Planning and Implementing Low Carbon-Communities in Canada

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Abstract. Given the urgency to mitigate climate change, an efficient and effective approach is to reduce carbon reduction at the community level. This is more cost-effective than addressing buildings individually because it opens opportunities for both cost-effective economies of scale to deploy renewable energy and other technologies.

While there are currently several low/near net zero-community pilots in existence or in the making, they usually occur in specialized circumstances such as residential subdivisions or model communities, and they tend to focus on technology fixes. To achieve climate change mitigation goals, a more holistic approach is needed that consists of a planning process for existing communities, which integrates energy and resiliency, and involves the utilities. This paper explores common barriers to an integrated process and examines the advantages of a utility-led approach.

1. Introduction
Net-zero community planning is a complex problem requires engagement with a diverse set of stakeholders. The National Renewable Energy Laboratory (NREL) defines a net zero-energy community (ZEC) as “one that has greatly reduced energy needs through efficiency gains such that the balance of the energy needed for vehicles, thermal, and electrical energy in the community is met by renewable energy”.

While there are several aspiring low/near net zero-community pilots, few have provided evidence of achieving such a goal. They also usually occur in specialized circumstances such as residential subdivisions or model communities. However, to mitigate climate change on the scale needed to ensure human survival, most existing communities will need to be transformed.

The slow uptake of community solutions to achieve low-carbon and net zero energy can be hard to understand, given the clear energy and economic advantages of low-energy/carbon strategies for a group or cluster of buildings compared to strategies aimed at individual buildings.

In recent years, many new district projects have been announced, only to disappear from the headlines. Their failure appears to be due largely to the deeply engrained traditional economic models that govern development, and to limitations and inconsistent policies regarding utility grid connections. There are also challenges associated with measuring the carbon footprint of a community [1].

Notwithstanding the challenges, if we are to drastically reduce GHG emissions and increase climate-change resilience, a community approach is our best hope, due to improved economies of
scale and the strategy of cost-effective, distributed renewable energy. It is also a fact that most city buildings could not meet low energy consumption objectives individually without assistance from a community energy system.

Clearly there is a need to raise awareness and demonstrate the advantages of a community approach. One way to get the message out is to present success stories of low carbon communities or groups of buildings that are successfully using microgrid and thermal grid applications. It is also essential to bring key stakeholders – including utilities to the table.

Because of the existing challenges, there are few examples of network systems that have overcome ownership boundaries, and few models of how a multi-disciplinary and multi-stakeholder team works together.

To overcome some of the challenges, a more practical approach is to evaluate scenarios that describe net (or near-net) zero-energy communities (ZEC) using known data for specific sectors. Developing scenarios provides a framework to aggregate research across many sectors and activities. It also helps to identify key stakeholders and bring them to the table.

2. Complexities of planning a net zero-energy community (ZEC)

There are two principal energy components of ZEC: i) energy saving measures and demand management of the buildings and community infrastructure and; ii) provision of renewable energy to make up the energy needed to sustain the community. In turn, these have subcomponents, making the supply and demand description much more complex than it initially appears.

One example of the complexity is the decision to include or exclude transportation energy/carbon accounting from the analysis. In North America, the transportation energy of regular commuting to an office building can be as large or larger than the operations energy for the building itself. Commuting energy is dominated by the personal fossil-fueled automobile. If commuting energy is added to the mix, the carbon balance of the analysis shifts substantially, and the simplicity of a buildings-only focus is lost.

Even when the analysis is restricted to buildings, other complexities intervene. When balancing the overall demand and supply for a group of buildings, the boundaries of the number and type of owners is significant. That is why it is easier to create a ZEC university campus, under the ownership and management of one organization than it is to coordinate efforts across a city block of mixed owners.

Another challenge relates to privacy. Although building performance data is increasingly being made public, many owners (of poorly performing assets) would wish to keep this information private. Similarly, utilities have historically kept energy consumption information private. To bring credibility to a modeled scenario, it is helpful to engage utility partners who can bring real data for modelling scenarios.

3. Mixed modelling approaches

The energy consumption of buildings in a community is dependent on the urban form (typology), building construction and lifestyle and habits of residents, including commuting habits. The Urban Archetypes Project [2], initiated by Natural Resources Canada’s CanmetENERGY in Ottawa, investigated 31 neighbourhoods in 8 communities to explore these correlations. Each neighbourhood consisted of approximately 300 dwelling units that were consistent in their building type and urban form. Using GIS and energy mapping technologies, a database was created that showed correlations between urban form and energy consumption, and which demonstrated the combined impacts of previously disparate information – including commuting energy consumption.

In the absence of utility data, it was possible to model energy use of similar buildings with reasonable accuracy based on publicly available information from NRCan’s Comprehensive Energy Use Database (CEUD). This database is an aggregated record of the performance of existing Canadian building stock, arranged by occupancy classification according to the North American Industrial Classification System. It includes data from 1990 and to 2015.
By correlating buildings and transportation energy consumption, it was possible to establish the relative contributions to the energy/carbon footprint. One of the findings was that even though an older inner urban residential neighbourhood has housing stock that is less energy efficient than new houses in the suburbs, the reduced need for personal automobile transportation offsets the weaknesses of the building stock. This would suggest that in suburban areas, a carbon-reduction strategy should include: mixed-use development, increased density, access to frequent public transportation, as well as new building stock that is built to recent codes.

Figure 1 [3] indicates energy use in dwellings (houses and apartments) in communities located in the Ottawa study areas ranged from 61 to 276 gigajoules (GJ) per year with lower energy use in the denser communities, or an average consumption of 219 GJ per year (31 GJ/yr for electricity and 188 GJ for space and water heating) as represented by the Sankey diagram of the energy balances in Sandy Hill community in Figure 2 [4].

![Sankey Diagram of Energy Balances in Sandy Hill Community](image)

**Figure 1.** Building profile and energy consumption for different typologies in Ottawa Sandy Hill neighbourhood

4. **Demand reduction of the building component**

Various energy reduction programs, studies, methodologies typically recommend efficient lighting, efficient windows, air sealing, insulation and heating/cooling system upgrades, with programs such as Energuide [5], Energy Star for Homes [6] or Project Futureproof [7]. They indicate a potential reduction of as much as 62% of energy consumption [8]. Assuming a fairly optimistic assumption of
35% energy reduction on a larger, community scale, the remaining energy deficit of an average house would still remain approximately 142 GJ, which is considerable.

![Energy Inputs/Outputs Diagram](image)

**Figure 2.** Total household energy inputs/outputs for a representative house in Ottawa Sandy Hill neighbourhood

5. Meeting the energy deficit with renewables

Of all the energy: wind, energy from waste or biomass combined heat and power [9], solar PV appears to have the greatest chance of succeeding at the community level. Despite physical obstacles such as lack of solar exposure, and economic factors, the cost of solar-generated electricity is now on par with fossil fuel generation in several north-American jurisdictions. A 8kW solar PV system installation, in southeastern Canada is capable of generating approximately 36 GJ of electricity/year [10]. More investigation is needed to determine this on the scale of a community.

With some home energy management measures and battery storage, a solar system would be capable of supplying virtually all electrical annual consumption of a dwelling - with the exception of its thermal needs. Covering the thermal deficit may be only feasible with other community based thermal storage projects [11, 12].

6. The role of municipal and utility partners

6.1. Electricity

While many community projects use extensive public consultation, few address the critical issue of energy production and delivery. Achieving a net zero, low carbon, resilient existing community requires the participation of local electricity and natural gas utilities.

In most Canadian jurisdictions, non-utility generators – such as a campus combined heat and power (CHP) or heating plant trigeneration (heating, cooling, and electricity) – would require special engagement by the local distribution utility to connect into the local electrical distribution grid.
That’s because non-utility generation requires a modification of grid operation – from central generation and radial distribution to a more complex mesh of multiple suppliers who can come online at any time, over multiple distribution paths. The modernization of control systems and bidding protocols adds cost and work on the part of the utilities. If there is no direction from the utility ownership (possibly represented by a municipal council or city manager) to engage in such a modernization program, then the cost may need to be born by the new development.

Currently in Canada, utilities are the only corporate body with a mandate for efficiency/resilience. Eight of the ten Canadian provinces [13] have provincially regulated monopolies that manage generation and distribution. One (Ontario) consists of municipal or private utilities that have both generation and distribution assets linked by a provincial distribution company and operating under two oversight boards – one addressing generation and resource management, the other operating the province wide electrical grid connections. Many utilities in Alberta are fully deregulated, with separate and independent generators and distributors managed by a system operator.

Given that most utilities have been provincially regulated with some federal oversight, they have traditionally played a role in heading up programs that encourage energy efficiency, as well as services such as electrical demand management. Similarly, future community energy sharing projects could also be best led by utilities.

Many municipalities in Ontario own the local electricity distribution companies (LDCs), which purchase most of their power from Ontario Power Generation (OPG) and Hydro One (the transmission and distribution utility). Most utilities were formed in the 1890s to the 1940s when Canadian towns and townships were electrified for citizens and to attract industry. Not surprisingly, much of this municipally owned infrastructure needs upgrading beyond the normal needs for maintenance and population growth, to be able to support a multi-generator fed grid.

For a municipally owned utility, a networked energy sharing strategy needs participation of the utilities board and their shareholder - the municipality. The political complexities of engaging the local utility and convincing the board or municipal council to expand its services beyond business as usual is the one of the most significant barriers to a proposed ZECs.

Some progressive utilities are proactive and inventive in their transactive energy solutions to modernize the grid and achieve greater resiliency. For example, Alectra Utilities, a private generator and distributor serving municipalities north and west of Toronto, Ontario has run a demand management program featuring two-way communication between the utility and customers [14]. The test gave Alectra access to customer generation and storage assets, on the customer side of the electricity meter, for use in managing local grid demand. Another example in Southeast U.S., features collaboration between Alabama Power and its parent Southern Company, Oak Ridge National Laboratory (ORNL), and DOE’s Office of Electricity. This partnership developed and deployed a transactive microgrid approach for electricity supply and consumption management. This Smart Neighborhood [15] approach uses a leading-edge microgrid made up of solar panels, battery storage and a backup natural gas generator to support the community’s energy needs. The microgrid’s intelligent technology can also communicate with the homes’ heating, air conditioning and water-heating systems to determine the best way to provide energy.

Other transactional, virtual net metering, energy storage and microgrid community originated projects are coming to fruition [16,17,18]. Community solar is a way for other community participants who can't or don't want to purchase their own solar systems to add solar to the grid and receive the benefits that come with owning solar panels, but at a size and cost that works for them [19].

6.2. Natural Gas
When it comes to natural gas, decisions on consumption are building-site dependent, with a market that is structured primarily around the supply of gas to site. In cold climates, heating fuel is of great importance and accordingly, Canada’s natural gas distributors are regulated similarly to electricity providers. And as with electricity providers, they often assume similar responsibilities for promoting
conservation. In Ontario, the principal natural gas suppliers have been regular and generous supporters of energy efficiency programs.

In efforts to decrease GHG emissions, there is a move to electrify all new building services. In addition, natural gas suppliers are promoting new applications including on-site micro electricity generation, natural gas driven space-cooling, long-term energy storage, and natural gas as a feedstock for hydrogen fuel cells. Many of these novel applications are applicable to net zero communities and are preferable to direct combustion for space heating.

7. Making it happen
Low carbon community planning has tended to focus on technology fixes. A more effective approach needs to integrate energy, resiliency and urban planning processes.

The key to reducing emissions and identifying best strategies, is to understand the community’s energy profile. [20] For example, where the local electric utility has plans or has already decarbonized (i.e. a hydro/nuclear-based energy source), the community should focus more on space heating and transportation efficiency, since this would likely make a greater contribution [21].

On the other hand, where the electric utility has a relatively high emissions factor (i.e. a coal/gas-based energy source), there would be more impact in focussing on zero- and low-carbon electricity options (e.g. renewables) than purely efficiency options.

There are significant opportunities to reduce emissions in buildings and transportation fuels. Some examples include:

- Growing market around electrification of appliances such residential water heaters and space heating equipment [22].
- Introduction of Power-over-Ethernet, DC microgrids [23] and DC “off-grid” appliances.
- Electrification of personal vehicles, public fleets and buses, increased use of shared transportation and anticipation of the self-driving cars.
- Deep energy efficiency retrofits, which can be achieved through incentive-based or regulatory programs. [24, 25]
- Smart building technologies [26, 27] deployed in smart communities [28]

To help in planning and implementation, a net zero community project can follow the ISO standard 371040 Sustainable Development in Communities — Guidance for practical implementation in cities. This document offers practical guidance on initiating, planning, implementing, measuring and managing sustainable development activities in a way that is based on sustainability principles and is both inclusive and holistic. While aimed specifically at local authorities it nevertheless identifies steps a successful project needs to through such as:

- Establishing mandate for implementing
- Identifying and engaging stakeholders;
- Developing consensus on priorities; evaluating, benchmarking and measuring current and future conditions that impact progress toward sustainable development;
- Developing and implementing a coherent action plan;
- Setting targets and key performance indicators for development;
- Meeting organizations’ needs to carry out all of these functions; and monitoring, reporting and verification.

While they may be common sense, these steps can often be forgotten in the excitement of launching a project.

8. Conclusion
Net-zero energy/carbon at the community scale is within reach; however, fully transforming existing communities into 100 percent net zero communities in northern climates is a challenge due to the
significant resources needed to cover the thermal energy deficit. The steps needed to overcome this are both technical as well as jurisdictional with regards to adjustment of the utility grids. The increased availability, ease of deployment and affordability of renewables can help this transition. It also requires collaboration with utilities to identify the best opportunities and strategies for carbon reduction. To accelerate the change of the current modes of energy production and distribution also requires raising public engagement, which is best achieved by community participation in implementing net-zero energy/carbon communities.

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