Future of Microgrids & Smart Energy Networks

Research Priorities for Advancing Microgrid Deployment

As global energy systems shift towards decentralization, consumers are seeking heightened engagement with providers, and the cost of advanced energy technologies is continuing to fall. As these trends become more pronounced, microgrids have potential to offer benefits to utilities, communities, and industrial customers alike. The microgrid market is heating up, prompting regulatory agencies and governments to contend with policies and rules that can enable the cost savings and system-wide benefits of intelligent decentralized systems, while minimizing risks to utilities and consumers.

Communities seek deployment of microgrid systems due to a variety of factors – such as improvements to reliability in the face of extreme weather events, environmental benefits of local renewable generation, new local cost-management or revenue opportunities, increased autonomy, and more. However, Canada's electricity system has been effectively centralized for decades, and this has provided us with very reliable electricity, for relatively cheap. Today, the average Canadian experiences less than one hour of electrical outage annually from the utility grid, at a rate that is less than the cost of energy self-sufficiency.

High reliability and low costs are the legacy of investment in our centralized utility grid. However, the juxtaposition of falling solar and storage costs against rising utility rates, without additional value delivered through the central grid, prompts us to consider the future direction of electricity in Canada, and potential roles for microgrids.

Key Themes of Discussion

- Future Business Models and Economics
- Advanced Microgrid Technologies
- Public Policy: Drivers and Implications
- Value for Local and Engaged Communities

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Convening Stakeholders, Aligning Activities

The Advanced Energy Centre, Carleton Sustainable Energy Research Centre (CSERC), and NewEnergy Community Inc. convened a seminar and workshop on November 2nd, tasked with examining frameworks for advancing technology, business value, and public policy for clean energy microgrids. The event featured industry and utility leaders, multidisciplinary researchers, and community representatives coming together to discuss factors affecting deployment of smart microgrids into Ontario's energy system and beyond, and strategize for future academic research.

Building on the conversation sparked on June 2nd at [Micro] grids Today at the MaRS Discovery District, this event sought to build linkages between expert researchers, and the industry and utility leaders planning for deployment of microgrids in Canadian and global energy networks. This report presents a summary of the workshop discussion and findings, and aims to develop a roadmap for research and deeper collaboration on smart microgrids. Attendees explored the economic, public policy, and technical factors affecting deployment, and the implications for both communities and utility companies.

Potential Benefits & Opportunities of Community Microgrids

Resiliency	Mitigating the impact of power outages due to extreme weather event, including microgrids at community support centres.
Reliability	Support for overall electrical grid reliability and maximum customer 'up time' can be offered through microgrids, at a cost.
Sustainable Energy	Increased ability to connect and manage intermittent local renewable generation resources, such as solar or wind with energy storage.
Economic	Leveraging on site distributed generation may have potential to reduce customer costs and boosts overall system efficiency.
Grid Support	Provision of system ancillary services if controlled, owned or operated by utility or system operator.
Asset Optimization	Ability to connect and optimize diverse distributed energy resources (DERs) as an integrated system with local control.

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Future Business Models and Economics

QUESTIONS FOR FURTHER RESEARCH:

What are the most advantageous ownership models for microgrids? How are benefits, costs, responsibilities and risks to be divided among stakeholders?

What range of business models could be developed in the microgrid space?

How are microgrids to be defined legally, and obligations of parties with respect to microgrid deployment and operation to be specified?

What is the cost-benefit to the end consumer, and how are they best engaged?

How should we systematically evaluate the potential benefits and costs of microgrid operation to stakeholders?

Attendees and panellists felt that **defining new business models for microgrid operators** was crucial to unlocking future deployment in Canada and globally. The stakeholders debated future microgrid business models, and how those commercial relationships will account for reliability, resiliency, and sustainability.

There will be tension between the **existing structure of the industry** and the evolution of the microgrid business model for distribution utilities, primarily around regulated vs. non-regulated entities, asset use, as well as how generation companies will leverage demand-side management and storage to provide new services.

Utility representatives emphasized that our **existing electric system** should not be undervalued. Annual outage time is extremely low (less than one hour), and grid defection is still not economic based on utility electricity rates. There was broad acknowledgement that utilities are regulated, risk averse, and have little capacity to innovate – and that **consumers and disruptive competitors are now pulling them in new directions.**

The sector requires a common **legal and regulatory definition** for microgrids, and this will likely impact how utilities are empowered to participate in this emerging market. It is projected that there will be regulated and un-regulated utility companies as well as non-utility companies deploying microgrids, and the use cases for each may vary significantly (e.g. frequency regulation, resiliency, renewable energy integration).

For local distribution companies (LDCs) to participate in microgrid projects, there is a need for **a new formula for the costs and benefits** of smart local distribution systems with embedded generation. There is no existing incentive for an LDC to follow load or integrate renewables. Similarly, it is critical for the sector to understand 'why' the regulator has denied rate applications, even if it aligns with provincial objectives.

There is a distinct possibility for utilities to get 'squeezed out' of the microgrid equation, however, attendees reaffirmed that **utilities are one of the most trusted service delivery organizations** – which suggests that consumers may rather be part of a microgrid owned or operated by a public utility company.

It was observed that independent power producers (and potential microgrid operators) could store self-generated electricity and benefit from price arbitrage, and even sell directly to consumers 'behind the meter'.

Advanced Microgrid Technologies

QUESTIONS FOR FURTHER RESEARCH:

What are current technological barriers and enablers of microgrids?

How can we optimize generation, storage and grid support to maximize efficiency, cost-effectiveness, resilience, and carbon abatement?

How can simulation and modelling methods enable interoperability prior

Although a number of key microgrid components are advanced and well understood, there remains concerns regarding **interoperability, optimization, and integration** within a microgrid, which introduces a perception of risks to utilities and developers. Control systems and energy management hardware and software must maintain the rapid pace of innovation that has been seen with renewable energy and energy storage technologies, and should move towards **open standards for interoperability** rather than proprietary systems.

While microgrids can increase reliability in some cases, **emerging governance models can present a disparity of safety and service requirements**. During an outage, a customer within a microgrid may be confused as to whom they should contact, either the distribution utility or a local microgrid operator – and there may be different standards of signal tolerance and trip-safety requirements in each case. Furthermore, utilities and systems operators must improve visibility to critical (e.g. hospitals) and non-critical

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lsystems, which **uncovered a lack of standards and codes for microgrid operations** – expected to create new complexities for system operators. Although it was suggested that independent operators be required to follow utility codes for design, this could also result in higher costs and an overbuilt system with unnecessary redundancies.

It is crucial that grid operators and microgrid managers plan for **proliferation of electric vehicles on the grid**, as they represent a significant behind-the-meter controllable load – which could be used for microgrid load balancing and vehicle-to-grid energy storage in the future. For this reason, and the proliferation of new home energy solutions, utilities and grid operators should start rethinking the degree to which the residential load is passive. In addition to consumer products, there are also new grid technologies that can support **voltage smoothing, frequency control, and predictive load analytics.**

Public Policy: Drivers and Implications

QUESTIONS FOR FURTHER RESEARCH:

What is the public interest rationale for significant microgrid deployment in Ontario?

What adjustments should be made to the existing structure of the Ontario electricity system to enable appropriate microgrid deployment?

How might changes in federal and provincial climate change and green house gas policy affect and potentially help enable microgrid activity?

Attendees emphasized the value of a more holistic viewpoint on resource distribution within a community through the **creation of a distric-tutility** responsible for heat, water, and electricity. **Combined heat and power (CHP) systems** using biomass or natural gas have been deployed on campuses, and can be an effective approach to increasing resiliency, reducing net system emissions, and optimizing a local energy system using different fuel types. There is an opportunity to utilize **CHP in northern and remote communities,** where heating represents a significant portion of peak load, as well as opportunities for thermal energy storage within microgrids.

Furthermore, attendees felt that **utilities should be rewarded for embracing and testing new technologies** within the distribution network, and that a risk-averse culture and strict regulatory environment were inhibiting deployment of microgrid systems in Ontario. Under a revised risk-reward structure, utilities could be more comfortable with investments supporting self-generation and microgrids. This is particularly true when considering that we may be over-estimating grid defection rates due to the tangible value of utility macro-grid connection for nanogrids and microgrids, including **delivery of reactive power, opportunities for price arbitrage,** and **avoiding redundant capacity**.

In summary, attendees felt that microgrids could offer value at multiple points within energy distribution systems, and should be considered as a **vital 'tool' within the toolbox available to communities and utilities.** There are emerging microgrid use-cases for which the economics are being further considered, and Canadian utilities are encouraged to explore the implications of these scaling microgrids beyond pilot phase.

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Value for Local and Engaged Communities

QUESTIONS FOR FURTHER RESEARCH:

What patterns of community ownership, management and engagement can maximize collective gains of microgrid development?

What governance mechanisms are most appropriate for microgrids?

To what extent are different approaches required in different deployment contexts (campus, urban or rural communities, First nations communities, etc.)?

How is the cicommunity's voice heard as the above policy, technology and business models are developed?

Microgrids could represent a **fundamental shift in the delivery and provision of energy** in Canadian communities, and as such, we must conduct a critical review of public policy drivers and implications. Over the past century, we have effectively transitioned from a decentralized to the centralized electricity grid of present-day – and are now provided with reliable and relatively low-cost electricity through the utility grid.

Utility customers are now demanding **higher sustainability, reliability, and options for local empowerment** – which, although niche in today's energy sector, represent a potentially dramatic shift towards decentralized systems. The potential for reduced greenhouse gas emissions, locally owned energy infrastructure, and resiliency during extreme weather events, are important policy factors contributing to this transition.

In order to reduce greenhouse gas emissions, the energy sector is **accelerating deployment of renewable electricity generation resources,** including wind, solar, biomass and hydroelectricity. Similarly, energy efficiency projects within the residential, commercial, and industrial sectors are being advanced as low-cost alternatives for consumers and utilities. The deployment of microgrid systems is effectively co-locating load and generation, and allowing communities to 'future-proof' local energy systems.

With the introduction of a price on carbon, renewable microgrid systems will become **increasingly cost-effective in regions with carbon intensive generation fleets,** including many regions of the United States, Germany, China, and Alberta. Ontario's installed generation capacity is 72% carbon-free (from nuclear, hydroelectric, wind, biomass, and solar) with the remaining 28% of capacity provided from natural gas generation, according to the Independent Electricity System Operator (IESO).

There was discussion around how the **current compensation structure for energy conservation** within Ontario's local distribution companies could affect microgrid rollout – projects 'behind the meter' will be viewed as reduced kWh consumption, as delivered by the utility.

Since the Government of Ontario empowered local distribution companies to create unregulated affiliates, utilities have been presented with options for deploying microgrids, renewable energy, and other energy services to their customers. However, this also **prompts utilities to consider different business models** in an increasingly competitive market, facing threats from disruptive new entrants such as Google or SolarCity. Positive and negative elements of **market deregulation** were debated, as many alternative utility business models contrast with the traditional (regulated) revenue model based on energy (kWh) sales.

In regards to resiliency of utility infrastructure, attendees felt that microgrids were a viable mitigation strategy for the risk of increased outages due to aging infrastructure, and that **systems planners should consider distributed energy resources and microgrids** as a valuable tool for lower-cost grid modernization. However, there was debate around the value of microgrids in this use-case, since an extreme weather event that disables the utility grid would also likely affect nearby microgrids.

Microgrid development must always **evaluate and respect the desires of local groups**, including First Nations, Metis, Innu and Inuit communities, grassroots community organizations, and local residents. Furthermore, individuals within the community should benefit directly or indirectly through **positive socio-economic outcomes, positive environmental impacts, or cultural benefits.**

Many past projects have lacked meaningful collaboration with local residents, or have missed out on opportunities to **include the community in critical decision-making processes,** form economic partnerships, or create positive cultural spinoffs. Project proponents must openly collaborate with the community to holistically assess and plan for sustainable job creation, youth training opportunities, and other forms of socio-economic community development.

To discuss the value of microgrids for local and engaged communities, we delineated between off-grid and grid-connected communities, and have summarized key themes and findings below. In both cases, attendees emphasized that respecting culture, the local environment, and ensuring mutual benefit must be holistically integrated into microgrid project planning.

A) MICROGRIDS IN GRID-CONNECTED COMMUNITIES

Grid-connected microgrid systems are often integrated into the existing fabric of cities and towns. By leveraging new or existing renewable generation, as well as energy storage and demand-side management, distribution utilities or developers can optimize local energy systems to meet the needs of the local community.

Customers will range from disengaged to hyper-engaged with energy

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management and generation; but in all cases, the **microgrid must align with the priorities and requirements of that community.** For example, a small town with an abundance of hydroelectric generation and municipally-owned solar might be interested in self-resiliency, and may wish to consider creation of a community microgrid using combined heat and power (CHP) to keep the lights on during a grid outage. Another community focused on environmental sustainability may prioritize self-generation and storage of low-carbon energy generation, in order to achieve carbon neutrality.

Utilities and community microgrid operators can **share and balance the costs and revenues** to ensure a sustainable business model. To evolve and scale the microgrid, both of these parties – as well as local residents – must receive tangible benefits from the system. **Cooperative ownership** is a popular governance model to ensure local support for a project. Public utilities have traditionally been an integral part of communities, and their voice often remains trusted.

In all cases, **education and effective communication of community benefits and concerns** are key factors for accelerating deployment of microgrids – effectively aligning with the desires of a community with the developer/utility business case.

B) MICROGRIDS IN REMOTE OFF-GRID COMMUNITIES

Remote First Nations, Metis, Innu, and Inuit communities across Canada are currently served by **aging diesel-powered microgrids,** and this presents a **significant opportunity** for deployment of renewable energy resources, energy storage, and active control technology - to achieve cost savings, community development, and new collaborative partnerships. It is expected that a strategic energy transformation in these communities could unlock broader socio-economic benefits, including access to affordable housing, resources for education and healthcare, and sustainable local employment.

However, attendees identified factors inhibiting deployment of renewable energy and microgrids in these communities, which emphasized a historical lack of respect and collaboration, entrenched policy enabling the status quo (e.g. fossil-fueled generation), and a perception of increased risk associated with new clean technologies.

Most provinces and territories also **lack a viable contracting structure** (e.g. a standard formula for 'avoided cost of diesel' that leads to a power purchase agreement [PPA] rate) to incentivize a project proponent from partnering with the local community to construct lower-cost alternatives to diesel generation. This has been a challenging issue to resolve, since provision of energy in remote communities is a **multi-jurisdictional public policy file**, requiring collaboration between local and regional First Nations governments and councils, the Government of Canada, and provincial/territorial ministries.

Across Canada, there are many communities **currently underserved by diesel-powered microgrids.** Upon reaching nameplate electrical capacity, grid operators cannot connect additional loads; which has forced many families to abstain from living in brand new homes, and instead forces them to crowd into existing substandard housing. This trend also limits development of new tourism and commercial operations in remote communities. In the community of Deer Lake in Northern Ontario, the construction of 152kW of solar on the rooftop of the school, by NCC Development and Canadian Solar, enabled the electrical connection of five brand new homes to the community's grid.

It is crucial that, as remote communities reduce the lifecycle operating cost of local energy systems, **funding agencies do not 'claw back' those funds,** but rather empower the community to **reallocate towards local priorities,** such as education, community infrastructure, or health care. In addition for opportunities for new revenue and job creation, operation and development of community energy projects empowers residents with a sense of pride and self-sufficiency.

Broadly, remote communities seek the opportunity to collaborate on **equal footing with public utilities and private developers,** and expect a meaningful long-term relationship that includes maintenance and operational support, while training local operators and skilled trades workers. And more importantly, decision-making authority must reside with local community leaders, with buy-in from residents.

With **respect and through meaningful collaboration,** attendees agreed that there were no major barriers inhibiting partnerships between private developers, public utilities, and aboriginal communities. There exists a **spirit of entrepreneurship and keen sense of business** in many communities, which presents many mutually beneficial opportunities for clean energy microgrid development partnerships.

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Moving Forward with Microgrids

Looking forward, this group plans to advance several initiatives focused on accelerating smart microgrid systems in Canada and globally – focused on sharing best practices and enhancing collaboration between industry, communities, academia, and utilities. The Advanced Energy Centre plans to convene unguarded industry conversations around the use-cases and benefits for microgrids in Canada, and continue to advance key findings to policymakers and utilities. The Centre believes that it is crucial that Canadian clean energy innovation gains market access through domestic microgrid deployment, and prepare to rapidly expand into emerging global opportunities.

In parallel, Carleton University will advance a multi-disciplinary research initiative through the Carleton Sustainable Energy Research Centre (CSERC), that includes faculty from the Sprott School of Business, the School of Public Policy & Administration, and the Faculty of Engineering and Design. In addition to the content of this report, updates from ongoing smart microgrid case studies, simulations and pilot projects such as those being undertaken with the software and service of NewEnergy Community Inc. will inform this research initiative and help to tailor the focus on high-value insights that will accelerate microgrids globally. This will also create learning opportunities for students and researchers around an important emerging trend, equipping the next generation of energy sector leaders with insights and knowledge focused on microgrids.

The Carleton Sustainable Energy Research Centre (CSERC), the Advanced Energy Centre at MaRS Discovery District, NewEnergy Community, and the Independent Electricity System Operator (IESO) would like to sincerely thank all attendees for their contributions and insights on November 2nd 2015 at 1125@Carleton. We are grateful to Jenni Myllenen (IESO), Norm Fraser (Hydro Ottawa), Jeff Westeinde (Windmill Developments), James Meadowcroft (Carleton University) and Niraj Bhargava (NewEnergy Community) for your participation on our expert panel.

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