direct Project*, prepared for Kinder Morgan, Inc., 2015

(iii) They are relatively cheap to construct and quick to construct;
(iv) They are cleaner than coal units;
(v) As long as gas prices remain low, gas-fired plants benefit from low marginal fuel costs;
(vi) When gas prices are low, gas-fired plants are cheaper to operate than some coal power plants; for base load plants, this reality means more constant hourly generation; and,
(vii) Underutilized gas-fired capacity means that natural gas use for electric generation can increase without new construction.

In spite of the benefits from gas-fired generation, there has been resistance in the U.S.to the increased use of natural gas for electric generation. The reasons are:

(i) Some gas buyers are reluctant to commit to investments that require the purchase of natural gas over a multi-year period unless the gas producers can offer price and supply stability;
(ii) Even though natural gas prices have become more stable over the past few years, a common perception is that they are inherently volatile;
(iii) Many gas buyers are therefore reluctant to commit on a long-term basis to a fuel source whose future prices could increase substantially above current levels;
(iv) Some electric utilities are hesitant to rely almost exclusively on natural gas to fuel new generation or replacement generation; they desire more diversity of generation technologies as a physical hedge; and
(v) Some policymakers are concerned that, similar to the early 1990s, new generating capacity will be predominately natural gas.

Most recently, there has been concern over the methane emissions from the production and delivery of natural gas. As expressed in the EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, methane emissions from the natural gas sector originate from varied sources:

> [Methane] emissions from natural gas systems include those resulting from normal operations, routine maintenance, and system upsets. Emissions from normal operations include: natural gas engine and turbine uncombusted exhaust, bleed and discharge emissions from pneumatic controllers, and fugitive emissions from system components. Routine maintenance emissions originate from pipelines, equipment, and wells during repair and maintenance activities. Pressure surge relief systems and accidents can lead to system upset emissions.[134]

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[134] U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013*, April 2015, 3-68.

Natural gas systems are a close second to enteric fermentation (i.e., livestock flatulence) as a source of methane emissions. About half of the methane emissions derive from one or the other of these two sources. Nearly 25 percent of methane emissions comes from the production, processing, transmission and storage, and distribution of natural gas.[135]

Natural gas also plays a large role in small-scale electric generation. For example, 71 percent of existing combined heat and power (CHP) capacity in the U.S. is fueled by natural gas. CHP systems consume annually about 4.5 Tcf of natural gas, or an estimated 2.2 Tcf more than the natural gas consumed by onsite boilers or furnaces in the absence of CHP.

In the U.S., gas turbine and steam turbines are the major CHP technologies that use natural gas as a fuel. For example, combined cycles and combustion gas turbines represent 50 and 13 percent of existing CHP capacity, respectively. Boiler/steam turbine systems, which use primarily coal and wood waste, represent 34 percent of total CHP capacity. Reciprocating engines, fueled by natural gas, represent 3 percent of CHP capacity in the United States while microturbine systems and fuel cells make up less than one percent.

Some gas-fired CHP technologies have much faster start-up times than others: The fastest technologies are reciprocating engines and microturbines, which can almost immediately provide electricity when the local-utility grid goes down. This feature has received greater attention recently because of rather widespread power interruptions caused by severe weather conditions.

The costs of different gas-fired CHP systems vary widely: Large systems have much lower capital cost per kW, reflecting economies of scale. Steam turbines have the lowest capital costs. O&M costs are highest for small systems, such as fuel cells, microturbines and reciprocating engines.

Low natural gas prices and heightened interest in power resiliency have also contributed to the growing support for CHP technologies. These factors should continue in the future to make long-term financial commitments to CHP investments more likely.

Oil is barely used in the U.S. for electricity generation − less than 1 percent.[136] Some diesel fuel is used in peaking generators, including back-up generators (BUGs) at facilities with needs for the highest reliability, such as hospitals and other essential services. In addition, there are some dual-fuel generators that are able to switch between oil and natural gas, depending on fuel price and availability and some diesel generators are available to be used for black-start capability when needed.

[135] Other contributors to methane emissions include landfills, coal mining, manure management, petroleum systems and wastewater treatment.

[136] Just over the period 1978-1984, for example, oil-fired generation plummeted by over 68 percent. Reasons for this included the second OPEC price shock, starting in late 1978, and the enactment of new federal legislation that discouraged oil consumption (for example, the Power Plant and Industrial Fuel Use Act of 1978).

5.2.3 Concentrating Solar Power

Concentrating solar power (CSP) technologies collect solar energy using mirrors to reflect sunlight onto receivers that convert the light into heat, which then powers either a turbine or a heat engine to drive a generator. Converting the light into heat allows the energy to be stored for as much as several hours, so that electricity production can take place even when the sun is not shining. The U.S. is already home to about 2,000 MW of CSP capacity. The U.S. DOE SunShot Initiative goal for CSP is to reach a levelized cost of energy of about six cents per kWh by 2020. As of early 2016, the cost has already decreased to about13 cents per kWh (USDOE 2016g).

In the U.S., almost all CSP facilities are in the sunny southwest (Wood 2014). At present, this technology is likely too expensive for commercial operation in a cloudier, more northerly latitude like Ontario. But, it is not too early for Ontario to identify any potential locations that could host CSP technology and to consider the role that CSP or conceivably some other combinations of solar-plus-storage technologies might serve in the future.

5.2.4 Coal

In the U.S., dozens of smaller, older coal plants are being permanently shuttered. That is the combined result of long-anticipated environmental rules and the recent span of low natural gas prices. In just 2015-2016, over 125 coal-burning power plants in the U.S. will be closed, totaling over 18,000 MW of capacity. The average age of the plants being closed in 2015 was 58 years. Almost half of all U.S. coal plants were built prior to 1970, nearing the end of their useful lives regardless of future environmental rules. Six U.S. states already have no coal-burning power plants, other than CHP units, three states plan to close all their remaining plants by 2025, and three more states will have only one operating coal plant each. Less than two dozen new coal plants are under active consideration for construction, only three by 2021, and several of the others are planned primarily as sources of liquid fuel, rather than primarily for electric power production. Most of this activity is a response to environmental rules other than the proposed clean power plan (CPP). Coal use for making electricity is down almost one-third since a 2007 peak in usage. That coal use decline is a response to both flat or declining demand for electricity since 2007 and to growth in natural gas use for making electricity plus continuing growth in wind and solar. In about a dozen states, coal usage is down by half or more. (Fitzpatrick 2016; USEIA 2016b).

Ontario has placed a moratorium on using coal, because of concerns about greenhouse gas emissions. Ontario might keep some attention focused on new technologies being developed, which could solve environmental concerns associated with coal use. If emissions problems can be greatly reduced, including GHG emissions, then at some point in the future it could be practical again to consider using coal for making electricity, perhaps in facilities that also produce clean liquid fuels for transportation. U.S. DOE has a program to support development of a half-dozen such technologies. (USDOE 2016f). And, Ontario’s Queens University is already working with a U.S. company, Enviro Ambient, on one promising technology for such emissions improvements (Enviro Innovate 2016).

5.2.5 Biomass

Biomass plants that burn solid fuel for electricity generation typically range in size from about 10MW to as large as 200MW, mostly towards the smaller end of this spectrum with many of the plants in the size of 50 MW or smaller. Biomass fuel is not as energy-dense as fossil fuel sources; it is rather bulky and has high water content. That means it is seldom practical to transport the fuel more than about 120 kilometers. Power plant size is often determined along with fuel procurement and delivery planning, to make sure that the resource base in the geographic area surrounding the power plant will be able to supply fuel sustainably and at reasonable cost. One possibility for Ontario lake-side communities could be biomass fuel delivery by Great Lakes vessels. That could change the economics of fuel procurement enough to support one or more biomass plants that would be in proximity to loads but could obtain fuel from greater distances.

Planners need to take into consideration the potential for biomass production on a sustainable basis, and all of the competing needs and uses for biomass. Biomass fuel is sometimes called an “opportunity fuel” because using biomass waste materials for fuel sometimes helps the producers to avoid costs otherwise associated with waste disposal. Planning is complex, though, because there are many competing uses of biomass for food, fiber, and chemical feedstocks. (Bryan, King, and Wang 2010).

Before embarking on plans to utilize biomass wastes for electric power generation, Ontario should undertake a thorough resource assessment and engage with local communities in long term planning. That kind of effort should be repeated every few years, in conjunction with energy systems integrated resource planning. Smart biomass energy planning will support smart agriculture and forest management practices, helping to make sure that utilizing biomass for fuel does not threaten the long-term sustainability of farms or forest lands. (USDOE 2016a).

Even after studies determine that some portion of sustainably produced biomass is viable for use as fuel, then competing mechanisms for conversion to liquid or gaseous fuels should also be considered. The value as converted to wholesale electricity, even with a co-generation or tri-generation capability, could be lower than the value as liquid fuel (bio-diesel or bio-gasoline) for example. Furthermore, bio-fueled electric generation can be sized and sited where as much of the waste heat as practical can be applied to some useful purpose, effectively at least doubling the useful energy produced and delivered to serve local uses. No different from the experience with thermal power plants using other fuels, if the generators are built at too large a scale, waste heat utilization can prove impractical. This has been the experience in Michigan, where a handful of ~30MW and ~10MW wood-waste-fueled power plants were constructed, without plans to utilize any of the waste thermal energy. Subsequent efforts to identify and implement waste heat utilization have proven unsuccessful (Michigan Biomass 2016).

5.2.6 Hydro and Hydrokinetic

Hydroelectric and hydrokinetic resources can be developed at utility scale, and should be considered in IRP modeling. There might be few, if any, promising sites for traditional hydroelectric dams that have not already been developed, and there can even be serious interest in removing at least some existing dams, because of a social preference for the environmental attributes of free-flowing streams. (USDOE 2016l). Nevertheless, hydroelectricity and hydrokinetic options do offer several promising opportunities for future development:

- Existing hydro facilities can be refurbished, installing improved modern turbine designs to capture additional useful energy. Typical gains are in the range of 10 percent production improvements.
- Installing new hydroelectric generators at existing dams. Cite to U.S. DOE Idaho Lab study that shows some states could double hydro capability by installing generators where dams already exist, with no additional impoundments.
- Existing facilities used for pumped storage hydro. Cite to German example.
- Future designs for hydrokinetic (wave power, river current). These include buoy generators bobbing in the water, and even hydroelectric generation from water flowing through water purification plants and sewer treatment plants.

Although fully cost-effective hydroelectric developments could be scarce at the present, Ontario should consider mapping its hydroelectric resources to develop a detailed resource assessment of its technical potential. That can be updated with economic potential data as technologies improve.

5.2.7 Wind

Wind energy projects are usually considered to be central power options when they are in the scale of 50MW and larger. There is no clear cut size limit for distributed wind as opposed to centralized wind, but if wind projects are interconnected to the transmission system, they are generally considered to be utility-scale, centralized options. The biggest wind projects are presently on the order of a couple hundred MW. Wind generating technology and operating characteristics have improved substantially in recent years, making wind one of the lowest cost generating resources available, in areas with strong wind resources. At the same time, improved turbine designs that capture more wind at lower wind speeds have made it practical to install wind, cost-effectively, in more areas. (USDOE 2016m). The U.S. Department of Energy is presently projecting that wind generation might cost-effectively provide as much as 1/3 of all electricity supplies by 2050 (USDOE 2016n).

Wind resources are variable, but not completely unpredictable. Utility operators have made major gains in recent years, in being able to more accurately forecast wind resources and reduce the costs of incorporating more wind into daily utility operations (Xcel Energy 2016).

Both Ontario and Michigan are in unique positions vis a vis offshore wind. Importantly, both have vast territories in multiple Great Lakes, where the wind resource is gigantic (GLIN 2016). Although critically important engineering challenges remain to be addressed, especially about the potential survivability of ice-flows in the fresh-water Great Lakes and foundation designs for turbines in deep water, an experimental project is already starting in Lake Erie, near Cleveland (Sandy 2016).

Ontario had previously moratorium on offshore wind development (Spears 2014). But, the potential offshore resource is such an important opportunity that it deserves serious attention. If the existing technical problems and social acceptance concerns can be resolved, then offshore wind will move forward. In the meantime, offshore wind modeling capabilities can be greatly improved using existing data and obtaining new, more accurate wind resource data using floating platforms (GLIN 2016; GVSU 2011; USDOE 2016i and 2015d).

Interestingly, a Michigan company, Accio Energy, Inc. (2016), is already developing new wind-power technology with higher capacity factors and no moving turbine blades, for both offshore and onshore, even building integrated, wind-powered electric generating technology.

In this context, lessons from Denmark are important. Denmark went from essentially nothing, in wind energy, to become one of the world leaders (Lema, Nordensvärd, et al. 2014). Most recently Denmark and the U.S. just signed a memorandum of understanding about how the two countries will cooperate on offshore wind (North American Windpower 2016). In the still-early stages of North American offshore wind power development, Ontario could take advantage of its existing manufacturing capabilities and research universities to lift itself rapidly into a leading position.

One important function that Ontario could develop is the capability to engage communities in wind power planning, identifying those lands that are suitable for development and any that should be excluded. That high level assessment is sometimes called macro-siting. Once that major task is completed, then more detailed work can proceed to identify promising locations for individual turbines, sometimes called micro-siting. U.S. experience has shown that bottom-up planning that includes input from local communities can make a big difference in acceptability for wind turbine siting. Spending the time and effort early in the planning process to determine the most suitable locations with respect to other kinds of land uses can be instrumental in facilitating development. (Simao, Densham, and Haklay 2009; Trutnevyte, Stauffacher, and Scholz 2011). Until the local community input activity is conducted, community by community, it will be very difficult to understand Ontario’s wind development potential.

5.2.8 Solar PV

The dividing line between utility-scale solar and distributed solar, like with wind, is unclear but as Ontario observes, most solar power there is interconnected with the grid at distribution voltage (IESO 2016b). In the U.S., utility scale solar is usually defined as being 20MW and larger, all the way up to 250MW (Chan 2012). The National Renewable Energy Laboratory *Open PV Project* database includes all projects 5MW and larger under the category of utility scale. (NREL 2016b).

Utility scale solar PV installations are generally cheaper to build and operate, compared to smaller PV systems. There are persistent economies of scale in designing, building, and operating solar PV that makes bigger systems less expensive. Presently, the total installed capacity of U.S. utility-scale solar PV is doubling every couple of years. Some caution should be observed, though, because there is at least some evidence that economies of scale can be exhausted, and even reversed, in the largest utility-scale projects. Plus, smaller scale systems are amenable to further economies due to improvements in manufacturing, systems standardizing, and the reduction of soft-costs. (Stanton et al. 2014).

A simple comparison based on system cost, however, could be misleading because by itself it overlooks the benefits that solar PV installations can provide. Because locational values can be so substantially different based on operational conditions, it can be just as important to identify the most favorable locations on the grid for installing solar PV as it is to determine what size system might provide the best profile for lifecycle cost.

As with other renewable energy resources, solar resources can be mapped accurately enough to provide at least high-level data to help guide siting decisions. A good starting point for Ontario would be to provide a basic mapping system to help planners explore capabilities, to develop ideas about how much solar power can reasonably be developed (Villalpando 2016). A primary U.S. example is the Energy Zones Mapping Tool, developed for the Eastern Interstate Planning Council (EISPC). The EZ Mapping Tool system includes over 250 geographic information system (GIS) data layers, for the entire Eastern U.S., including information about biomass resources, geothermal potential, solar power, energy storage in both pumped storage hydroelectricity and by virtue of geological zones that might be used for compressed air energy storage, hydropower and hydrokinetic energy, and wind. (EZMT 2016).

5.3 Business As Usual Scenario

In understanding BAU, Ontario needs a continuously updated set of information upon which decisions can be made. Options such as nuclear, natural gas, and oil can be articulated through updated information about project types and costs, similar to the U.S. NEMS data (USEIA 2016a). Siting options for such plants can be determined ahead of time by understanding all of the basic system design parameters and analyzing the best available locations based on proximity to the existing grid and loads.

For all of the other options – biomass, hydro, solar, wind – the exercise of identifying suitable locations will directly affect how much of each resource might be practical to develop. Long before 2050, Ontario could usefully engage in a province-wide process engaging ongoing public participation, to identify potential central station resources and develop comprehensive assessments for siting. Combining all of the basic resource data into one mapping system will help all interested parties to visualize the relevant geo-spacial concerns, to best understand the practical limits to production from each power source. There are already plenty of examples of both problematic and promising locations for siting renewable resources (Brun 2016; Leader-Telegram Staff 2016; Lundin 2016c; Morita 2016; Morris 2016; Nelson 2016; Prather 2016).

In BAU, Ontario has to consider what will happen as nuclear plants reach retirement age, and need to be phased out or replaced. It will certainly help to understand the options and anticipate the timing, so that replacements can be considered and contingencies planned ahead of time. It is also necessary to consider future prices for natural gas and oil, as a fuel for power plants, and to carefully weigh the choices between the different possible configurations for power plants, including CHP installations from the largest-scale utility plants for district heating and cooling applications, which are probably in the order of magnitude from 10 to 50MW, all the way down to the smallest CHP units for residential or small commercial customers.

A Michigan example shows how quickly BAU plans can change as new information becomes available. In response to a series of proposals for constructing as many as eight now baseload coal plants in the state, Michigan completed a "Capacity Needs Forum" process, which resulted in a statewide plan for future electric power needs, published in January 2006 (MI-PSC Staff 2006). At that time, expected load growth was pegged at about 2.1 percent per year. After making accommodations for enhanced energy efficiency, new renewable resources, additional transmission infrastructure, combustion turbines for peaking power, and load management, the need was still anticipated for two new baseload coal plants to be operational by as early as 2011. Just a year later, Michigan's *21st Century Electric Energy Plan* was published (Lark 2007). By that time, future load growth projections had been reduced to about 1.2 percent per year, and modeling showed a need for a new baseload plant by 2015. A major lesson is that no one anticipated the major economic downturn that began in 2008, followed by the still-continuing sluggish recovery. Today, almost a decade after the most recent statewide assessment, no new baseload plant has yet been ordered, about a dozen of the older, smaller, coal units are retired, and the future still looks much the same, with at least some observers warning that Michigan still has an acute need to build at least one or two new baseload plants, to come on line by about 2020 or so. (Poppe 2016).

Similarly, Pletka (2016, pp. 13) reports that renewable electricity serving the Hawaiian Island of Kauai grew from about 6 percent to 38 percent in the ten year period from 2007 through 2016, and California's renewable portfolio standard (RPS) objectives grew from a 2002 version calling for 20 percent by 2017, to a 2011 standard of 33 percent by 2020, to a 2015 standard of 50 percent by 2030.

The problem with understanding BAU is that it is a constantly changing picture, with many causes and effects swirling around in as yet incompletely understood patterns. Since central station power supplies each typically represent such large financial commitments, planners should continue to watch for every opportunity for plans that build in option value and flexibility.

5.4 Focus on Short-Term Cost-Effectiveness Scenario

In this scenario, DER fills all cost-effective roles, leaving the need for gaps in power production to be filled by flexibly operated central stations. Eventually, some central station power plants will need to be flexibly operated, in a kind of "virtual power plant." That means managing power plants in conjunction with multiple DER resources and central station wind, hydro, biomass, and solar PV, so that the end result is steady power that is fully capable of cost-effectively managing the inherent variability in wind and solar production (Asmus and Lawrence 2014). Solomon, Faiman, and Meron (2012) have started to model the quantities of conventional capacity needed to support a grid with very high fractions of power supplied by solar and storage. That type of analysis will be needed to determine how much traditional, central station power will be needed as the grid transforms to use more central station variable-output generation and DER. Ideally, DER can be expanded in concert with the retirements of existing central-station power plants, so that operational gaps can be managed with a minimum of new investments in expensive central station plants.

Also, for all fuel sources, CHP opportunities should be explored and implemented wherever they prove cost-effective, because they enable much more complete utilization of the energy inherent in the fuel, helping reduce total environmental emissions while delivering as much as double or more the total useful energy. (ACEEE 2016a; Shibata 2016; USDOE 2016e).

5.5 Focus on Innovation

It is difficult to understand how widespread the potential transition to DER could be in the coming 30 years or more, because there are presently so few examples where DER are being intensively developed in particular locations. The only U.S. examples are those where DER are being developed in order to implement non-transmission alternatives (NTAs) (Stanton 2015b). As explained in Stanton (2012a, pp. 4-5), service using microgrids might already be less expensive compared to the traditional options of central-station power plants connected to loads by high-voltage transmission systems. Hurdles remain, though, because:

- Few utilities are fully equipped to model the full costs and benefits of DER options;
- Utilities are likely to be predisposed towards traditional central-station and transmission options, because of long-standing practices and financial incentives that reward major, lumpy capital expenditures;
- Few customers are fully apprised of DER options, costs and benefits; and,
- Existing laws, rules, and regulations are blocking the full use of DER options in almost all jurisdictions.

These kinds of issues caused Patterson (1999) to conclude that the two different possible futures for utilities might even be mutually exclusive. Preliminary steps towards better understanding these options are the kinds of modest actions recommended by Stanton (2015b, pp. 9-15 and 2012a, pp. 30-33).

In addition, Ontario should carefully assess its own capabilities to determine whether the Province has any defensible niches in sustainable energy futures. Off-shore wind could be one example, where Ontario action as an early mover could help the Province to take advantage of its own rather spectacularly large wind resources while also supporting its own manufacturing and project development capabilities that could then support export opportunities to other jurisdictions. Another opportunity might be built around district heating and cooling capabilities, including the example already in use in Toronto, that uses cold Lake Ontario water (Enwave Energy Corporation 2016; NREL 2016a).

5.6 Summary

Detailed scenario planning using an open GIS system is a sensible early action that Ontario can take to help visualize central station options. Ontario has already noted that municipalities want and expect greater opportunities for consulting on energy resources decision making and siting (IESO 2016a). A system along the lines of the Energy Zones Mapping Tool (EZMT 2016) can be used to help identify promising, plausible locations for all kinds of central station resources and transmission lines necessary to interconnect those locations with the existing grid. GIS data can be used to help identify the most promising sites and thus resource potentials for biorefineries, hydroelectric and hydrokinetic resources including micro-hydro and pumped storage hydro, solar, and wind power. When functionally combined with power planning software, such mapping capability can function as an integral part of utility and community integrated resources planning (Stanton 2015c, p. 5).

6 Cybersecurity in the Utility of the Future

Cybersecurity is an issue that is relatively new to utility regulation. It is already the subject of intense focus, and will be increasingly important. Cybersecurity concerns are not limited to any one specific aspect of utility operations, but rather will involve multiple areas of regulatory decision-making. Cybersecurity is relevant to many customer trends and grid technology developments, as it limits some of the potential actions utilities might take to find solutions. This section identifies several major considerations relevant to shaping future utility cybersecurity activities.[137]

One of the primary responsibilities of a utility regulatory commission is to provide the oversight necessary to ensure safe and reliable service. A cyber attack represents a threat to the system reliability of each utility sector, and could impact a system in many different ways. Furthermore, the highly integrated nature of multiple utility infrastructures has wide-reaching ramifications for public health and safety (i.e., without electricity, communications systems, gasoline pumps, water purification systems, and other utility systems are unable to function). Each utility system offers invaluable support to other utilities, which means that the cascading effects of any specific cyber attack have a potential to trigger widespread negative consequences. While any individual attack might have a unique target and method, a cyber attack could ultimately impact multiple systems' reliability and customer service.

Utilities hold and store valuable customer information, including financial information, usage data, and physical information. Information systems can efficiently store this data and enable utilities to offer innovative new services. Future utilities will ultimately find themselves using technology in increasingly creative and useful ways to manage their systems. This will afford solutions to a number of issues that utilities face today; however, the same systems also entail risks. Every new device that is added to the electric grid with some means of communications, brings some new cybersecurity risks. These devices are proliferating now on both sides of the utility meter, some owned and operated by utilities but many others by third-parties.

The breach of a utility's information technology system, including the networks it uses to complete business processes, could allow access to customer information, business practices, or security information related to control systems. A utility operating these systems without ample cybersecurity provisions opens its infrastructure to dangerous cyber attacks, including the possible compromise of consumer privacy and risk of identity theft.

Overseeing cybersecurity presents a major new challenge to utility regulatory commissions, with the regulatory role complicated and perhaps even confounded by factors such as jurisdiction, liability, confidentiality, and the development of new technologies and technical knowledge. Various state commissions have adopted new rules and regulations; expanded commission and commission staff knowledge of cybersecurity; held meetings and briefings with regulated utilities; and continue to develop rules through ongoing regulatory proceedings.

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[137] Information in this section is drawn from Phelan 2014.

In addition, many other actors are working in the field of cybersecurity, including multiple federal agencies, state legislatures, and utility trade associations. The result to date is that cybersecurity programs in the U.S. are something of a patchwork, which offers both pros and cons in a developing field. There is no overarching theme to the country's cybersecurity, no singularly responsible entity, and no all-encompassing legal framework behind it. However, the current approach allows private utility companies to remain flexible in their cybersecurity planning and implementation. One common theme identified in state regulatory approaches is that no "best" method for cybersecurity regulation has yet been determined. The states that have approached the issue have different priorities and resources, and therefore come to different conclusions.

As utilities begin to utilize increasingly technological solutions that employ two-way communications, cybersecurity regulation will continue to develop. Cybersecurity is, and will remain, an extremely important function for providing safe and reliable utility service, but the details of each program are not yet known. Ultimately, flexibility could prove beneficial during such a transformative time

7 Conclusions

Policymakers and decisionmakers can easily get overwhelmed thinking about the sweeping changes coming to the electric utility industry in the coming few decades. Prognostications about the industry future are coming from multiple directions (for example, America's Power Plan 2013; Bade 2015a and 2015b; Clean Energy Institute 2015; EPRI 2014; Fox-Penner 2014; Keisling 2015; Lehr 2015; MIT Energy Initiative 2011; Muhr 2016; Patterson 1999; SEPA 2015; SolarCity Grid Engineering 2016; and Zinaman et al. 2015). Cory and Aznar (2014) summarize some of the many challenges facing utilities, regulators, and stakeholders.

Mowat asks, what have U.S. jurisdictions already done about integrating DER, and what do they plan to do? The answer generally involves net energy metering, in all but a handful of states, but beyond that one idea, there is little consistency. Even within the one policy, named net metering, there are many variations among the states. (Bird, Reger, and Heeter 2012; Speiser 2013; Stanton and Phelan 2013).

Mowat further asks, what has been the role of net energy metering (NEM), and how might NEM apply in the future? NEM has been important in enabling nascent markets for DG, most especially small-scale solar PV (Stanton and Phelan 2013; Stanton 2015a). The question of what comes next, after the early success of NEM, is now being addressed by almost half of all states, where proceedings are underway to either substantially revise or perhaps even replace NEM with some other compensation mechanism (Durkay 2014; Stanton 2016 forthcoming; Muro and Saha 2016).

Perhaps the best that can be said about U.S. policies towards DER in mid-2016 is that this policy arena is looking like a major work in progress. Several states are actively engaged in proceedings to explore what changes might be necessary for utilities to fully accept cost-effective DER, notably California, Hawaii (Akiba 2015; Cardwell 2015; HI-PUC 2014), Massachusetts (MA-DPU 2013), Minnesota (MN-PUC Staff 2016), and New York (Energy Industry Working Group 2014; Fine, De Martini, and Robison 2015; NY-PSC 2014). Demand response and dynamic pricing are making serious inroads in some jurisdictions (Faruqui 2015a and 2015b). Energy storage is starting to find profitable niches in some areas (Keith 2016). And, researchers are developing protocols for enabling microgrids, non-wires alternatives, and eventually perhaps transactive-energy (Barrager and Cazalet 2014; Maryland Energy Administration 2014; Rocky Mountain Institute 2013; Stanton 2015b and 2015c, 2012a; Tweed 2016). However, there is nothing yet in the U.S. like a coherent single vision of the utility of the future.

Mowat asks, what have been principle obstacles to utilizing DER? One answer is that pre-existing business models and regulatory financial incentives have not pre-disposed utility companies to fully engage in transitioning to a future dominated by DER. U.S. utilities developed for over a century focusing on the model based on developing and managing central station power plants and a transmission grid. Since the initial public utilities regulatory policy act passed in 1978, opening the possibility of non-utility generation, and since the series of FERC orders opening the transmission system to wholesale competition, there has already been a lot of change in many utilities (Borenstein and Bushnell 2014). But, the details remain elusive of a possible transition to a future where all cost-effective DER might be implemented, and the grid becomes an omni-directional network instead of a one-way flow from utilities to customers. (Barrager and Cazalet 2014; Woolf, Whited, et al. 2014)

Mowat asks, how might local and regional utility planning procedures be changed to best accommodate DER? The U.S. experience is beginning to offer clues, that utility planning will need to be effectively reversed. Utilities previously focused integrated resource planning from the top down, or perhaps better characterized as planning from the center out towards what observers are now calling the grid edge. That type of modeling needs to be supplemented with, or perhaps eventually even replaced by, a focus from each customer and distribution feeder at the grid edge, back towards the substations and the centralized grid. (Ackerman and Woychik 2016; Fitzsimons 2014; Martino, Kristov, and Erickson 2015). That shift in focus requires new planning tools, but there appears to be substantial progress already in designing and implementing them (Stanton 2015c).

Mowat asks, have DER resulted in legacy obligations, which are typically called stranded assets in the States, and if those exist, how are they being allocated and recovered? Generally, the answer is that progress towards implementing DER has been gradual enough in most jurisdictions that legacy obligations have not been implicated. U.S. policies have focused mainly on NEM, with program limits in place in most jurisdictions to prevent stranding new assets. And, clean energy portfolio standards have modest goals: As the various states developed portfolio standards, they all started with goals for bringing onto the existing system the new required resources, whether energy efficiency or renewables, at a pace deemed slow enough to result in minimal, if any, stranded assets. Almost all the RPS laws centered on the idea of having utilities bring on the new renewable resources at the rate of approximately one percent per year. Similarly, energy efficiency standards typically capped expenditures and sales reductions at modest levels.

Mowat asks, what kinds of rate designs are best applied to utility systems that are beginning to accommodate more DER, and are best practices emerging in the U.S. for how fixed charges might be applied? The answers are not at all clear yet, but there is a great deal of attention focused on these questions (Bird, McLaren, et al. 2013; Chitkara, Cross-Call, et al. 2016; Costello 2015; CSIS 2016; Kennerly, Wright, et al. 2014; King, Lewin, et al. 2016; Inskeep, Wright, et al. 2016; Jamison 2016; Lazar 2016; Keyes and Rábago 2013; Kihm, Lehr, et al. 2015; Linvill, Shenot and Lazar 2013; Satchwell, Mills, and Barbose 2015; Stanton 2015a).

Mowat asks, what policies and regulatory actions have worked best, and what has not worked as well? And, for those policies and regulatory actions that have not worked well, what is the explanation for why they did not work out? For better or worse, it is fundamentally too soon to tell. The changes at play are being reviewed all over the U.S., but only time will tell which approaches offer the best prognosis for what might be ailing the utility industry, now and in the future.

Finally, Mowat asked NRRI to identify both the best ideas about DER policies and regulations from U.S. jurisdictions that Ontario might adopt and not-as-helpful ideas that Ontario might avoid.

Ontario might usefully focus its attention on undertaking all no-regrets policies. Fundamentally, that means using market forces as much as practical with limited taxpayer or ratepayer incentives, to achieve all cost-effective DER. A touchpoint would be to try to identify all the actions that make sense irrespective of likely changes in fuel prices, global energy markets, future environmental regulations, and the like. If guided by sufficiently robust, broadly-inclusive community integrated resource planning modeling, many DER technologies will prove to be fully cost-effective already, and in the coming decades more are sure to become available. Ontario could easily play a leadership role in understanding and applying DER technology.

Tester, Drake, et al. (2012, p. 957) call for a transition in energy planning, away from traditional "solving modes." They note that utility planners have traditionally restricted IRP analysis almost exclusively to deterministic analyses of only a small number of utility silos. What is needed instead, they propose, are "new classes of 'learning modes,'" capable of examining complex systems from perspectives of multiple diverse stakeholders. The goal is to make continuous progress towards systems "sustainable over at least a millennium."

In this context, it is essential to realize that the electric utility industry future, whatever form it takes, represents only one dimension of a sustainable future. An electric utility industry continuously moving towards comprehensive sustainability objectives will be one necessary component of any future sustainable society, but by itself a sustainable utility industry will not be sufficient. Fundamentally, energy systems planning must in some ways be coordinated with or possibly even subsumed under a broader context of sustainability planning for towns, cities, and whole regions. Utility IRP cannot really be integrated if it remains inside its own planning vacuum. Instead, utility planning has to be included in a much broader community context that eventually applies to multiple dimensions that address the triple-bottom-lines of economic, environmental, and socio-cultural sustainability (Elkington 1998). A lot of attention is starting to focus on such planning, beginning with the fundamental principles that define sustainability (Natural Step Canada 2016; Iwaniec, Childers, et al. 2014; Portney 2013; Reliable Prosperity 2016).[138] There is already a wealth of literature about creating and applying community sustainability indicators to help guide decision making (Community Indicators Consortium 2016).[139] Plus, along the same general lines as the world-wide conversation about modern grid

[138] The "Natural Capital Protocol," "a standardized framework for incorporating natural capital impacts and dependencies into planning and decision-making" is being released worldwide on July 1. http://www.naturalstep.ca/update-from-the-natural-capital-lab

[139] The Community Indicators Consortium (2016) already lists 29 Canadian projects, including four from Ontario – Greater Ottawa Region, Greater Sudbury Region, Sault Ste. Marie, and Toronto. Also, Portney notes that the International Council for Local Environmental Initiatives, now known as "ICLEI – Local Governments for Sustainability" has a headquarters in Toronto, and he reports on Toronto's "Tower Renewal Project" (Portney 2013, pp. 23, 115). ICLEI – Local Governments for Sustainability has over 1,000 members throughout the world, and Canadian membership already includes over two-dozen communities, including 12 from Ontario (ICLEI Canada 2016).

capabilities for electricity infrastructure, a "smart cities" movement is rapidly gaining traction. The general goals of this effort are to help the world's cities develop more sustainable systems of all kinds, including transportation, energy, water, communications, networking, and more, especially through applications of computerized sensors and controls (Gelernter 1991; IEEE 2016; Rector, Wilder, and Pernick 2016; Smart Cities Council 2016; White House 2015).[140] And, major efforts to develop combined modeling and planning capabilities for combined food, energy, water, and ecosystems networks are also coming to the fore (Ferroukhi, Nagpal, et al. 2015; Saundry 2016; UN Water 2016; Webber 2016). Ontario, with its province-wide transmission organization and many municipally oriented distribution companies that are already engaged in long-term energy planning, could be in an ideal position to implement such comprehensive integrated community futures planning.

In particular, planners are beginning to better understand the close linkages between water and energy systems. Thermal power plants need water for cooling, and water systems are among the biggest users of electricity for moving and treating water. Energy systems need to be planned for operations during floods and droughts, and water systems need the highest reliability of electricity service. Wastewater utilities usually have some opportunity to use methane produced in their treatment processes as a fuel to help power their own operations, and some companies are already designing systems to generate hydroelectric power from the large volumes of water that flow downhill through water purification and wastewater treatment plants. These few ideas just scratch the surface of some of the many ways that water and energy are inextricably linked. (Lubega and Farid 2014; Tidwell, Moreland, et al. 2015; Vilhelmsen 2016).

At a minimum, this means that water and energy planners need to work together on integrated resources plans so that those systems can be co-optimized. Eventually, the same principles will apply to more and more community-based systems, and utilities will work with extensive input about future plans and needs from many government agencies and customer representatives.

Ontario might usefully consider how its Long-Term Energy Plan (LTEP), updated every three years, could serve as a focal point for engaging communities in futures planning. Specific goals and objectives for DER could be adopted in concert with each round of the LTEP process, and incremental policy and industry changes could be scheduled to help providers achieve those goals. To the extent possible, series of experimental and pilot programs, followed by targeted deployment, and eventually full scale deployment, could be coordinated using the ongoing series of three-year cycles, so that the result will be continuous progress towards community sustainability, employing DER wherever and however they prove cost-effective.

In this context, Ontario should recognize that small utilities will face serious obstacles in deploying the resources necessary to undertake comprehensive planning and the many kinds of adaptation necessary for DER to reach its economic potential in the coming decades. Cybersecurity concerns also present a serious challenge for small utilities, that will need to

[140] Advisors to the Smart Cities Council® include the Sault Ste. Marie (Ontario) Innovation Centre, University of Ontario Institute of Technology, and Waterloo (Ontario) Institute for Sustainable Energy.

develop new capabilities to manage both physical and cybersecurity (Phelan 2014). Because Ontario has so many small utilities, the Province should consider possible roles for province-wide agencies and consortia to help manage the coming transition.

A conscious move towards implementing all cost-effective DER could lead to positive economic growth for Ontario. Ontario, with its large industrial base and several world-class research universities, could easily become a vitally important center of best practices for sustainable energy development. There are already plenty of examples of other communities that are moving forward on similar paths towards sustainability and economic renewal (Liu 2016; Rector, Wilder, and Pernick 2016; Van Agtmael and Bakker 2016, Chapters 5 and 6).

Although the Ontario feed-in-tariff domestic content provisions did not survive the World Trade Organization challenge, there are other mechanisms for supporting local businesses that have not been overturned on the basis of free trade agreements. One example is utilities providing special assistance to and specifically requesting bids for services from local firms (Roberts 2016). Another is business incubator services such as those managed by NextEnergy and the Muskegon Innovation Hub (MIHUB), which is part of Michigan's Grand Valley State University.[141] And, New Brunswick (New Brunswick Liberal Party 2014) has identified one promising strategy, for government purchasing, based on the idea that low-bid purchasing can be informed by full life-cycle analysis of the total effects of spending within the provincial economy, including taxes paid by all of the entities that provide goods and services and taxes paid by their employees. Shuman (2015) outlines over a dozen other strategies for localized economic development, that are already being successfully applied elsewhere and could easily be considered for Ontario.

Economic input-output modeling analyses in the U.S. has consistently showed that small scale energy resources for saving or making energy have job-multipliers that are typically anywhere from 1.5 to three times greater than the central station generators and transmission projects that they might replace, thus producing more direct and indirect economic benefits than the alternatives. That is true for more jobs and local economic support both per million dollars invested and per megawatt of delivered capacity. Plus, the monetary savings from cost effective DER generates even more economic benefits, termed induced benefits, because consumers with more available discretionary funds are generally likely to spend at least some in the local economy. (ACEEE 2016b; Bell, Barrett, and McNerney 2015; Carley, Lawrence, et al. 2011; Shmelev 2012). Thus, there are potentially large advantages for economic development as investment shifts away from traditional utility infrastructure towards DER. In addition, for the roughly two billion people who presently live without access to electricity, service is much more likely to be delivered by DER, assembled into small-scale microgrids (Alstone, Gershenson, and Kammen 2015; Stanton 2015a, pp. 25-27; Stanton 2015b, p. 15). The more Ontario learns about DER technologies and how best to deploy them, the more that portions of those fast-growing industries are likely to establish roots and maintain a long-term presence in Ontario, supporting a healthier, more sustainable economy.

141 See http://www.nextenergy.org and http://www.gvsu.edu/mihub. The GVSU Muskegon Innovation Hub was formerly known as the Michigan Advanced and Renewable Energy Center (MAREC).

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