Pathway Study on Existing Non-Residential Buildings in Ottawa

Presented to:
The City of Ottawa
110 Laurier Ave W
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In relation to:
The City of Ottawa's Energy Evolution Strategy (Phase 2)

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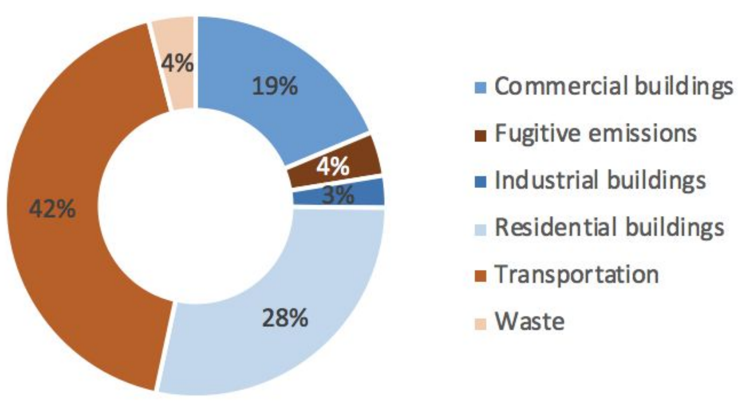
Executive Summary

This pathway profiles existing non-residential buildings in the City of Ottawa and details strategies to reduce their energy use and emissions in order to meet the goals and objectives of the City's Energy Evolution Strategy. Building types covered in this paper include industrial, commercial, institutional, and mixed-Use. These buildings can generally be considered larger than residential buildings.

Measuring and evaluating building energy use is an important first step in determining actions to make larger non-residential buildings more energy efficient. Recommissioning buildings ensures that building systems such as heating, and ventilation are operating efficiently. Retrofits update building components to minimize energy loss and can also replace GHG-intensive heating systems for lower carbon alternatives such as heat pumps or district energy—a strategy described as fuel switching.

The Canada Green Building Council (CaGBC) estimates that buildings in Canada currently contribute up to 35% of the country's annual carbon emissions.[1] In Ottawa, buildings represent the largest source of community GHG emissions, generating approximately 2.4 million tonnes of CO2e emissions annually and accounting for roughly 50% of the city's total emissions in 2016 (see Figure 1). Given the large impact of this sector on the city's emissions profile, any pathway to achieving an 80% reduction in GHG emissions by 2050 will require a transformation in energy supply and demand in Ottawa's existing building stock.

Figure 1. Emissions by Sector, Ottawa 2016.



[1] Canada Green Building Council (2017). A Roadmap for Retrofits in Canada: Charting a Path Forward for Large Buildings. Toronto. Retrieved from: www.cagbc.org/cagbcdocs/advocacy/CaGBC_Roadmap_for_Retrofits_in_Canada_2017_EN_web.pdf

The CaGBC has identified four major strategies to cut GHG emissions from large buildings in half in its “Roadmap for Retrofits” paper:[2]

1. Recommission buildings that have yet to achieve high performance status by optimizing existing building systems for improved control and operational performance;

2. Undertake deep retrofits in buildings to high-performance standards such as LEED™, focusing on energy reduction and ensuring that key building systems such as lighting, HVAC and envelopes are upgraded;

3. Incorporate solar or other on-site renewable energy systems in buildings; and

4. Work with jurisdictions and the private sector to switch to low-carbon fuel sources in buildings.

This pathway study aligns with the four-step approach recommended by the CaGBC, while considering three scenarios of energy efficiency efforts: conservative, moderate, and aggressive. The conservative scenario reflects a Business-as-Planned outlook, moderate reflects interventions on the largest buildings and municipal/government buildings, and aggressive includes enhanced rates of recommissioning, deep energy retrofits, and fuel switching.

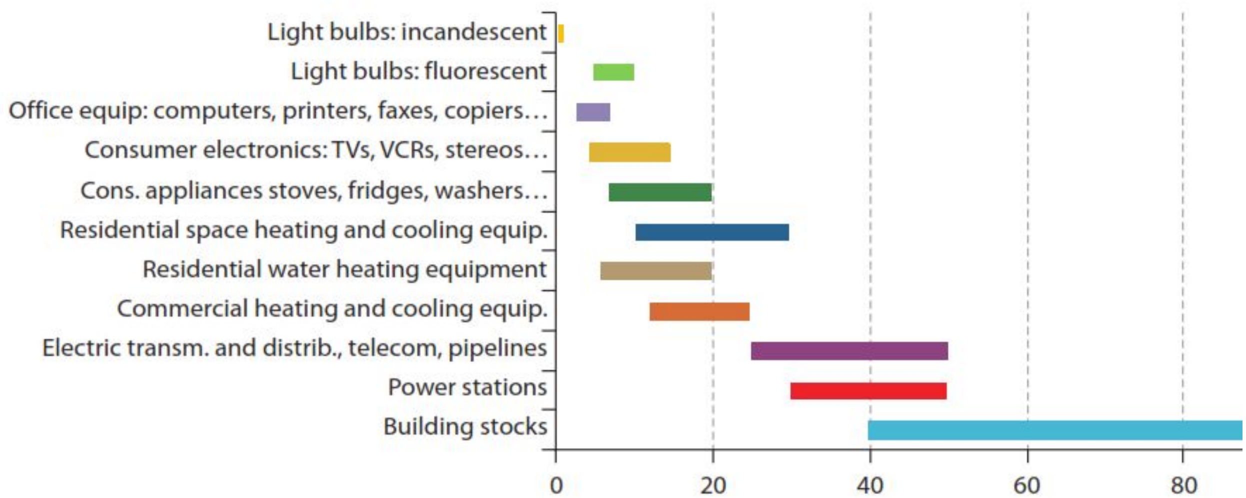
[2] Ibid.

Section 1: Present Assessment of Large Existing Buildings

Pathway Description

This pathway study focuses on increasing the efficiency of existing non-residential building stock in Ottawa, which is complementary to the New Non-Residential Buildings Pathway Study. The city's existing building stock has developed over the course of more than 100 years and accounts for much of Ottawa's current and future (projected) GHG emissions, thus presenting a large opportunity to reduce emissions community-wide. Each building is a system that includes very large components—such as the building shell—and very small components—such as light bulbs. All components combined determine the energy performance and GHG emissions associated with a building. The lifetime of each building component varies and there are opportunities to incrementally improve efficiency through natural replacement cycles. However, in order to achieve deep energy and emissions reductions (defined as a reduction of 50% or greater) a more proactive or interventionist approach is required, involving great uptake of new technologies and quick turnover in building energy systems. Almost all of Ottawa's current buildings will still exist in 2050.

Figure 2. Natural replacement cycle of different aspects of the building energy system.

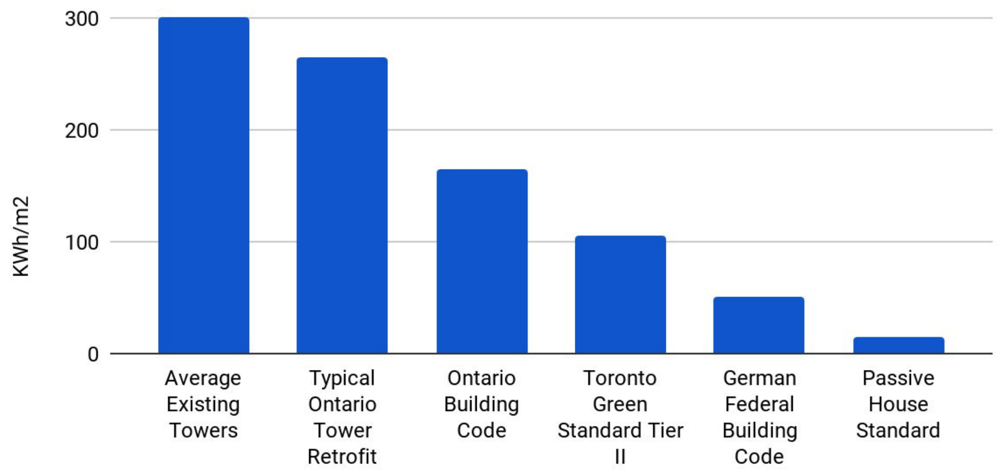


Addressing larger non-residential buildings as a class is important because they require distinct retrofitting approaches, policies and financing strategies in comparison to single family homes or other smaller residential buildings—a function of the complexity and scale of the systems, and differing ownership models.

The retention and retrofit of existing buildings have additional benefits beyond the reduction of GHG emissions. Improvements to the existing residential building stock can provide financial savings to building owners, tenants, or agencies through reduced spending on energy, for example. A major building retrofit program is an economic stimulus to the local economy through increased activity in the construction and contracting sector. Reducing energy use in residential buildings can also reduce demand burdens on electricity and natural gas providers, reducing issues with peak demand and therefore requirements for additional investments in new demand. Reduced demand for fossil fuels can also benefit the local economy as less money is spent on non-local energy sources, such as natural gas. When retrofits include on-site renewable energy such as solar, local businesses can also benefit. Retrofits can also improve household living conditions, improving indoor air quality and providing consistently comfortable temperatures.

Building size, choice of energy for operations (fuel source), GHG intensity from the electrical grid, and building type all determine a building's GHG emissions volumes. Older buildings that have been operating for 20 years or more may have degraded in performance and become leaky, for example, requiring greater energy for heating and cooling. Previous building codes were less stringent, and did not require window, wall, or roofing standards that provided the insulation performance that is possible today. Older large buildings may also use less efficient appliances, lighting, ventilation, or heating, ventilation and air conditioning (HVAC) systems. Figure 3 illustrates the difference between a "typical" tower in the Greater Golden Horseshoe, versus new construction standards that result in 83% to 95% energy savings.

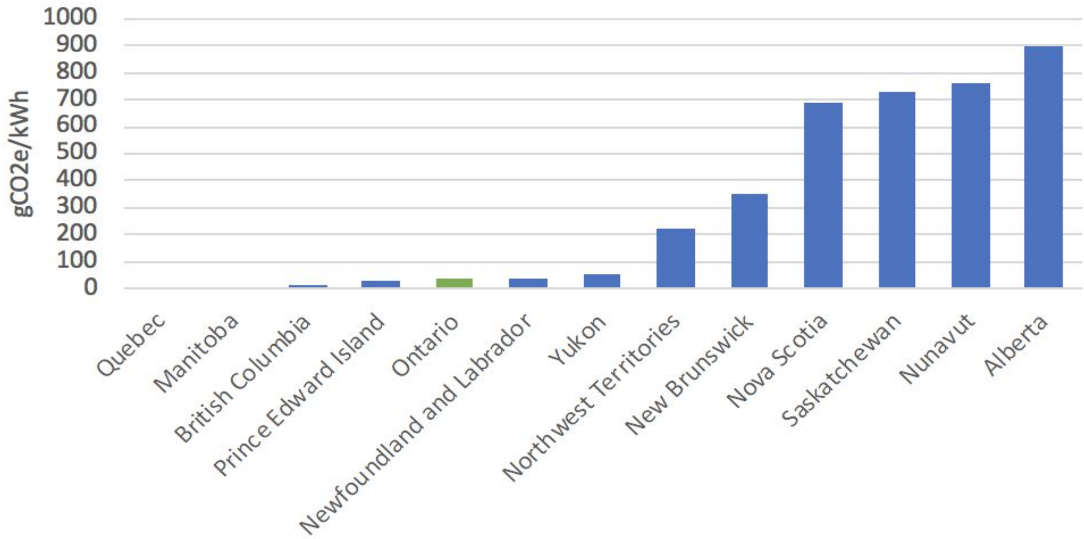
Figure 3. Comparison of the average energy performance of existing towers in the Greater Toronto area versus other standards.[3]



Although Ontario's electrical system has comparatively low GHG emissions intensity (Figure 4), the dominant source of space conditioning in buildings is natural gas—a major source of GHG emissions. Fuel switching to low carbon energy sources for heating is therefore a key GHG reduction opportunity.

[3] Tower Renewal (n.d.). Deep retrofit Towers and surrounding communities for a low carbon future. Retrieved from: http://towerrenewal.com/impact-areas/ghg-reduction

Figure 4. Provincial electrical grids emissions factors.[4]



Pathway Boundaries

This pathway identifies and contextualizes low carbon pathways for existing non-residential buildings in Ottawa that would benefit from upgrading or retrofitting of complex systems present in larger buildings with high energy demands. Table 1 identifies strategies reviewed in this paper for their effectiveness in reducing emissions, in the Ottawa context. This pathway examines policies that encourage uptake of the energy efficiency upgrades. Options for financing retrofits for large buildings are also discussed.

Table 1. Parameters and definitions for large existing buildings pathways study.

Parameter	Definition
Recommissioning	Recommissioning involves detailed energy and building systems performance audits resulting in recommendations for corrections. Recommissioning ensures that building systems such as heating, and ventilation work as required.
Retrofits	Retrofits update building components to minimize energy loss, reduce the thermal proportion of space heating fueled by a natural gas system, or replace natural gas heating systems. Retrofits can be small or extensive in scope.
Benchmarking	Benchmarking gathers energy use data including sources of energy, total energy use, and what activities use that energy in order to make comparisons to similar buildings or a building energy efficiency standard.
Fuel Switching	Switching of the fuel or energy source used in powering or heating a building.

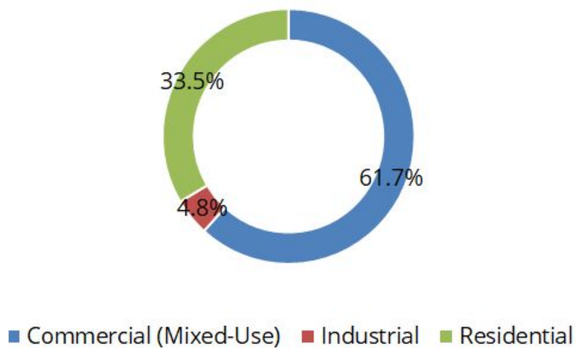
[4] Environment Canada (2018). National and Provincial/Territorial Greenhouse Gas Emission Tables. Retrieved from: http://data.ec.gc.ca/data/substances/monitor/national-and-provincial-territorial-greenhouse-gas-emission-tables

Background Information

Large Buildings in Ottawa

As of 2016, Ottawa had 2,944 large buildings in its inventory (greater than 2,323m^2). These large buildings totaled 27.7 million square metres of floor area, compared to 49.9 million square metres of small buildings. Of the 27.7 million square metres, commercial buildings represented 62% of the large building stock which is inclusive of mixed-use buildings, large residential buildings represented 33.5%, and large industrial buildings represented approximately 5%. Figure 5 represents the breakdown.

Figure 5. Large building stock by type, 2016



Ottawa's Historical Building Stock

Ottawa has 7,623 non-residential buildings which comprise 21 million square meters of floor space. The average building area is 2,800 square meters. Figure 6 illustrates the city's non-residential building stock by age and type (excluding industrial). For details on how specific buildings are assigned to these categories, see Appendix 1. There were three major building periods for non-residential buildings: before 1950, 1985-1990, and 2010-2015. More than 60% of the non-residential building floor space (m^2) is 20 years old or older and a quarter of the building floor space (m^2) is 50 years old or older.

Commercial buildings account for 45% of the current non-residential building floor space, followed by institutional buildings (32%), and retail space (25%).

Figure 6. Floor area of non-residential building stock by era and by class in Ottawa.

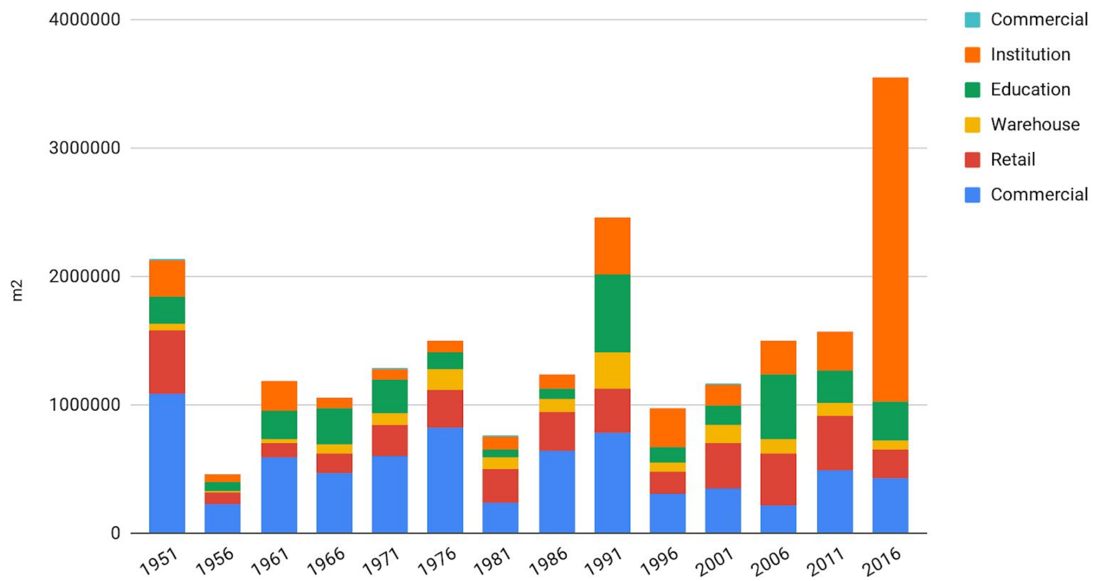
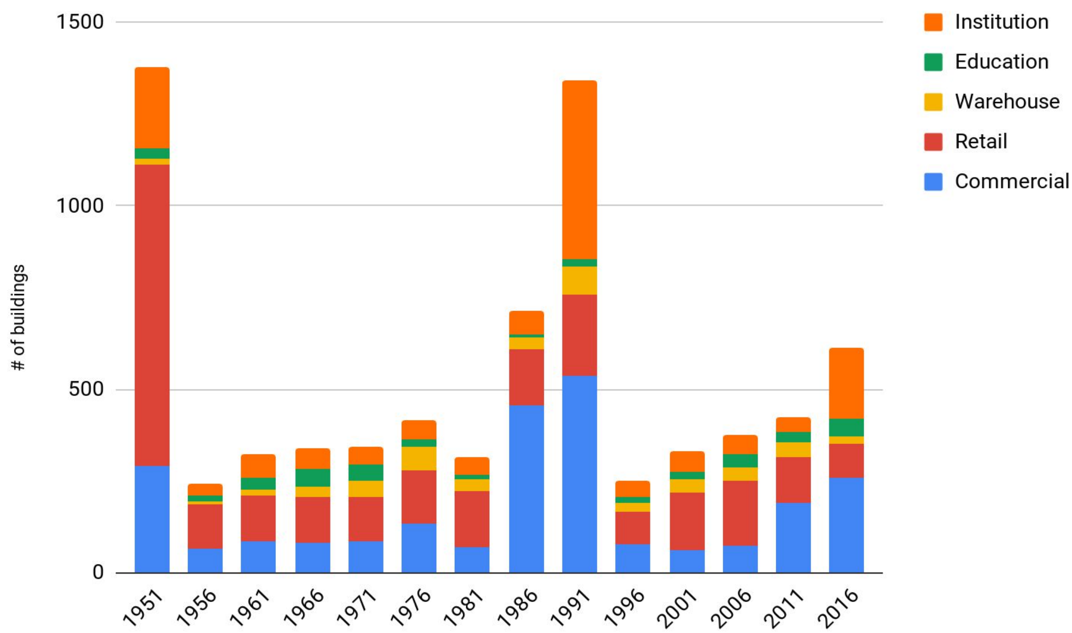


Figure 7 illustrates the number of buildings, as opposed to floor space, by the same categories in Figure 6. There are many pre-1950 retail buildings, indicating that they are relatively small in floor area, on average. There is a significant increase in institutional floor space between 2010 and 2015.

Figure 7. Number of non-residential buildings by era and by class in Ottawa.



Energy Consumption

Total energy consumption in buildings was 75,790 TJ (approx. 76 million GJ) in 2016. Of this total, commercial buildings used 29,618 TJ (approx. 30 million GJ). Residential buildings accounted for 52% of total building energy consumption in Ottawa in 2016, followed by commercial buildings at 39% and industrial buildings at 9%. Industrial buildings are separated from the rest of the non-residential building stock so that their unique patterns of energy consumption do not influence the broader non-residential sector tallies. Just over half of the energy used by all the buildings (54%) was provided by natural gas, while 38% was provided by electricity. Commercial buildings have a higher share of electricity (43%) and a lower share of natural gas (50%). Half of the total energy consumed in the entire building stock is used for space heating, 15% is used for water heating, and 10% each for plug loads and lighting.

Figure 8. Total building energy consumption by fuel and sector, 2016.

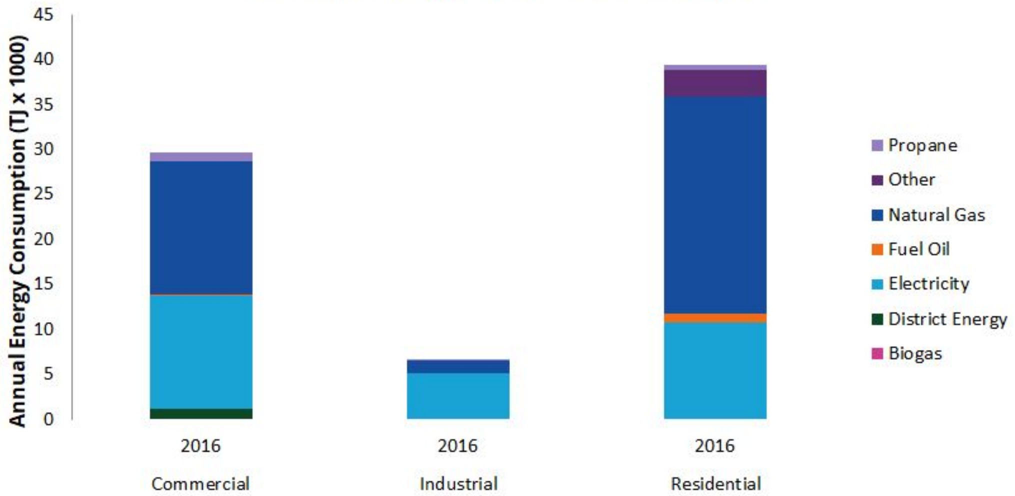
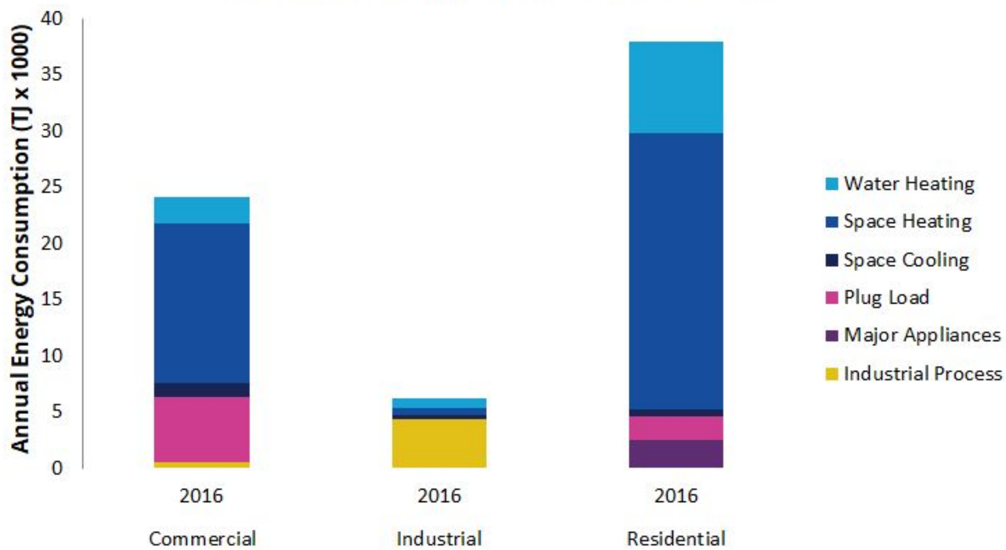


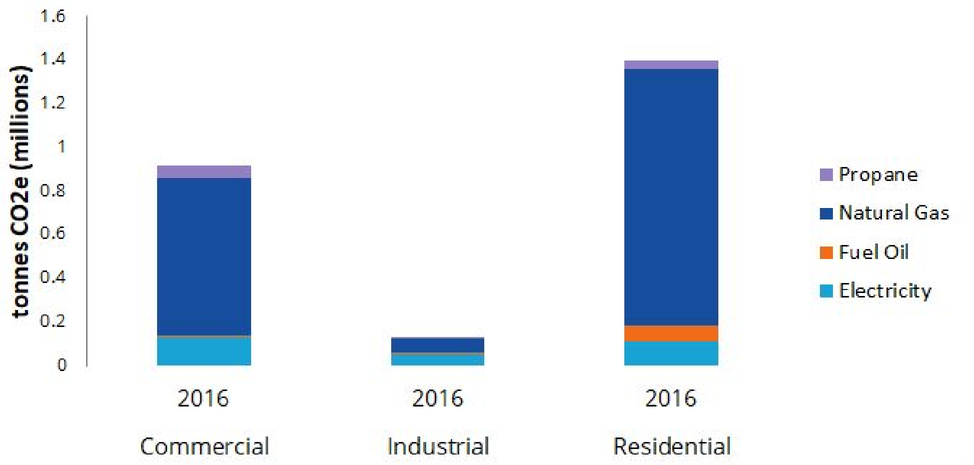
Figure 9. Total building energy consumption by end-use and sector, 2016.



Greenhouse Gas Emissions

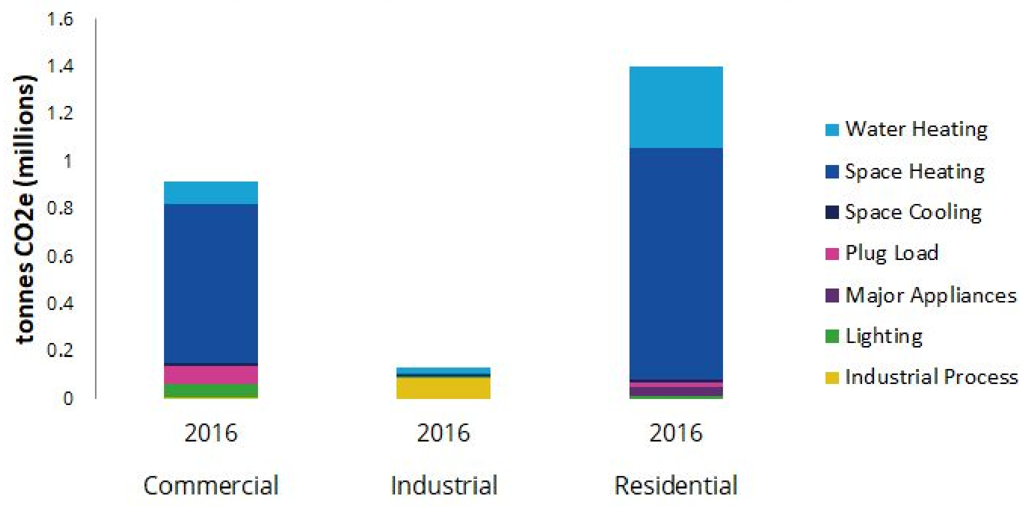
Energy consumption in buildings in Ottawa resulted in 2.4 million tCO2e in 2016, of which approximately 0.920 million tCO2e were from commercial buildings, 0.133 million tCO2e were from industrial buildings, and the remaining 1.40 million tCO2e were from residential buildings. 81% of the total GHG emissions resulted from the combustion of natural gas. In only commercial buildings, it was lower, at 78%.

Figure 10. Total building GHG emissions by fuel and sector, 2016.



Space heating and water heating accounted for 87% of the total GHG emissions, as a result of reliance on natural gas for heating. Emissions from heating are less in commercial buildings, at 83% of total.

Figure 11. Total building GHG emissions by end-use and sector, 2016.

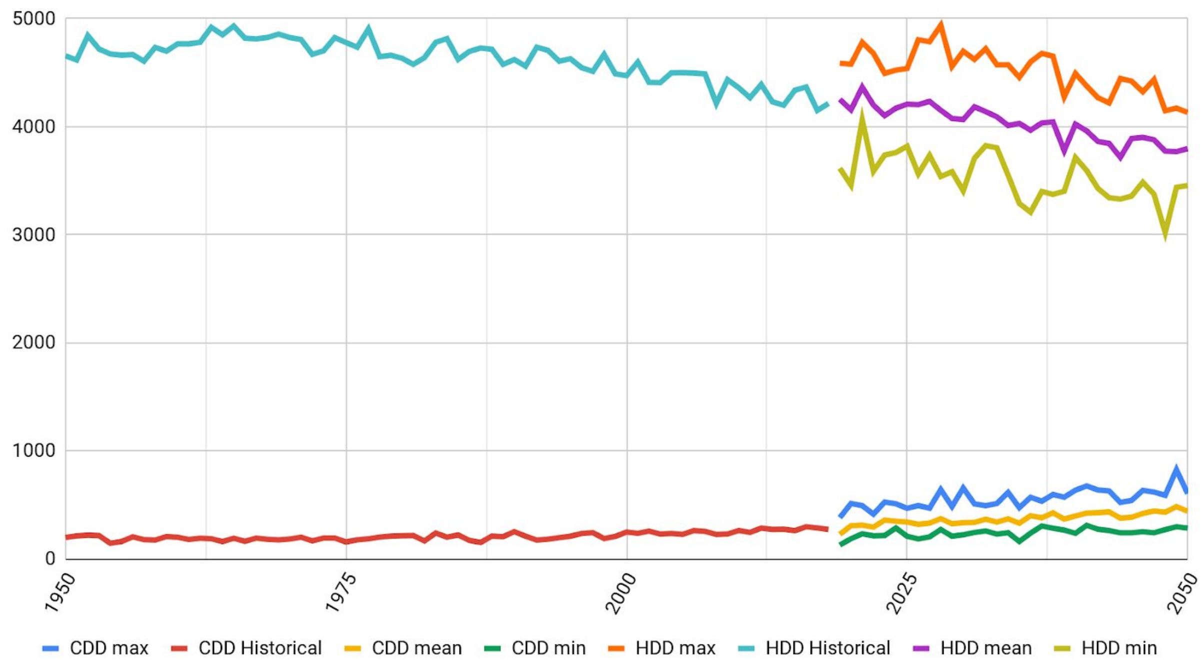


The Effect of Climate

One confounding factor influencing energy consumption and emissions is the weather, or, more specifically, the number of heating and cooling degree days (HDD and CDD, respectively). Relatively warmer years will result in greater energy consumption for air conditioning while relatively cooler years will result in greater energy consumption for heating. A heating degree day is the number of degrees that a day's average temperature is below 18°C, indicative of the amount of energy needed to heat buildings to operating temperatures in that day. For example, a day with an average temperature of 4°C has a Heating Degree Day value of 14. Similarly, a cooling degree day provides a measure of energy needed to cool buildings, noted by the number of degrees that a day's average temperature is above 18°C.

In Ottawa, heating degree days are projected to decline by 10% by 2050 over 2018, with cooling degree days increasing by 60% over the same period (Figure 12). Under a BAP scenario, space heating will go down while air conditioning use will increase.

Figure 12. HDD and CDD projections for the City of Ottawa.[5]



[5] Prairie Climate Centre (2018). The Climate Atlas. https://climateatlas.ca/data/city/459/hdd_2060_85

Evaluation of Current Pathway

Typical approaches to building retrofits in Canada do not achieve the level of GHG emissions reductions required for low carbon pathways. Retrofits are typically divided into sets of specific actions called energy conservation measures (ECMs). ECM implementation is prioritized on the basis of cost effectiveness, thus the lowest cost ECMs are completed first.[6] However, ECMs with greater costs are often those that are required to achieve low carbon building outcomes.

An alternative approach is a whole system retrofit or a comprehensive building upgrade, in which the building is analyzed and retrofit as a system. This approach has three key advantages:

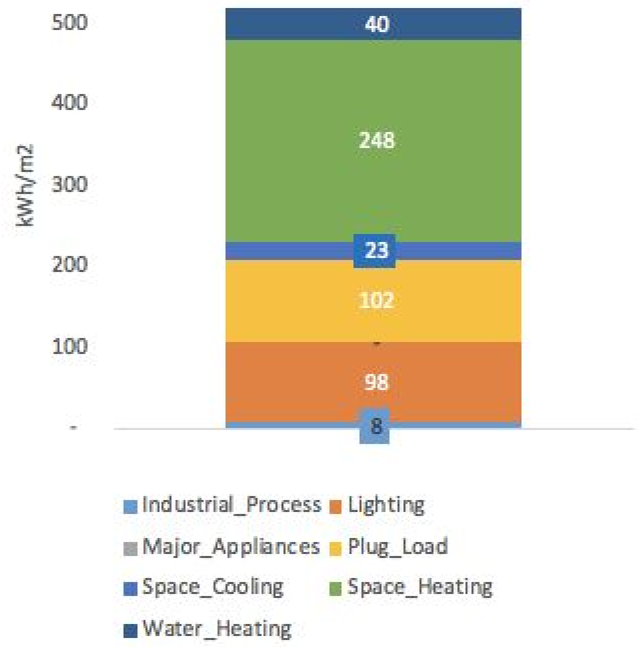
- The building is analyzed as a whole system, reducing unintended effects;
- Overall capital costs can be lower. For example, thermal upgrades can result in lower capital costs for equipment such as HVAC, whereas in a standard ECM approach, the same HVAC system may be installed, depending on when or if thermal upgrades are undertaken;
- ECMs with faster paybacks can be bundled with less cost-effective measures resulting in greater overall energy savings and GHG reductions; and
- Fuel switching—critical to GHG emissions reductions—can be incorporated as part of the systems approach.

Retrofit program with energy and GHG intensity targets

Retrofit efforts build upon recommissioning efforts by making changes to building exteriors and requiring greater changes to building materials and fixtures. There are different degrees of effort for retrofits, but they generally range from shallow, to moderate, to deep. Different actions and results are summarized in Table 2, and a more extensive description can be found in the Existing Residential Buildings Pathway. For the purposes of larger non-residential buildings, deep retrofits with an energy or emissions reduction of 50% are considered useful in meeting emission reduction targets.

[6] For a comprehensive study of ECMs, costs and GHG reductions, see: City of New York. (2016). One City: Built to Last: Transforming New York City Buildings for a Low Carbon Future. Retrieved from https://www1.nyc.gov/assets/sustainability/downloads/pdf/publications/TWGreport_04212016.pdf

Figure 13. Average energy use intensity for non-residential buildings by end-use, 2016.



Retrofit programs often target energy use reductions which result in costs savings for occupants. However, it is important to also target GHG reductions. As Ontario's electricity grid has a low emissions factor, priority should be given to actions that reduce natural gas used in thermal energy applications (i.e. heating). A focus on reducing consumption of electricity will not have much effect on emissions, so it is recommended that total emissions and not electricity or energy consumption be the focus of retrofit work in Ottawa. Table 2 summarizes varying scopes of building retrofit efforts.

Deep retrofits for larger buildings, particularly commercial or industrial, are an important strategy to help Ottawa reduce GHG emissions, highlighted by the fact that the majority of the GHG emissions are associated with space heating (Figure 14). The existing residential buildings pathway also cautions against "lock-in effect" wherein a shallow retrofit step is taken then not changed or upgraded over time. If shallow retrofits are undertaken, no additional improvements in the installed equipment can be expected over the course of its lifetime without considerable additional expense. In this way, lower levels of energy reductions can be locked in for a long period, thus neglecting opportunities for greater energy reductions.

Table 2. Comparison of retrofit depths.[7]

Retrofit Criteria	Shallow Retrofit	Moderate Retrofit	Deep Retrofit
Typical energy conservation measures	• Lighting • Smart controls • HVAC motors and fans -Caulking and sealing • Optimization	• Boiler, furnace, or AHU replacement • Steam to hot/low-temp water • Heat pumps • Drain/waste heat recovery • Heat recovery ventilation Roof/cavity insulation	• Window replacement • Wall and foundation reinsulating • Shading • Envelope replacement • Conversion to renewable district energy
Energy savings range	10-20%	30-50%	40-80%
Typical payback period and costs	1-3 year payback Commercial: <$21.5/m^2 MURB: <$2,000/unit	3-6 year payback Commercial: $21.5-$54/m^2 MURB: $2,000-$6,000/unit	6+ year payback Commercial: $215-$540/m^2 MURB: $10,000-$60,000/unit
Advantages	• Short payback • Cost-effective • Incentivized by current program and policy structure	• Attractive balance of energy savings and payback • Can be performed with minimal disruption to tenants	• Holistic approach • Optimizes components • Large and lasting energy and emissions reductions • Reduces the demand for externally sourced energy and local dollars leaving the community
Disadvantages	• Small energy savings • Weakens business case for deeper retrofits in the future • Missed synergies between building components • Does the least to address occupant comfort and operational issues	• Higher energy reductions difficult to achieve without envelope upgrade • May result in oversized mechanical systems compared with a deep envelope retrofit	• Complex • Longer payback period • Potential of a disruption to tenants/owners in some cases

Payback periods for building retrofits can vary greatly depending on levels of expertise, the retrofit path chosen, and the depth of the retrofit. Economic dimensions such as incentives offered or carbon pricing can greatly speed up payback periods, and the lack of of these items can make payback periods lengthy and thereby less attractive to undertake.

[7] Frappé-Sénéclauze, T., Heerema, D., Tam Wu, K. (2017). Deep emissions reduction in the existing building stock. The Pembina Institute.

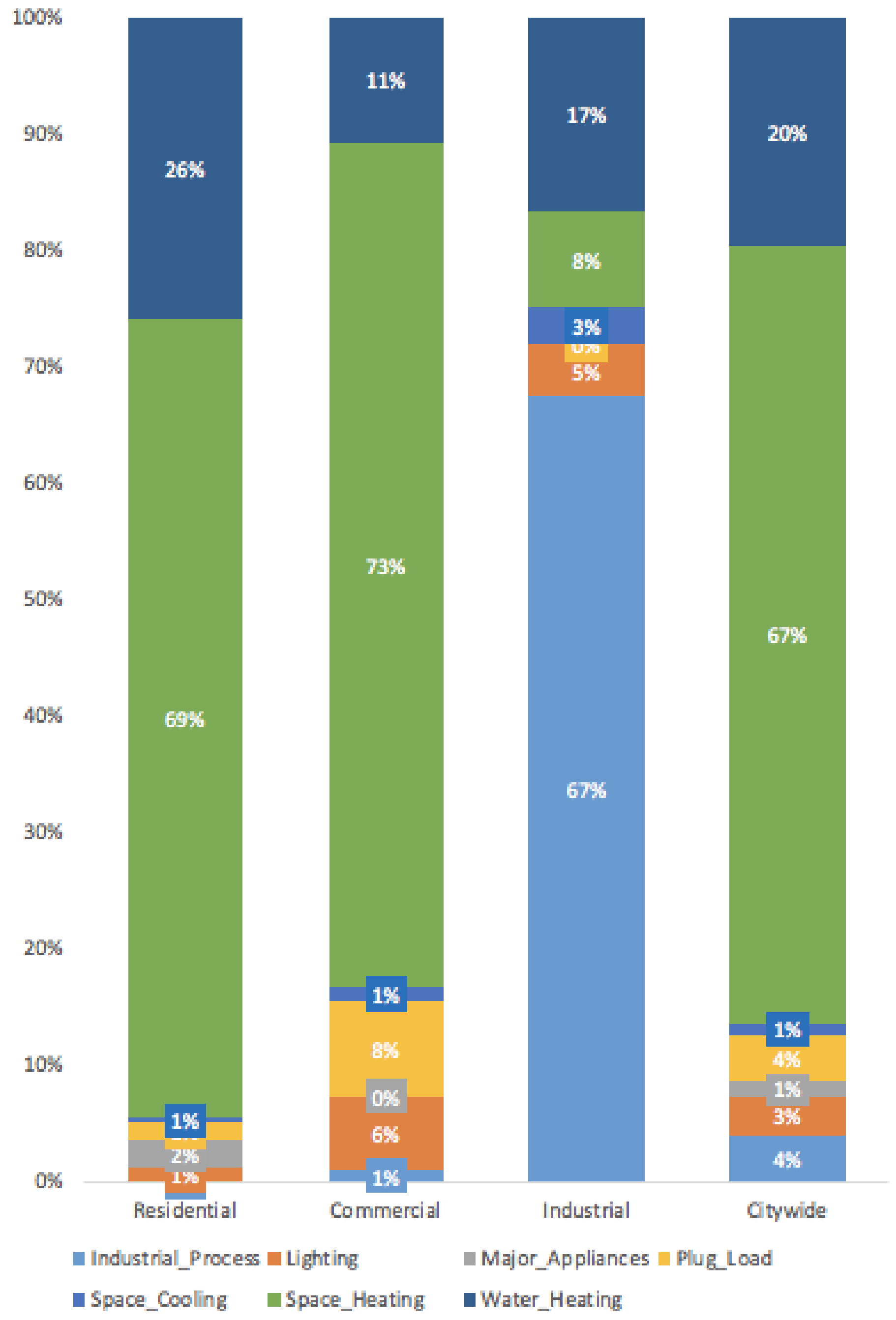
Case studies on large building retrofits by The Toronto Atmospheric Fund (TAF) show that reasonable paybacks (4-6 years) can be achieved on older and less efficient buildings in Ontario. The TAF helped to finance and provide grants for a portion of these retrofit programs.

Table 3: Retrofit case studies and payback periods.

Project Description	Retrofits	Energy, Utility, and water savings	Payback Period
45-year old multi-family building in Burlington, Ontario[8] 210 units over 18 storeys	• Boiler replacement • Toilet replacement • Chiller replacement	• 20% natural Gas reduction • 29% water reduction • 50% electricity demand reduction • 300 tonnes GHG reduction	4.4 Years
20-year old social housing apartment building, Toronto Ontario[9] 13-storeys high with with 125 1-3 bedroom units	• Boiler replacement • Make-up air/HVAC upgrade • Lighting system upgrade to LED • Toilet, shower, aerator replacements	• 11% electricity reduction • 31% natural gas reduction • 33% water reduction • 166 tonnes GHG reduction	6.2 Years
30-year old social housing building in Toronto Ontario[10] 8-storey building combined with 4-storey section, 102 1-3 bedroom units	• Programmable electric baseboard heating system installed • Boiler upgrade • Make-up air/HVAC upgrade • Centralized control for building systems added • Domestic cold water booster pump system installed • Lighting system retrofit to LED • Toilet, Showerheads, and Aerators replacement • Exterior door and lobby air conditioner replacement	• 22% Electricity reduction • 29% Natural gas reduction • 47% Water reduction • 82 tonnes GHG reduction	4 Years

[8] "15 Kensington Road." 2011. Case Study. Towerwise. Toronto, ON: Toronto Atmospheric Fund. http://taf.ca/wp-content/uploads/2018/02/TAF_TowerWise_Case_Study_Kensington_Road_2011-01-21.pdf.
[9] Finn, Derrick. 2016. "Development of Three Multi-Unit Residential Building Energy Efficiency Retrofit Case Studies." Case Study. Housing Research Report. Ottawa, ON: CMHC. ftp://ftp.cmhc-schl.gc.ca/chic-ccdh/Research_Reports-Rapports_de_recherche/2017/RR_Three_Multi_Unit_Retrofit_Case_Studies_Jun2.pdf.
[10] Ibid

Figure 14. GHG emissions by building type and end-use, 2016, City of Ottawa.



Section 2: Growth Projections for Large Existing Buildings

Projected Pathway Assessment

The projected pathway assessment is modelled as the aggressive scenario, representing the low-carbon pathway. The actions and assumptions based on this pathway paper are presented in Table 4.

Table 4. Integrated Low Carbon Pathway Actions and Parameters.

Action	Conservative scenario	Moderate scenario	Aggressive scenario
Retrofits for commercial, and office buildings	1% of the existing building stock is retrofitted to a performance level in compliance with the current building code.	Assume 40% of current building stock over 35 years old takes on deep retrofit and reduces energy (electricity and natural gas) use 50% by 2030. After 2030, assume that 1% of non-residential buildings experience major renovations each year towards 2050.	Assume 95% of the current building stock is retrofitted by 2050, achieving an average of 50% energy savings.
Fuel Switching[11]	5% of non-residential floor space uses heat pumps	13% of non-residential floor space uses heat pumps	21% of non-residential floor space uses heat pumps
Fuel Switching: District Energy	16% of existing commercial buildings; 16% of apartments; 3% of residential buildings: 14% of the system low carbon	40% of existing commercial buildings; 40% of apartments; 8% of residential buildings: 40% of the system low carbon	80% of existing commercial buildings; 80% of apartments; 15% of residential buildings; 70% of the system low carbon
Municipal Buildings	10% of existing municipal buildings are retrofitted to net-zero emissions by 2050.	50% of existing municipal buildings are retrofitted to net-zero emissions by 2050.	100% of existing municipal buildings are retrofitted to net-zero emissions by 2050.
Recommissioning of commercial buildings on an ongoing basis*	None	Recommission 50% of buildings over 18,580 m2, and 20% of buildings over 2,323 m2 every ten years. Assume 5% reduction of energy use and thermal demand of natural gas usage per building.	Recommission all buildings over 18,580 m2, and 40% of buildings over 2,323 m2 every ten years. Assume 10% reduction of energy use and natural gas usage per building.

*The recommissioning action responds to overall building degradation, where energy performance weakens over time and is brought back to baseline through the recommissioning process, thus resulting in neutral emissions.

Methodology

[11] Heat pumps are addressed in more detail in a separate pathway paper.

The modelling methodology for all of the building pathways (existing residential / non-residential and new residential / non-residential) is similar. A summary is shown below, and more information can be found in the Data, Methods, and Assumptions (DMA) manual. The CityInSight model simulates the impact of future building code standards that will affect residential and non-residential buildings in the municipality by applying target Energy Use Intensity (EUI) and thermal energy demand intensity (TEDI) values for each vintage of buildings. These target values are expressed as a percent improvement from the previous time period. CityInSight adjusts various energy use parameters such as thermal transmittance, output energy intensity, and equipment efficiencies until the modelled EUI and TEDI values meet the target. The steps involved in developing a projection are as follows:

1. Place existing buildings in space in the base year, disaggregated by geographic zone, year building and building type;
2. Simulate additions to and removals from the building stock over time, as required by the population and employment projections;
3. Derive energy use in buildings according to the thermal envelope profile, energy-using stocks (appliances, equipment);
4. Disaggregate energy use by end-use and fuel type as well as building categories;
5. Calibrate projected energy use with observed energy consumption as provided by the energy utilities;
6. Apply energy use intensity targets incrementally to the existing building stock, targeting specific criteria such as age, size, use and location of buildings; and
7. Analyze the cost of the retrofits that achieve the energy use intensity targets.

Constraints

The following are examples of the challenges that are confronted in undertaking large scale, deep energy retrofits for large buildings.

Making a business case: When energy costs are low and large businesses or building owners can still create profit per square metre of building despite poor building performance, then it can be difficult to build a business case to retrofit a building. Further, a lack of policy from all levels of government accompanied by incentives does not signal the need for change in business practice, nor create different competitive advantages to acquire new customers into energy efficient buildings.

Logistical Challenges: Large buildings may present different challenges than retrofitting personal homes. The buildings being larger may have multiple processes that need to be running on 24-hour timelines, with multiple employees or services. Shutting a system down for a longer term may require back up services or better scheduling to time a deep energy retrofit.

No current carbon pricing: The cost of avoiding carbon pricing can incentivize Ottawa residents to take on the actions in this pathway willingly but is not present currently. Ottawa can only advocate for a carbon tax; however, the Federal Government has mandated a carbon tax by 2019 for all provinces who do not have an equivalent carbon tax in place.

Net metering: Ontario has a net-metering policy in place where renewable on-site energy is sold back to utility company. This incentive is limited as businesses or building owners have not been able to sell to customers directly or capture and distribute energy credits when they have multiple buildings in their inventory.[12]

Behavioural: One of the major energy users in buildings in end-user loads, so how people interact with their buildings. If building occupants add additional loads to buildings with space heaters, air conditioning, fans, appliances, then the energy use for buildings will increase. This may not be significant when a deep energy retrofit is completed and done to maximize occupant comfort.

Ability to scale: Without a consistent funding pool, there is an inability to create a stable industry that operates at a scale needed to make retrofits less costly. In Ontario and Canada there has been little consistency for the industry and the ability to scale has therefore been limited.

Social inclusion: Many efforts to make buildings or the urban environment more sustainable with less energy use and carbon emissions may not reach people of different incomes or backgrounds. Large and expensive technologies or building overhauls may be too expensive for lower income earners. Further, in the case of older affordable housing stock that is not run by a non-profit or housing society, a lengthy retrofit can temporarily evict families, or increase prices to a non-affordable level.

[12] Gloss, Adlar. 2017. "Net-Metering in Ontario: Current Issues and Challenges." Cekap: Community Energy Knowledge. July 20, 2017. http://www.cekap.ca/blog/net-metering-in-ontario-current-issues-and-challenges.

Uptake Projections

Conservative Scenario

Figure 15. Floor area retrofit for existing non-residential buildings under the conservative scenario (m2).

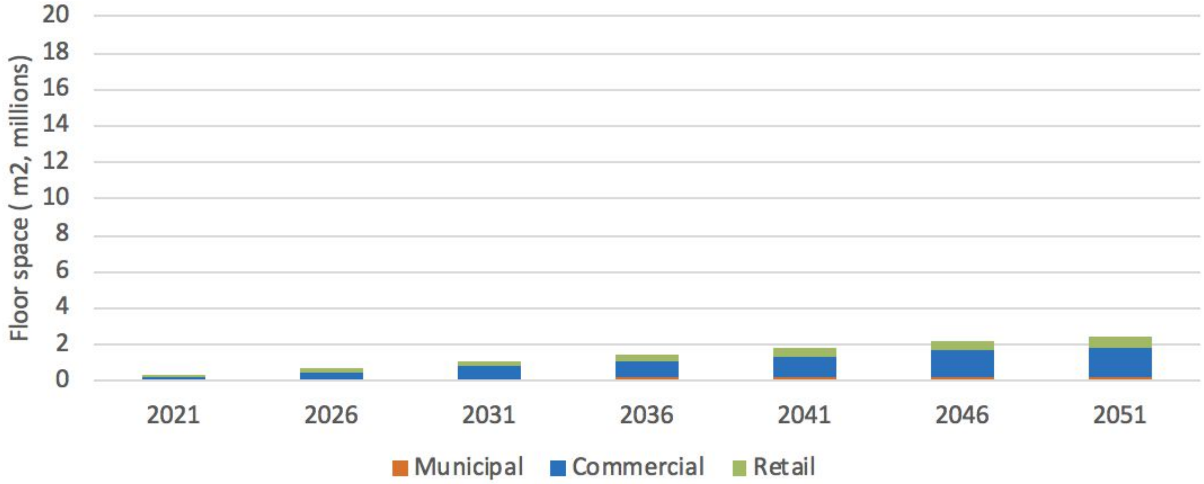


Table 5: Energy and GHG emissions results of the conservative existing non-residential buildings pathway.

Action		Cumulative emissions reductions 2018-2050 (kt CO2eq)	Emissions reductions 2050 (kt CO2eq)	Cumulative energy reductions 2018-2050 (TJ)	Energy reductions 2050 (TJ)
Retrofits for commercial and office buildings	1% of the building stock is retrofit each year in compliance with the current building code	1,136	93	30,588	2,612
Municipal Building Retrofits	50% of existing municipal buildings are retrofit to net zero emissions by 2050	417	33	6,816	500
Heat Pumps	5% of commercial floor space	512	29.19	8,204.78	432.91
District Energy	16% of existing commercial buildings; 16% of apartments; 3% of residential buildings: 14% of the system low carbon	2,006	87.03	4,049.88	175.77
Building Recommissioning	No Action	N/A	N/A	N/A	N/A

Moderate Scenario

Figure 16. Floor area retrofit for existing non-residential buildings under the moderate scenario (m2).

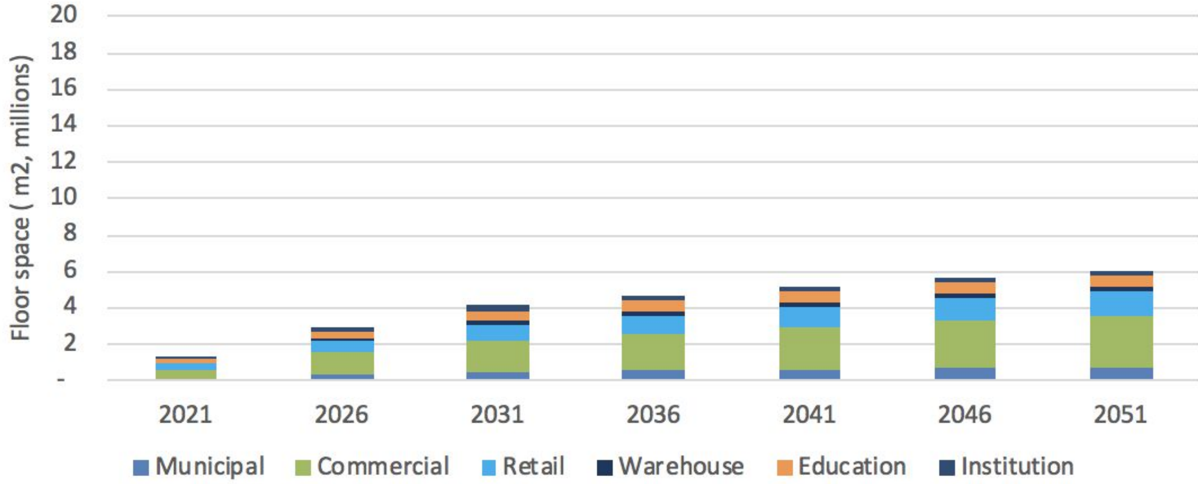


Table 6: Energy and GHG emissions results of the moderate existing non-residential buildings pathway.

Action		Cumulative emissions reductions 2018-2050 (kt CO2eq)	Emissions reductions 2050 (kt CO2eq)	Cumulative energy reductions 2018-2050 (TJ)	Energy reductions 2050 (TJ)
Retrofits for non-residential buildings	40% of the building stock over 35 years old retrofit for electricity and natural gas savings of 50% by 2030; after 2030, 1% of non-residential undertake deep retrofits each year	2,526	131	61,308	3,312
Municipal Building Retrofits	100% of existing municipal buildings are retrofit to net zero emissions by 2050	2,896	259	54,908	4,921
Heat Pumps	13% of commercial floor space	1,450	83.88	20,554.68	1,168.28
District Energy	40% of existing commercial buildings; 40% of apartments; 8% of residential buildings: 40% of the system low carbon	4,922	220.23	10,301.15	476.11
Building Recommissioning	Recommission 50% of buildings over 200,000 ft2 and 20% of buildings over 25,000 ft2 every ten years. Average savings 5% of energy.	1,860	130	42,204	3,051

Aggressive Scenario

Figure 17. Floor area retrofit for existing non-residential under the aggressive scenario (m2).

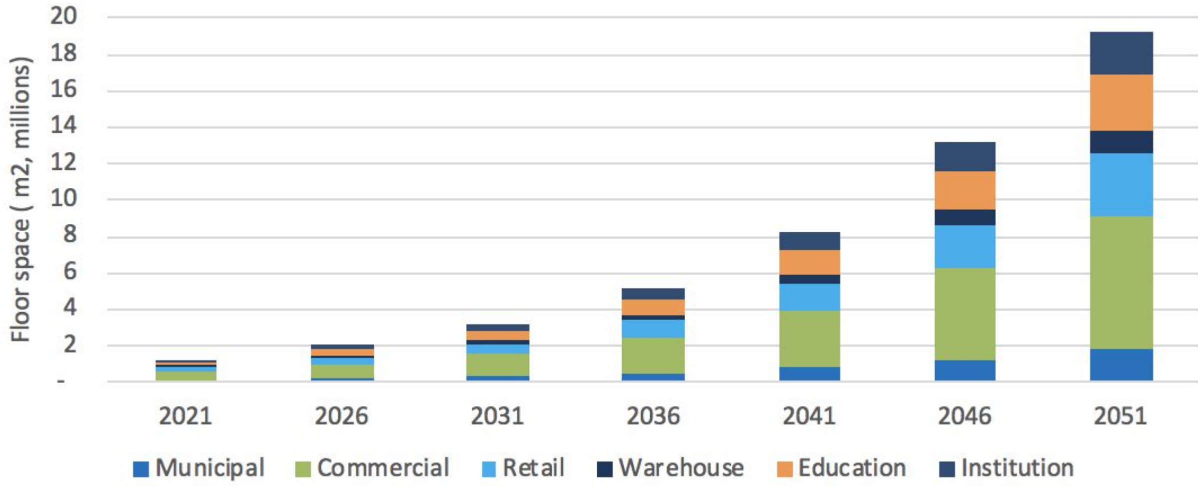


Table 7: Energy and GHG emissions results of the aggressive existing non-residential buildings pathway.

Action		Cumulative emissions reductions 2018-2050 (kt CO2eq)	Emissions reductions 2050 (kt CO2eq)	Cumulative energy reductions 2018-2050 (TJ)	Energy reductions 2050 (TJ)
Retrofits for non-residential buildings	95% of the existing building stock is retrofit by 2050 with average savings of 50%	2,935	252	71,390	6,184
Municipal Building Retrofits	100% of existing municipal buildings are retrofit to net zero emissions by 2040	4,867	277	94,278	5,643
Heat Pumps	21% of commercial floor space	2,388	139	32,905	1,904
District Energy	80% of existing commercial buildings; 80% of apartments; 15% of residential buildings; 70% of the system low carbon	10,077	454	20,547	961
Recommissioning	Recommission all buildings over 200,000 ft2 and 40% of buildings over 25,000 ft2 every ten years. Average savings 10% of energy.	3,907	255	86,334	5,854

Opportunities to Advance the Pathway

Benchmarking

A comprehensive picture is necessary to know which buildings to retrofit. Energy benchmarking is a key strategy to systematically track building energy use over time. In addition to serving a strategic purpose for targeting building segments or geographies for retrofits, energy benchmarking also provides tenants or owners with information on building selection or investment decisions. Due to lack of systematic benchmarking, the CaGBC's Roadmap to Retrofits report was unable to classify one third of building assets due to incomplete data.[13]

New York City is an early adopter and innovator in creating regulations for benchmarking, and targeting large buildings (over 4,645m^2).[14] The rationale for this decision was to mimic behaviour of nutrition labels or vehicles where consumers are more likely to choose healthier foods or more efficient vehicles; potential tenants of buildings would choose more efficient buildings.[15] Research indicated that availability of data that indicates energy consumption can urge the real estate market to keep their buildings as efficient as benchmark rates.[16]

Ontario has also adopted new legislation (Regulation 20/17) under the Green Energy Act (2009) where large buildings (4,645m^2 or greater) are required to report their energy use. Utility companies such as Hydro One will be providing aggregated use data to building owners to facilitate reporting. Benchmarking will be phased in as summarized in Table 8.

Table 8. Ontario benchmarking requirements.[17]

Deadline for Reporting to Ministry of Energy	Commercial & Industrial Buildings Gross Floor Area	Multi-Unit Residential Buildings (MURBs) Gross Floor Area
July 1, 2018 (usage for 2017 calendar year)	250,000 sq. ft. and larger	Not required to report in first year
July 1, 2019 (usage for 2018 calendar year)	100,000 sq. ft. and larger	100,000 sq. ft. and larger
July 1, 2020 (usage for 2019 calendar year)	50,000 sq. ft. and larger	50,000 sq. ft. and larger

[13] Canada Green Building Council (2017). A Roadmap for Retrofits in Canada: Charting a Path Forward for Large Buildings. Toronto.
[14] Kontokosta, C. (2012). Predicting Building Energy Efficiency Using New York City Benchmarking Data. *New York University*, 2012, 12.
[15] Ibid.
[16] Ibid.
[17] "Energy Reporting and Benchmarking." 2018. Hydro One. 2018. https://www.hydroone.com/business-services/energy-reporting-and-benchmarking-for-large-buildings.

Recommissioning

Commissioning is a corrective audit process undertaken prior to the initial occupancy of a building to ensure a building's components are functioning as intended. This includes heating and ventilation systems, appliances, and control systems. Commissioning is more extensively performed for large commercial, residential and institutional buildings due to the complexity of systems and their intended uses. Commissioning is not as extensive for smaller residential buildings which generally have more simple systems. Commissioning is a necessary step for larger non-residential buildings to ensure they are ready for initial occupancy. The process can result in better efficiency in space heating, cooling, and heating of water systems which are the most common energy users and sources of emissions within a building. However, it should be noted that the commissioning process can vary widely and greatly affect the performance of the building for years to come.

In the context of existing buildings, recommissioning is done some time (typically years) after the building has been initially occupied in order to increase efficiency, or re-tune existing systems. Examples of common deficiencies that recommissioning can fix include duct leakage, HVAC systems running when the building is unoccupied, HVAC being unbalanced, lighting systems running all day, valves leaking, improper refrigerant or appliance charge.[18] Continual recommissioning is recommended to ensure the most efficient building performance. Costs vary by the size of the building and the potential upgrades highlighted in the process, however, previous studies have shown the cost to be \$3.25 / m^2 with a payback period of 1-3 years.[19] Estimates place energy efficiency improvements to be 10-20% from recommissioning.[20]

Reaching Net Zero or Passive House Standards

Net Zero buildings have zero net energy consumption; the total energy used by the building annually is approximately the same as energy produced by the building. Passive House certification is currently the most established high-performance standard for building efficiency, with requirements for energy demand, airtightness, and thermal comfort. Net Zero builds on Passive House levels of performance by ensuring that what energy consumption that remains is provided by renewable energy.

Retrofit programs are gaining popularity in Canada due to decreasing costs, simplicity of construction, and reduced time for completion. However, Canada has not reached a scale where programs are easily available across the country, but one emerging exception may be the Energiesprong program developed in the Netherlands. The EnergieSprong program provides a turn-key retrofit service to existing buildings to convert them to Net Zero or Net Zero ready when renewable energy becomes available.[21] Energiesprong retrofits can be completed in 10 days and have been successful in updating social housing without requiring upfront capital from tenants.[22] As the process has evolved for Energiesprong, costs have decreased by 60% in three years.[23] The

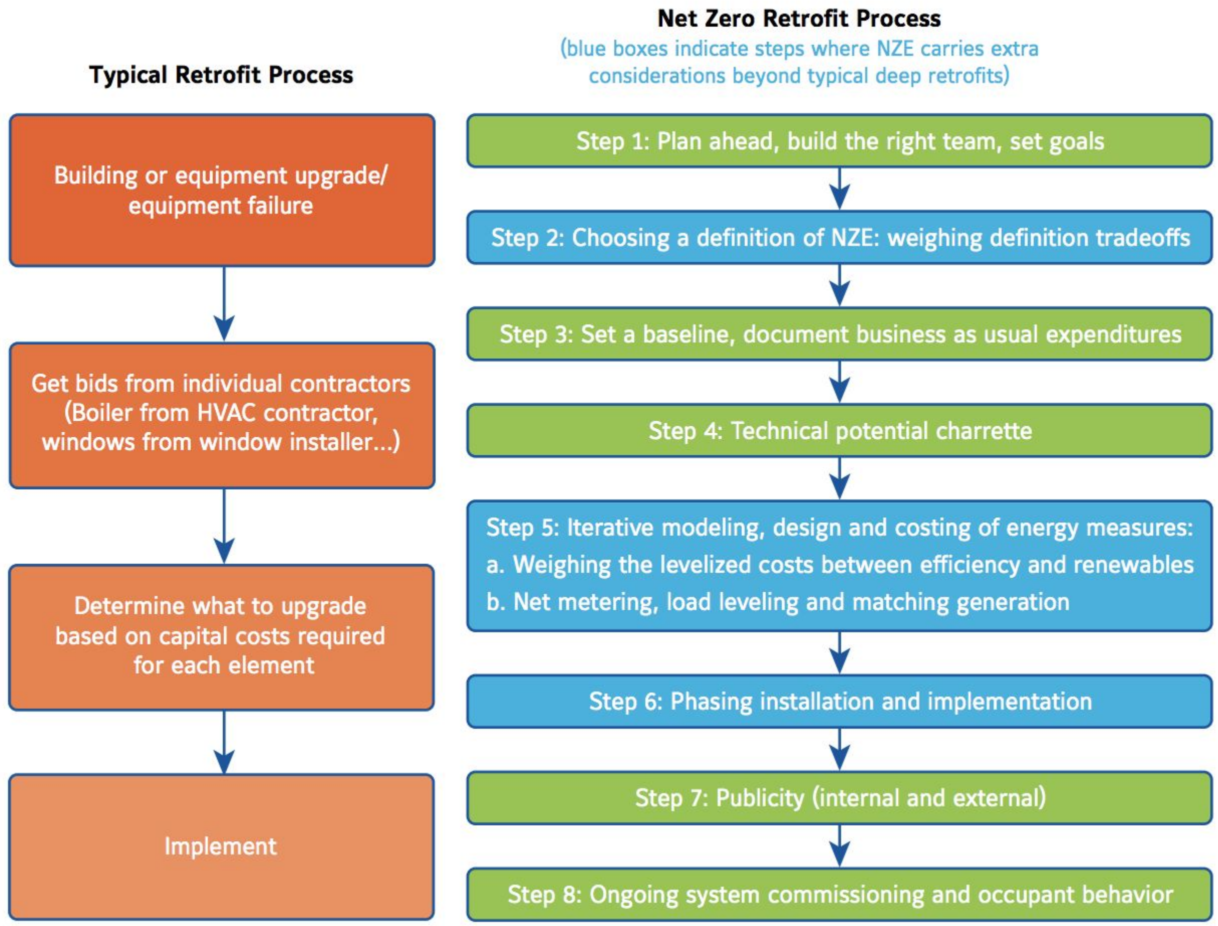
[18] "A Guide to Building Commissioning." Pacific Northwest National Laboratory, September 25, 2011. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-21003.pdf.
[19] State and Local Energy Efficiency Action Network. (2013). Energy Audits and Retro-Commissioning: State and Local Policy Design Guide and Sample Policy Language. Prepared by A. Schulte, ICF International.
[20] Frappe-Seneclauze, T., Heerema D., Wu, K. 2017. Deep emissions reduction in the existing building stock. The Pembina Institute.
[21] Sustainable Buildings Canada. (2016). Energiesprong Summary Report. Retrieved from: https://sbcanada.org/wp-content/uploads/2017/09/Energiesprong-Summary-Report.pdf
[22] "How-to-Guide: Net-Zero Retrofit Technical and Cost Benchmark Studies." Rocky Mountain Institute, n.d. https://www.rmi.org/rmi_techno_economic_study_how_to_guide/.
[23] Ibid.

EnergieSprong model is quick and efficient by using prefabricated facades and building envelopes, efficient heating and cooling system, and insulated roofs fitted with solar PV.

New York State Energy Research and Development Authority (NYSERDA) has also announced a program called RetrofitNY based on EnergieSprong with the objective of creating a volume market for net-zero retrofits with larger buildings. Finally, Natural Resources Canada is currently working on a similar project titled Prefabricated Exterior Energy Retrofits (PEER) in the Ottawa area, and may be more applicable to the Canadian context as it factors in colder weather patterns nationally.

Irrespective of the technologies applied, achieving a retrofit with the level of ambition of net zero requires a different type of process than a conventional retrofit, with a more intensive design program, and with greater upfront costs (Figure 18).

Figure 18. Comparison of the convention versus net zero approach to retrofits.[24]



In order to expedite the design process, deep energy/net zero retrofit pathways can be developed for specific building archetypes that are relevant to the City of Ottawa. These pathways provide a basis from which more detailed design can be completed.

[24] Carmichael, C. (2018). Reinventing existing buildings: Eight steps to net zero energy. Rocky Mountain Institute.

Fuel Switching

Non-residential buildings can reduce their carbon emissions by switching boilers and heating systems to renewable energy, high-efficiency electric heating systems such as ground or air source heat pumps, or to district energy systems that uses low GHG energy inputs. Ottawa currently operates 5 district energy plants, producing 1.1 million GJ of energy annually[25,26] and some of these systems are intended to become net zero GHG emissions in the near future. District energy provides a different option to reduce dependency on natural gas, and to increase the size of low or zero carbon solutions with the potential for economies of scale.

Currently, fuel switching is disincentivized by the low cost of natural gas in Ontario. This presents a critical barrier for widespread uptake of fuel switching and the electrification of heat. Ground-source heat pumps, which Ottawa has more experience with, may have a better business case especially when combined with any potential carbon pricing measures that may be mandated by the Federal Government.

Fuel switching becomes most viable in the context of retrofits which reduce the demand for space heating, enabling the introduction of smaller equipment with reduced capital and operating costs relative to the business as usual case. The financial case is further strengthened if this process can occur at the end of life of major components in the building.

In order to achieve the target of net zero, electrification is unlikely to be sufficient, as the electricity is not 100% clean in Ontario. As a result, the building will need to provide renewable energy using solar PV or purchase renewable electricity from other sources. Balancing the costs of incremental renewable energy versus the incremental savings from energy efficiency measures is an important design question for the retrofit.

Funding & Financing Retrofits

Creating a business case for private building owners to recommission their buildings or do deep energy retrofits can be challenging. The CaGBC recommends sending consistent messages to the retrofit and recommissioning industry by ensuring that grant programs or incentives stay in place over the long term.[27] With these programs, the industry can develop, gain expertise, and be able to make efficiencies with their practices or procurement chains. However, a variety of financing methods may become available from the Province, Federal Government, or utility companies to help reduce energy and emissions from existing buildings.

The large upfront costs of deep energy retrofits are a barrier to organizations, stratas, or building residents who may have to pay to refurbish a building envelope, add high-performance windows, or overhaul an HVAC system. In response, The Rocky Mountain Institute (RMI) advocates for an integrated design approach where the whole building is considered and passive strategies that make better use of existing environmental features are prioritized, such as maximizing solar gain.[28] RMI also advocates for retrofit strategies that may have faster payback periods to begin with, using those gains to tackle more expensive items that will reach a 50% reduction in energy use.[29] The

[25] "Ottawa: Steam to Hotwater Conversion." Ever-Green Energy, 2018. http://www.ever-greenenergy.com/project/ottawa/.
[26] As modelled by CityInSight.
[27] Canada Green Building Council (2017). A Roadmap for Retrofits in Canada: Charting a Path Forward for Large Buildings. Toronto. Retrieved from: www.cagbc.org/cagbcdocs/advocacy/CaGBC_Roadmap_for_Retrofits_in_Canada_2017_EN_web.pdf.
[28] "Deep Retrofit Tools and Resources - Rocky Mountain Institute." Accessed September 9, 2018. https://rmi.org/our-work/buildings/deep-retrofit-tools-resources/.
[29] Ibid.

CaGBC recommends deep retrofits at a time when a building may need to renew their envelope, replace major equipment, when there is new ownership, or if the building is attempting to gain green building certification.[30]

Local Improvement Charges

Local Improvement Charges (LIC) are an important tool for encouraging uptake of energy efficiency upgrades. This financing method will securitize a loan against a building asset rather than an individual owner. Essentially, building owners receive a loan from municipalities, which is repaid through the local taxes, called a local improvement charge. This financing structure is often referred to as Property Assessed Clean Energy (PACE) in the United States. Ontario Regulation 586/06 Local Improvement Charge allows municipalities to undertake works that provide local benefits and recover the costs from benefitting properties.[31] Regulation 322/12 allows such projects to be used for a wider range of uses, including home retrofits.

On-bill Financing

On-bill financing programs for retrofits have a similar repayment schedule as LIC structures, except repayment occurs through monthly utility bills. On-bill financing ties retrofit activity to actual energy and cost reductions. In theory, on-bill financing aims to reach bill neutrality, where monthly costs are equal to the savings achieved through retrofits and there are little incurred costs to customers; in practice, bill neutrality is far from guaranteed.[32] Loans are transferable if the unit is sold. Utilities need to provide upfront capital for project administration and initial loan funding. Large buildings may offer a different advantage than small buildings where a building is used as a security and has more value. The larger collateral can be used to target a deep retrofit strategy which can reduce operating costs at a higher rate.

Third-party financing

Both on-bill financing and local improvement charges present an alternative to loans from a traditional lending institution. In some cases, third-party financing can be advantageous, especially if an institution can provide low interest and long-term loans or bundle energy efficiency measures within a mortgage. Third party loans are seen as a lower risk to utilities and local governments, both of which are institutions that are not traditionally designed to provide loans.

Large commercial buildings may be able to use other revenue sources to secure larger loans from a lending institution and target a deep retrofit strategy if it is proven to reduce operating costs significantly. The same advantage could be offered to a large condominium building which can use strata fees.

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[30] Canada Green Building Council (2017). A Roadmap for Retrofits in Canada: Charting a Path Forward for Large Buildings. Toronto. Retrieved from: www.cagbc.org/cagbcdocs/advocacy/CaGBC_Roadmap_for_Retrofits_in_Canada_2017_EN_web.pdf
[31] Government of Ontario. O. Reg. 586/06: Local improvement charges. Retrieved from: https://www.ontario.ca/laws/regulation/060586
[32] Bardhan, A., Jafee, D., Kroll, C., Wallace, N. (2014). Energy efficiency retrofits for US Housing: Removing the bottlenecks. Regional Science and Urban Economics, 47, 45-60.

Ways to Encourage the Pathway

To move forward with reducing energy use and emissions from large existing buildings, the Ottawa community may want to consider the following actions:

- The City and its partners can help promote the new requirement of Ontario to benchmark buildings that are 4,645 m^2 or greater. As suggested in the benchmarking strategy of this pathway, there is a lack of data available to consistently measure performance of like buildings within Canada or Ottawa. Benchmarking can stop this trend and also encourage building owners to retrofit without incentive. The city can possibly start this shift by assisting in the benchmarking buildings that are 18,580 m^2 or greater and are 35 years or older.

- Encourage retrofits with modular facades. To encourage programs such as EnergieSprong which provide rapid retrofits that are cost efficient, the city can promote pilot projects the Federal Government is undertaking with the PEER program and expand the breadth of the program. Without direct financial incentives, the City can further modular facade retrofits by making the permitting process simple and straightforward.

- Incentivize deep retrofits by offering tax waivers, reduced fees, or permitting times. One way to help create a business case to conduct a deep retrofit is by offering reduced permitting fees to business owners, which can act as incentives for building owners who are contemplating renovations for other purposes. The City can also consider tax waivers for extra floor space added, such as mezzanines in large offices or industrial buildings, to further stimulate the retrofits.

- Prioritize financing options. As discussed in the "Financing and funding retrofits" section, the city and its partners have a small number of options to help finance retrofits. Local improvement charges (LICs) can be used to secure loans building improvements against the building asset, and not the owner to reduce financial risk. Further, The Ottawa community currently has the "Ottawa Sustainability Fund." This fund can prioritize the recommissioning or retrofitting of large buildings, starting with buildings greater than 18, 580 m^2, and are 35 years or older. This program could be further developed as a revolving loan fund for large buildings similar to Better Buildings Partnership in Toronto.[33]

- Target deep retrofits for organizations with multiple buildings. Organizations that have multiple buildings in their inventory such as universities, government, or military should be targeted to do campus-wide retrofits. The CaGBC suggests that greater efficiencies can be found with this approach, such as waste heat recycling and other forms of district energy.[34]

[33] For more information, see: https://www.toronto.ca/business-economy/business-operation-growth/green-your-business/better-buildings-partnership/
[34] IIESO. (2017). An examination of the opportunity for residential heat pumps in Ontario. Prepared for Ministry of Energy.

Appendix 1: Mapping of non-residential buildings from MPAC classifications to high level categories

bldgType	Municipal	Commercial	Retail	Warehouse	Education	Institution
college_university					100%	
school					100%	
retirement_or_nursing_home						100%
special_care_home						100%
hospital						100%
municipal_building	100%					
fire_station						100%
penal_institution						100%
police_station						100%
military_base_or_camp						100%
transit_terminal_or_station						100%
airport						100%
hotel_motel_inn						100%
greenhouse						
greenspace						100%
recreation						100%
community_centre						100%
golf_course						100%
museums_art_gallery						100%
retail			100%			
vehicle_and_heavy_equipment_service			100%			
warehouse_retail				100%		
restaurant			100%			
commercial_retail		50%	50%			
commercial		100%				
commercial_residential		100%				
retail_residential			100%			
warehouse_commercial		50%		50%		
warehouse				100%		
religious_institution						100%
energy_utility						100%

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