Pathway Study on New Non-Residential Buildings in Ottawa

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

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January 2019

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Executive Summary

This pathway study examines new non-residential buildings in the City of Ottawa. The non-residential sector includes institutional, commercial, industrial, and mixed-use buildings, and the buildings typically have large floor space, requiring more complex systems for space heating and cooling, lighting, or other processes related to commercial uses. The pathway will detail strategies for newly constructed non-residential to meet emissions reduction goals in the Ottawa's Energy Evolution Strategy.Buildings have a long life cycle of 40 to 80 years or more, which locks in building energy consumption patterns for decades. Ensuring that new buildings have low operational energy use is important for reducing future emissions. Emissions from new buildings is dependent on a variety of factors. Insulation, solar insolation and other aspects of urban form influence the energy required for building operation. Occupant density can also reduce energy use per capita from buildings.

Green building standards requiring new buildings to reach specified energy targets and include other sustainable design features such as green roofs and connections to district energy systems are a key tool for influencing energy efficiency in new buildings. The impacts of urban form on building energy use can be assessed on individual buildings, with flexibility provided to individual building designers.

This pathway considers three scenarios for new large buildings: conservative, moderate and aggressive. The conservative scenario represents a business as planned outlook, moderate reflects application of a Green Standard on a delayed time frame, while the aggressive scenario considers immediate uptake of a Green Standard. Each scenario achieves a different degree of emissions reductions.

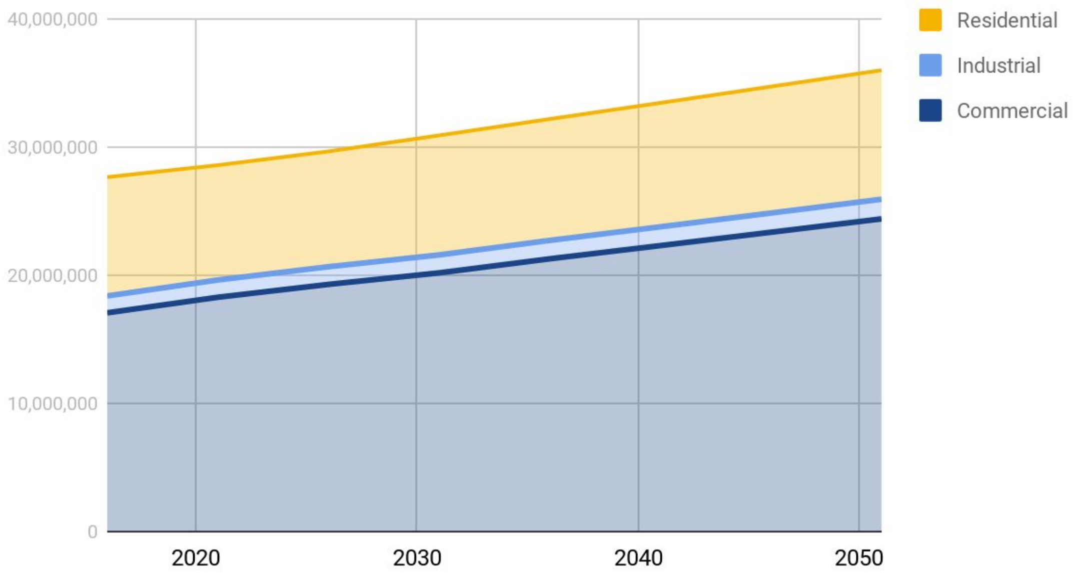
Section 1: Present Assessment of New Large Buildings

Pathway Description

Buildings lock in patterns of energy use and GHG emissions for many years due to their long life cycle. It is easier and more cost-effective to build a new zero energy building than it is to retrofit an existing building to achieve the high levels of energy performance that will enable deep GHG emissions reductions. In a context in which the entire building stock needs to be as close to net zero as possible, the more quickly new buildings can increase their performance, the lower the burden on society to undertake retrofits. Two leading jurisdictions, the City of Vancouver[1] and the City of Toronto,[2] have recently identified detailed pathways and policies to ensure new buildings achieve net zero emissions or energy. These two approaches provide the basis for a pathway for new non-residential buildings for the City of Ottawa.

Ottawa's population is set to grow by 372,877 people by 2051, accompanied by an estimated 8 million m² of new construction for residential and non-residential buildings by 2050, as illustrated in Figure 1.[3] The commercial sector is projected to lead new development through this time period.

Figure 1: Floor space of new large buildings between 2018 and 2050.



Buildings last 40 to 80 years or more. Ottawa's existing building stock will have a more significant impact on the overall trajectory of energy and GHG emissions than its new buildings over the next 32 years. Initial construction represents the most significant investment over the course of the building's life and is the primary opportunity to maximize energy efficiency through building and systems design.

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[1] City of Vancouver. (2016). Zero emissions building plan. Retrieved from https://vancouver.ca/files/cov/zero-emissions-building-plan.pdf
[2] Integral Group, Morrison Hershfield, & Provident. (2017). City of Toronto Zero Emissions Buildings Framework (p. 118).
[3] Population projections provided by the city of Ottawa towards 2031, and projected using CityInSight Modelling towards 2050.

Pathway Boundaries

This pathway identifies and contextualizes low carbon pathways for new non-residential buildings inclusive of institutional, commercial, mixed-use, and industrial buildings. Table 1 identifies the primary action reviewed in this paper and its influence on emissions in new large buildings, in the Ottawa context.

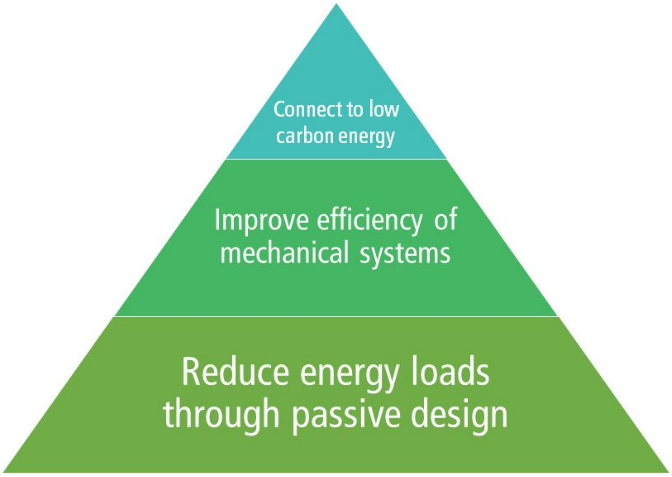
Table 1. Parameter and definition for new large buildings pathways study.

Parameter	Definition
Green Standard	Building design requirement structure that is tiered based on performance. The lowest tier is mandatory. Higher tiers are voluntary but are subject to reductions to development charges. A green standard becomes more rigorous over time.

There is increasing consensus around performance-based frameworks for new construction, which identify energy-use intensity and GHG intensity targets. This approach maintains flexibility for designers and adaptability to local contexts, whereas some certification building standards are highly prescriptive and lack a focus on energy and emissions performance. Performance-based pathways can incorporate the influences described below.

In designing for high performance, passive design strategies are essential in order to minimize costly mechanical systems and even more costly renewable energy technologies. Figure 2 illustrates the hierarchy of the design approach.

Figure 2: Hierarchy of building design principles.[4]



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[4] City of Toronto. (2017). The City of Toronto zero emissions buildings framework.

Urban form refers to individual building morphology and interaction with surrounding structures. It plays a role in building energy consumption in two key ways: heat transfer and solar access.[5] At the individual building scale, building morphology refers to characteristics such as: size and shape of a building, surface to volume ratio (S:V), plan depth, building height, and façade design characteristics (glazing ratios and distribution, building orientation, and envelope performance). At the block or neighbourhood scale, urban structure refers to the arrangement and spacing of buildings, streets, and open space, which include measures such as density (floor area ratio or FAR), land coverage, and spacing between buildings.

Assessing energy and emissions at the neighbourhood scale also captures the cumulative impact of the relationships between multiple buildings (building massing, heights, arrangements and spacing), and their impact on energy consumption. The impacts of urban form on energy at the neighbourhood scale are less frequently considered and have less developed methods available for modelling in comparison with those available at the individual building scale.

Other considerations include the embodied energy of buildings related to construction and component manufacturing, as well as the impact of the location of buildings. These considerations are not included in the modelling scope.

Background Information

Building Heating and Cooling

Heating and cooling energy density are a function of the characteristics and use of the built environment. While these characteristics represent design and planning decisions, they in turn are driven by the level of economic activity, fuel prices, climate and other variables.[6] The growing focus on the relationship between the built environment and energy demand is highlighted in Chapter 8 of the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report which explicitly recognizes the extent of urbanization anticipated and the idea that urbanization can itself be a greenhouse gas emissions mitigation strategy that integrates multiple sectors.[7] The IPCC chapter specifically references the urban form characteristics of density, land-use mix, connectivity, and accessibility as drivers of energy and GHG emissions. This section narrows to consider the factors influencing energy consumption associated with heating and cooling future buildings.

Data on energy consumption in buildings is currently measured by the utilities that provide energy to these buildings and is reflected in a utility bill. This data provides a reliable and accurate basis from which to understand the energy demands of the existing building stock and to model the energy demand of the future building stock.

Energy consumption in buildings is expressed using energy intensity factors, as GJ/m²/yr or eKWh/m²/yr. Figure 3 illustrates the factors that affect energy consumption in buildings; these are the factors that will influence the heating and cooling energy density.

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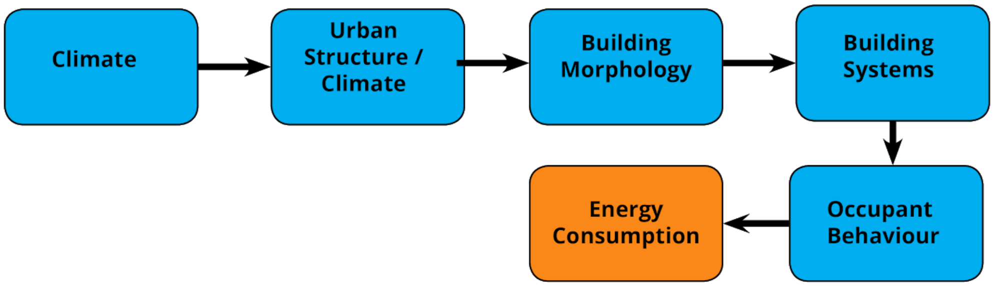
[5] Miller, N. (2013). Urban form and building energy: Quantifying relationships using a multi-scale approach. University of British Columbia, Vancouver.

[6] Creutzig, F., Baiocchi, G., Bierkandt, R., Pichler, P.-P., & Seto, K. C. (2015). Global typology of urban energy use and potentials for an urbanization mitigation wedge. *Proceedings of the National Academy of Sciences*, *112*(20), 6283–6288. https://doi.org/10.1073/pnas.1315545112

[7] Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G. C., Dewar, D., … others. (2014). Human settlements, infrastructure and spatial planning. Retrieved from http://pure.iiasa.ac.at/11114/

Figure 3: Factors influencing energy intensity in buildings. [8]



The Effect of Climate

Energy demand is climate and context specific, and any analysis of energy systems needs to consider *all* greenhouse gas emissions associated with the system. For example, buildings in warmer climates can have lower operational energy use due to the reduction in heating energy required. However, this does not necessarily imply that buildings in warmer climates use less energy overall, as warmer climates may result in increases in energy demand for mechanical cooling. The most common working fluids in mechanical cooling systems on the market today are hydrofluorocarbons (HFCs), which are greenhouse gases with a high global warming potential thousands of times more potent than carbon dioxide. The mechanical cooling load is also dependent upon building design and whether non-mechanical cooling methods, such as operable windows, are implemented. Therefore, climate has a significant impact on heating and cooling energy consumption, and the extent of this influence is determined by the way in which the built environment responds to the climate, through design, or the lack thereof.

In Ottawa, heating degree days (HDD) are projected to decline by 10% by 2050 over 2018, with cooling degree days (CDD) increasing by 60% over the same period (Figure 4). This has potential implications in heating and cooling requirements for buildings in Ottawa, with potential reductions in natural gas requirements for heating in the winter, and increasing electricity loads for cooling in the summer.

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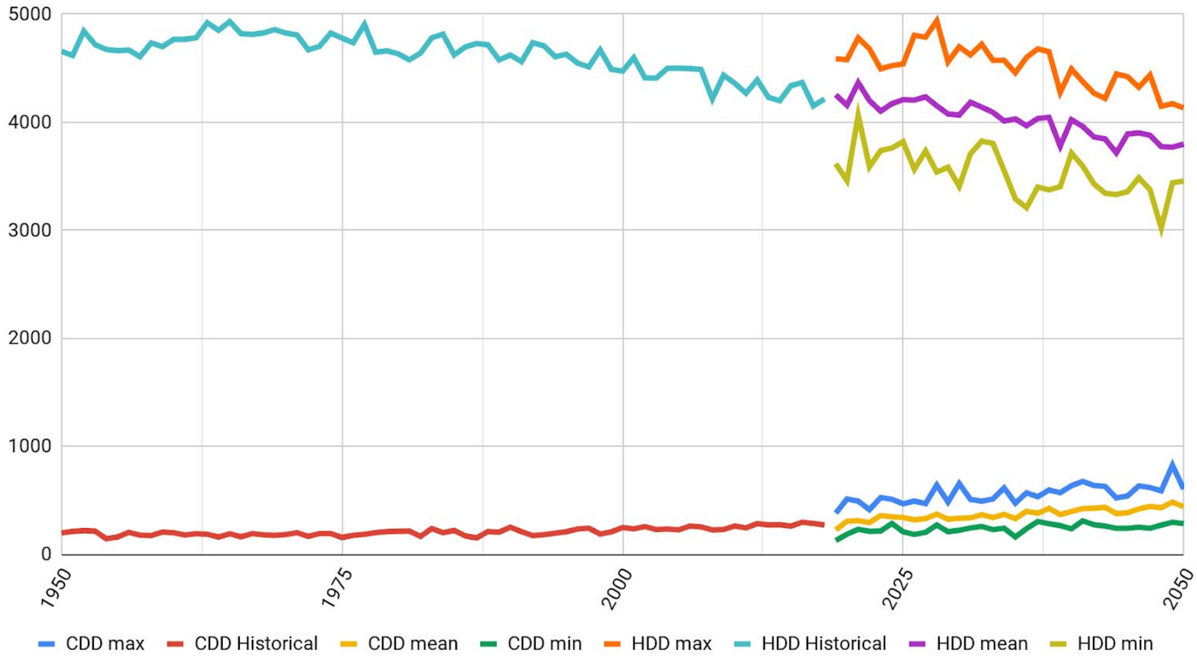
[8] Adapted from: Ratti, C., Baker, N., & Steemers, K. (2005). Energy consumption and urban texture. *Energy and Buildings*, *37*(7), 762–776; Salat, S. (2009). Energy loads, CO2 emissions and building stocks: morphologies, typologies, energy systems and behaviour. Building Research & Information, 37(5–6), 598–609; Miller, N. (2013). Urban form and building energy: Quantifying relationships using a multi-scale approach. University of British Columbia, Vancouver.

Figure 4: HDD and CDD projections for the City of Ottawa.[9]



Building Density

Density is a measure of the concentration of development (residential, commercial, industrial, etc.) per unit of land. Density is measured in a number of ways including people per hectare/acre, dwelling units per hectare/acre (for residential), and floor space ratio (FSR) or FAR. FSR and FAR are a measurement of the ratio of a building's floor area to the area of the lot on which the building is built.[10]

As density increases, total energy demand increases (i.e. the energy intensity factor is applied across a greater floor area). However, buildings typically consume less energy per capita or per area basis as density increases.[11] That is, energy intensity factors decrease as building density increases. Shared walls and floors/ceilings and shared building mechanical systems contribute to lower heating and cooling loads. Annual heating and cooling energy per square metre for apartments can be very similar to those for detached houses.[12] However, when comparing energy per person (by considering people per unit), the energy usage for apartments is significantly lower than for detached houses, as the occupancy per square meter is higher for apartments than for detached houses.

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

[10] Senbel, M, Church, S., Bett, E., Maghsoudi, R., & Zhang, K. (2010). The relationship between urban form & GHG emissions: A primer for decision makers. Urban Design Lab.

[11] Ratti, C., Baker, N., & Steemers, K. (2005). Energy consumption and urban texture. *Energy and Buildings*, *37*(7), 762–776. https://doi.org/10.1016/j.enbuild.2004.10.010

[12] Newton, P. W., Tucker, S. N., & Ambrose, M. D. (2000). Housing form, energy use and greenhouse gas emissions. Retrieved from http://researchbank.swinburne.edu.au/vital/access/manager/Repository/swin:8196

Compact urban form also contributes to improved health outcomes. In the past five to ten years there has been an explosion of literature on this relationship. Higher density is associated with higher levels of active transportation,[13] which in turn translates into improved health outcomes with respect to heart disease, type 2 diabetes, colon cancer, breast cancer, and mortality.[14]

Municipalities also provide services such fire as protection, policing, recreation, schools and transit, all of which are significantly impacted by the spatial distribution of buildings in a city. The City of Calgary found in an analysis of alternative growth scenarios that savings of 33% or $11 billion over 60 years could be achieved in operations and maintenance through compact growth.[15]

Building Envelopes

The building envelope (i.e. the physical separator between a conditioned indoor space and unconditioned outdoor space) and its performance have a significant impact on building energy consumption. As the majority of energy consumed in buildings is for space heating and cooling, heat transfer between interior and exterior space determines the level of energy required in a building to maintain comfortable levels of heating and cooling. Improving the thermal performance level of a dwelling can have a dramatic effect on its heating and cooling energy consumption. In general, energy use decreases as thermal performance increases. However, results also show that as envelope performance increases in certain cases, heating demand decreases while cooling demand increases.[16] This is in part due to other factors such as glazing ratio, building compactness and local shading, which are discussed further in this section.

Vertical Surface Area to Floor Area Ratio

A building's compactness refers to the surface-to-volume ratio of a building, or the ratio between total building surface area and total enclosed building volume. In general, as building density increases (and building height increases), more building volume is enclosed by building surface, resulting in a lower surface-to-volume ratio, and a more compact building. The predominant effect of compactness is reducing heat transfer, as more compact building shapes enclose more building volume with less surface area through which heat can escape. Analysis for the BC Step Code compared the energy performance of three buildings which were identical except for their shape, which was classified according to the vertical surface area to floor area ratio (VFAR). Figure 5 illustrates the VFAR for different configurations of buildings, while Figure 6 shows the impact of VFAR on energy performance for different Canadian cities. Energy performance is described by energy use intensity (EUI), a measure of energy per unit area, and by thermal energy demand intensity (TEDI), which describes thermal energy requirements for a building per unit area basis. Articulated and narrow building shapes result in a higher VFAR, which results in greater thermal energy loss through exterior walls and increases overall thermal energy demand.

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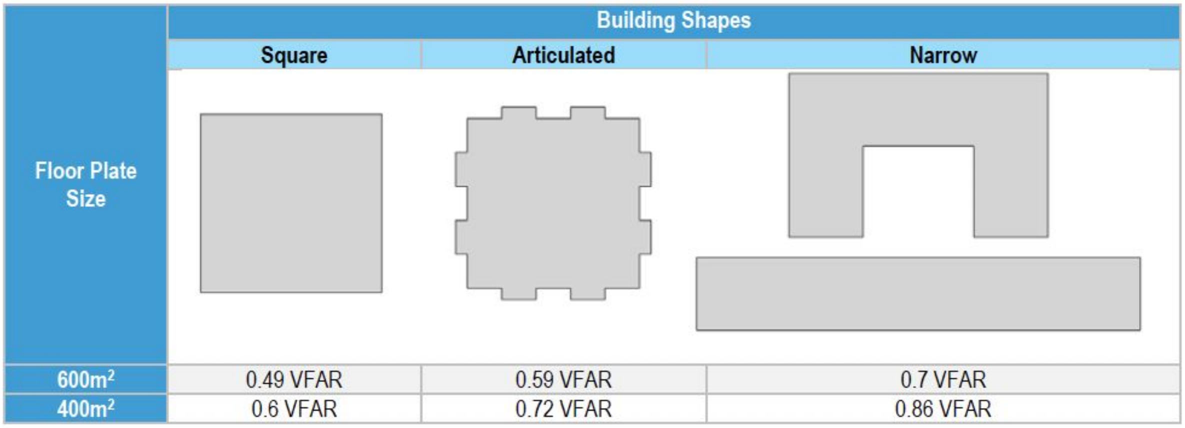
[13] Sallis, J. F., Cerin, E., Conway, T. L., Adams, M. A., Frank, L. D., Pratt, M., … Owen, N. (2016). Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. The Lancet, 387(10034), 2207–2217. https://doi.org/10.1016/S0140-6736(15)01284-2

[14] Hankey, S., Marshall, J. D., & Brauer, M. (2011). Health Impacts of the Built Environment: Within-Urban Variability in Physical Inactivity, Air Pollution, and Ischemic Heart Disease Mortality. Environmental Health Perspectives, 120(2), 247–253. https://doi.org/10.1289/ehp.1103806

[15] IBI Group. (2009). The implications of alternative growth patterns on infrastructure costs. City of Calgary.

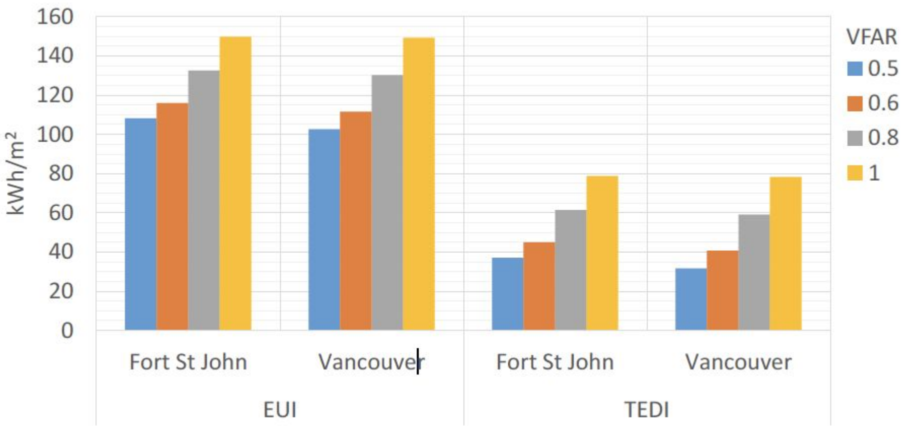
[16] Miller, N. (2013). Urban form and building energy: Quantifying relationships using a multi-scale approach. University of British Columbia, Vancouver.

Figure 5: Example of the influence of building shape on VFAR.[17]



Floor Plate Size	Building Shapes		
	Square	Articulated	Narrow
600m^2	0.49 VFAR	0.59 VFAR	0.7 VFAR
400m^2	0.6 VFAR	0.72 VFAR	0.86 VFAR

Figure 6: Example of the influence of the VFAR on EUI.[18]



Glazing Ratio

Glazing ratio is the ratio between total glazing area and total building area. Heat loss through glazed surfaces is higher than typical wall assemblies, and as such is a significant factor in overall envelope performance and building energy demand. In general, higher glazing ratios result in higher heating and cooling demand, counteracting much of the benefit of efficient surface-to-volume ratios. During cold weather, heating demand increases with increased glazing due to loss of heat through the less thermally resistive glazing components of the building envelope. However, increased glazing allows for passive solar heating opportunities, where heating demand is decreased as passive zones (areas adjacent to glazing) experience heat gain from sunlight. The loss of heat, however, generally outweighs passive heating effects during cold weather. In contrast, cooling demand primarily increases with increased glazing due to the increase in solar gains during warm weather. Buildings with excessive glazing ratios and untreated façades (symptomatic of high-rise buildings) make them particularly vulnerable to overheating during the summer and to heat losses during the winter.

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[17] Integral Group. (2017). Energy step code: 2017 metrics research. BC Housing.
[18] Ibid.

Building Orientation

A building's orientation, and the distribution of glazing, relative to the sun's position, also impacts a building's opportunities for passive heating. For space heating, glazing oriented to the east and south (for buildings in the northern hemisphere) provides the most useful gains. In comparison, western orientations provide solar gains late in the day when temperatures are at a maximum and buildings are already heated.[19]

Solar access is influenced primarily by building spacing and arrangements, which are dependent upon a number of urban pattern elements such as street widths, parcel size, building setbacks, building heights, and the distribution of open spaces. A measure of building spacing and arrangement is the urban horizon angle (UHA). The UHA is the average angle of elevation of surrounding buildings from the centre of a given façade and is affected by the height of and distance between structures. The UHA accounts for building shading and significantly affect solar access; particularly in the winter when the sun is lower in the sky.[20]

While any findings are context and climate specific, one analysis indicated that the UHA can affect heating energy demand by as much as 30%, cooling demand by 20%, and lighting demand by 150%, with the greatest impacts occurring for south-facing façades.[21] In general, higher-density development provides the benefit of reduced heating demand through more compact building shapes and more efficient use of floor area (e.g. smaller residential units). However, several key urban form factors tied to increased density also work against heating demand benefits, such as high glazing ratios, high-rise buildings with lower envelope performance requirements, and increased shading effects due to high UHAs. An analysis completed by SSG for Waterfront Toronto found that by reorienting the buildings in a neighbourhood, energy savings of nearly 20% could be achieved through additional solar gain, if the buildings were designed to be able to capture the solar energy.[22]

Focus on Thermal Energy Needs

The operational energy consumed in buildings is predominantly used in space heating and cooling, and in running appliances, including domestic hot water and lighting. Energy consumption changes for different building uses or activities. In general, residential dwellings are dominated by space heating, while commercial buildings have significantly larger requirements for space cooling and lighting. Commercial buildings also consume more energy per square metre than both residential and industrial buildings.[23]

Different building-use activities require different types of heating and cooling systems and equipment, lighting and hot water systems, with large variations in capacity and efficiency. In general, as systems and equipment efficiency decreases, energy demand increases. Also, buildings containing different activities do not use energy at the same rate and at the same time of day. In general, commercial and industrial uses consume more energy during working hours, whereas residential energy consumption peaks in the morning and evening, before and after regular working hours, respectively.

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[19] Baker, N., & Steemers, K. (2000). Energy and environment in architecture: A technical design guide. E & FN Spon.

[20] Ratti, C., Baker, N., & Steemers, K. (2005). Energy consumption and urban texture. *Energy and Buildings*, *37*(7), 762–776. https://doi.org/10.1016/j.enbuild.2004.10.010

[21] Steemers, K. (2003). Energy and the city: density, buildings and transport. Energy and Buildings, 35(1), 3–14. https://doi.org/10.1016/S0378-7788(02)00075-0

[22] SSG. (2016). Waterfront Toronto Villiers Island precinct plan climate positive assessment report.

[23] Doherty, M., Nakanishi, H., Bai, X., Meyers, J., & others. (2009). Relationships between form, morphology, density and energy in urban environments. GEA Background Paper. Retrieved from http://www.academia.edu/download/32180219/GEA_Energy_Density_Working_Paper_031009.pdf

Heat Island Effect

Many urban areas are subject to the urban heat island (UHI) effect. Increased densities are generally accompanied by increases in built materials and paved areas and decreases in natural land cover (e.g. vegetation and bare soil). These conditions exacerbate UHI, resulting in higher temperatures in denser city centres, which can lead to increased cooling demand.[24] Vegetation can play a significant role in regulating the urban microclimate through solar absorption and the cooling effects provided by shade and evapotranspiration. Interestingly, UHI effects may also reduce heating requirements in the winter.[25] In Ottawa, this can potentially equate to reduced heating requirements. Vegetation may therefore have more relevance to stormwater, noise and aesthetics over emissions reductions related to heat.

Occupant Behaviour

Occupant behaviour affects building energy use directly and indirectly through various activities including opening/closing windows, turning on/off or dimming lights, turning on/off equipment and electronics, turning on/off heating, ventilation and air-conditioning (HVAC) systems, and setting indoor thermal, acoustic and visual comfort criteria.[26] There are certain occupant characteristics and economic factors that can lead to increases in energy demand, such as increasing household income (related to larger residential homes and increasing area per person), uptake of more electronic and consumer goods due to declining prices, and, where applicable, low energy prices.[27]

Occupant behaviour is one of the most significant sources of uncertainty in the prediction of building energy use by simulation programs due to the complexity and inherent uncertainty of occupant behaviour. The effect can vary energy consumption by a factor of two between buildings, even among buildings with comparatively similar functions.[28] While some authors theorize that occupants could be more likely to adopt energy efficient behaviour if they live or work in an energy efficient building and are aware of its efficiency measures, others suggest that if occupants are aware that the building they occupy is very well insulated, they might feel less incentivized to monitor their heating consumption.[29]

Embodied Energy

In addition to the energy and GHG emissions that result from the operation of a building, there are also GHG emissions and energy use that occur as a result from building construction, known as embodied energy. Embodied energy can be further divided into three categories, namely, material manufacturing (including raw material acquisition, transportation and manufacturing), transportation to site and on-site construction. As building density increases and more square footage is constructed, more building materials are used, and the total embodied energy increases.

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[24] Doherty, M., Nakanishi, H., Bai, X., Meyers, J., & others. (2009). Relationships between form, morphology, density and energy in urban environments. GEA Background Paper. Retrieved from http://www.academia.edu/download/32180219/GEA_Energy_Density_Working_Paper_031009.pdf

[25] Sharlach, M. 92018). Cold wave reveals potential benefits of urban heat islands. Princeton University. Retrieved from: https://engineering.princeton.edu/news/2018/07/23/cold-wave-reveals-potential-benefits-urban-heat-islands

[26] Hong, T. (2014). Occupant behavior: impact on energy use of private offices. In ASim 2012-1st Asia conference of International Building Performance Simulation Association., Shanghai, China, 11/25/12-11/27/12. Retrieved from https://escholarship.org/uc/item/6jp5w8kn.pdf

[27] Gray, R., & Gleeson, B. (2007). Energy demands of urban living: what role for planning. In *Proceedings of 3rd National Conference on the State of Australian Cities*. Retrieved from http://soac.fbe.unsw.edu.au/2007/SOAC/energydemandsofurbanliving.pdf

[28] Ratti, C., Raydan, D., & Steemers, K. (2003). Building form and environmental performance: archetypes, analysis and an arid climate. Energy and Buildings, 35(1), 49–59.

[29] Salat, S. (2009). Energy loads, CO2 emissions and building stocks: morphologies, typologies, energy systems and behaviour. *Building Research & Information*, *37*(5–6), 598–609. https://doi.org/10.1080/09613210903162126

As building density increases, area per person tends to decrease, and embodied energy of built area decreases per capita.[30] It could similarly be argued that construction of a denser built environment could result in lower transportation and on-site construction energy per capita, as time and materials are focused at a centralized site over a shorter period of time, in comparison to decentralized low-density construction.

Building lifetime or durability is also important to consider. Initial embodied energy accounts for only the beginning of a building's life. The longer the building stands, the higher the benefit of that embodied energy over time. Over a 40 year life span, embodied energy can represent up to 15% of a buildings energy, while operational energy is closer to 75%.[31] At this time, embodied energy is beyond the modelling scope. As operational energy use declines with increasing deployment of net zero buildings, embodied energy will become an increasingly important contributor to emissions. Embodied energy is being increasingly considered in building policy, described in Table 2.

Table 2: Embodied energy and emissions policies in Canada.[32]

Policy	Requirement
Vancouver green buildings policy for rezoning	Developers seeking a rezoning application need to comply with one of two stringent sustainability requirements. One option includes requirement for whole-building embodied emissions reporting.
LEED™	The most recent version of the influential LEED Building Design and Construction (v4) green building rating system includes whole building LCA-optimization as a strategy for the first time. This includes meeting a 10% reduction in embodied emissions from a project-specific baseline.
Zero carbon building standard	The Canada Green Building Council (CaGBC)'s new zero carbon building standard includes a requirement to report embodied emissions.
Public Services & Procurement Canada	PSPC requires whole-building LCA for its new building projects, however it is unclear whether this requirement is typically followed.
Quebec's Wood Charter	Quebec requires a comparative analysis of GHG emissions for structural materials in provincially-funded new building projects.

Building Element Combinations

While increasing compactness and building density generally reduces heat loss, increasing these characteristics does not guarantee overall building energy reductions. The trend for increased glazing as building density increases can counteract some of the thermal performance benefits of more efficient surface-to-volume ratios and shared walls and floors, increasing energy demand. Minimizing heat losses during the winter requires minimization of the surface-to-volume ratio; but this implies a reduction of the building envelope exposed to the outside environment, thus reducing the availability of daylight and sunlight and increasing energy consumption for artificial lighting and mechanical ventilation.[33]

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[30] Stupka, R., & Kennedy, C. (2010). Impact of neighborhood density on building energy demand and potential supply via the urban metabolism. ACEE Summer Study on Energy Efficiency in Buildings, 239–252.bb

[31] Carpenter, S. (2010). How important is embodied energy? Building Magazine. Retrieved from: https://www.building.ca/features/how-important-is-embodied-energy

[32] Embodied carbon in construction: Policy primer for Ontario. (2017).

[33] Ratti, C., Raydan, D., & Steemers, K. (2003). Building form and environmental performance: archetypes, analysis and an arid climate. Energy and Buildings, 35(1), 49–59.

The relationships between compactness, building density and building energy are further complicated by differences between residential and commercial uses. For residential buildings, increasing building density from detached housing to apartments can reduce heating energy demand. However, such density increases typically require increased building depth, increased building height or reduced building spacing that limit access to passive heating and daylighting. In certain contexts, low-density residential design with high surface-to-volume ratios maximized for passive solar heating may provide greater opportunities than density for reduced energy demand. For commercial buildings, increasing the building depth of offices reduces the availability of natural ventilation and daylight, resulting in an anticipated increase in mechanical ventilation and artificial lighting. However, heat losses are likely to decrease as the surface-to-volume ratio decreases with increasing plan depths.

Arguments for and against density, balancing the need to reduce heat loss with the need for solar access (resulting in passive heating) are complex and affected not only by factors of building design and use, but also local context. At the block or neighbourhood scale, building energy consumption is influenced primarily by the shading of adjacent buildings, which limits solar access. This substantially reduces opportunities for passive solar heating and natural daylight, increasing overall heating and lighting demand. These same shading effects, however, also reduce overall cooling demand.

New Policy Measures

The introduction of new policy measures to increase the energy efficiency of new buildings as well as the adoption of voluntary standards such as Passive House will likely result in significantly lower energy density. Europe has been a leader in low energy building policies, through its Energy Performance of Buildings Directive, which requires member state countries have policies that require nearly zero energy buildings by 2020.[34]

Table 3: Requirements and standards driving towards net zero.[35]

Building Standard	Approach	Targets or requirements
Denmark BR10 Building Regulations 10	Mandatory	"Nearly Zero" required in Building Class 2020. Residential 20 kWh/m2/yr Non-Residential 25 kWh/m²/yr
Germany EnEV2009 Energy Savings Ordinance	Mandatory	By 2020 buildings should be operating without fossil fuel. 20% reduction in heat demand levels by 2020. 80% reduction of primary energy demand of buildings by 2050.
Norway TEK10	Mandatory	PassivHaus minimum requirement in 2015 Building Code. Zero-Energy Buildings by 2020.
France RT2012 Thermal Regulations	Mandatory	2020 all new buildings to be energy-positive.
England & Wales Part L Conservation of Fuel, UK	Mandatory	Residential buildings are net zero energy by 2016.
Seattle Target Performance Path - Seattle Energy Code	Mandatory	Total building energy use intensity of 40-65 kWh/m²/yr
Vancouver Building Bylaw	Mandatory	All new buildings zero emissions by 2030.
California Title 24 Part 6	Mandatory	All new homes and apartments required to be net zero by 2020.
Architecture 2030	Voluntary	Zero-Energy and Zero-Emissions Buildings by 2030.
Minergie	Voluntary (Switzerland and Europe)	Public/office/schools- 40 kWh/m²/yr (thermal) (requirements for other building types)
PassivHaus	Voluntary (Worldwide); Mandatory (Hanover)	120 kWh/m²/yr (total) and 15 kWh/m²/yr (thermal)

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[34] Vandevyvere, H., & Stremke, S. (2012). Urban Planning for a Renewable Energy Future: Methodological Challenges and Opportunities from a Design Perspective. Sustainability, 4(12), 1309–1328. https://doi.org/10.3390/su4061309

[35] Integral Group. (n.d.). Global best practices in energy efficiency policy, 110.

Evaluation of the Current Pathway

Low emissions buildings are becoming more prevalent. Canada Green Building Council recently awarded an office building in the ByWard market Canada's first zero carbon building certification.[36] The City of Ottawa has shown leadership through its Green Buildings Policy, with 23 municipally-owned LEED certified buildings. There are no large buildings in Ottawa that are certified Passive House.

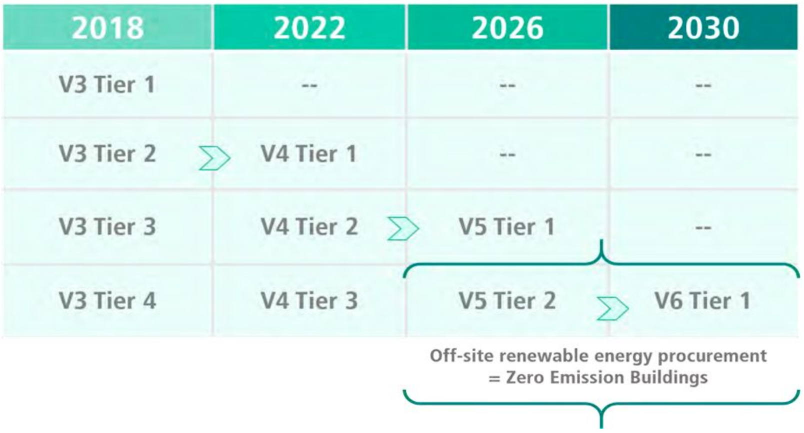
A critical tool in advancing low-carbon building policies for large buildings is through financial incentives for developers. A Green Standard consolidates building requirements with financial incentives for sustainable elements through a reduction in development charges.

The City of Toronto has invested considerable work in the development of the Toronto Green Standard with the objective of providing a transparent, incentive-based framework for increasing the energy performance of buildings towards net zero energy and emissions. Application of a Green Standard in Ottawa could be relevant because both Ottawa and Toronto have similar GHG reduction targets, both of which have a considerable portion of emissions resulting from buildings energy use. Both cities have relatively similar humid continental climates, and each face growth pressures for large buildings to encourage urban density. Application of an existing program tailored to Ottawa's specific context could be an important tool for the City.

All new planning applications, including zoning bylaw amendments, site plan approvals and draft plans of subdivision are required to meet Tier 1 of the Toronto Green Standard, while Tier 2 is voluntary. Those projects which achieve Tier 2 are eligible for a partial refund of development charges as an incentive to support early action and innovation.

The Green Standard includes a set of targets for the five most common building archetypes that achieve a near-zero emissions level of performance by the year 2030. While most buildings codes are prescriptive in describing specific components or assemblies, the Green Standard establishes intensities for energy performance, thermal demand and GHG emissions. Energy targets are performance based, which can provide greater flexibility to building designers,[37] and mitigate elements of energy loss in a building, based on the context of the individual building.

Figure 7: Stepwise introduction of the tiers to illustrate increasing mandatory performance.



2018	2022	2026	2030
V3 Tier 1	--	--	--
V3 Tier 2	V4 Tier 1	--	--
V3 Tier 3	V4 Tier 2	V5 Tier 1	--
V3 Tier 4	V4 Tier 3	V5 Tier 2	V6 Tier 1

Off-site renewable energy procurement
= Zero Emission Buildings

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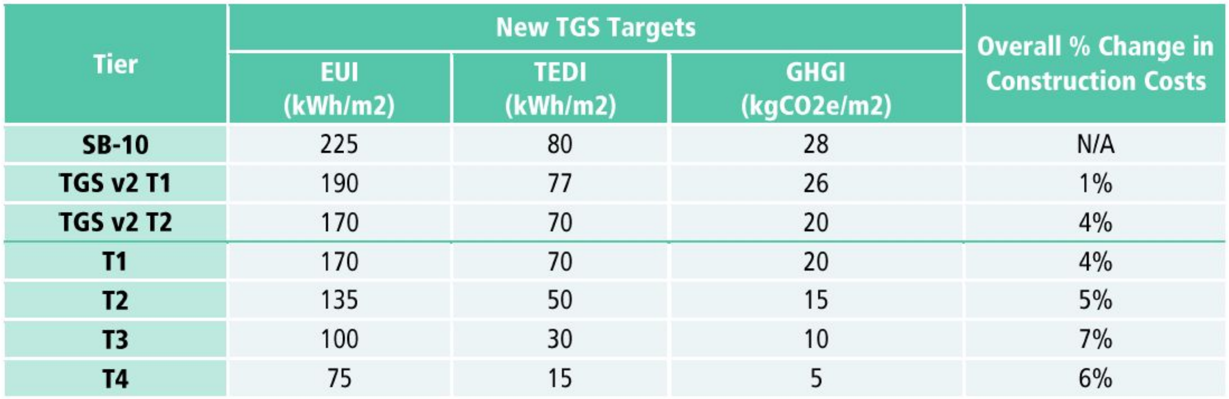
[36] Building. (June 13, 2018). CaGBC give Ottawa project 'Zero Carbon Building - Performance' Certification. Retrieved from: https://www.building.ca/cagbc-gives-ottawa-project-zero-carbon-building-performance-certification/

[37] NRCan. Canada's national energy code. Retrieved from: https://www.nrcan.gc.ca/energy/efficiency/buildings/20675

Figure 8: TGS targets for high rise multi-unit residential buildings.



Tier	New TGS Targets			Overall % Change in Construction Costs
	EUI (kWh/m2)	TEDI (kWh/m2)	GHGI (kgCO2e/m2)	
SB-10	225	80	28	N/A
TGS v2 T1	190	77	26	1%
TGS v2 T2	170	70	20	4%
T1	170	70	20	4%
T2	135	50	15	5%
T3	100	30	10	7%
T4	75	15	5	6%

In addition to the performance standards, TGS also has a series of mandatory requirements, including air tightness testing to validate energy modelling, building commissioning submetering, energy benchmarking and reporting and a climate resilience checklist. An optional requirement is to provide 5% of the total energy using on-site renewable energy sources, where renewable energy is defined as photovoltaics, solar thermal systems, biogas, wind or geoexchange.

A financial analysis of the impact of TGS found that the construction costs increased by between 1% and 7% as a result of the performance requirements of TGS. When lifecycle costs were considered, the investments resulted in a positive present value of savings.[38]

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[38] City of Toronto. (2017). Zero Emissions Building Framework.

Section 2: Growth Projections for New Non-Residential Buildings

Implementing a green standard in Ottawa represents a viable path for emissions reductions in new non-residential buildings. A green standard is a blanket policy tool that uses performance based compliance targets. Therefore, the influences on building energy use, as described above, are not explicitly modelled in this pathway because performance based pathways provide flexibility in the development of individual buildings.

The parameters below represent three pathways for emissions reduction in new large buildings. Three scenarios have been modelled: conservative, moderate and aggressive uptake of actions. The scenarios are described in Table 4.

Table 4. Low carbon pathway actions and parameters.

Action	Conservative	Moderate	Aggressive
New commercial	Building energy intensity levels held constant (2016)	Implement a Green Standard, delayed by five years in relation to Toronto's timeline	Implement a Green Standard in alignment with Toronto's timeline

Methodology

Energy modelling undertaken for this study is based on the following approaches and assumptions:

1. Identifying future population projections: future population by zone for 2023 and 2031 was provided by the City. Linear extrapolation was used to estimate population to 2050.

2. Assigning the population to dwellings, some of which will be apartments: Using MPAC data, population is assigned to dwellings based on historical people per dwelling ratios, which are carried forward. This calculation determines the number of projected dwellings.

3. Assigning the population to employment types: the working age population is allocated to employment sectors according to the historical mix of employment types. Existing employment projections informed the allocation of population to employment sectors.

4. Translating the employment into buildings: the ratio of jobs per floor area for each sector was calculated based on the calibrated year.

5. Reflecting trends of declining office space per employee and an increased mix of apartments: the 2016 ratio for employees per year and people per household were adjusted according to historical or projected trends. The mix of dwelling types can also be adjusted, either to align with the mix in the zone where they will be allocated or according to trends or projections.

6. Specifying the location of the buildings, as determined by current land-use plans: new buildings to accommodate population and employment projections were allocated to zones according to the Official Plan.

7. Setting EUI targets for new buildings based on TGS, according to the time period that each Tier of TGS will become mandatory. The energy performance (energy use intensity) targets were applied to buildings as they are added to the building stock.

8. Adjusting the building design and end uses to meet the energy performance targets: the performance of equipment and thermal envelope for new construction will be adjusted to achieve the energy performance targets.

9. Adjusting the energy system of the buildings: those buildings which are located in areas with sufficient energy density will be connected to district energy. Geothermal or heat pumps will be incorporated to the remaining buildings. Finally, solar PV will be added to the roofs of new construction according to a predetermined schedule.

Constraints

The primary legal constraint is that municipalities cannot directly require energy performance in buildings beyond the building code in Ontario. In BC, municipalities can select to apply different levels of a stretch code as a way to drive performance, but this option is not yet available in Ontario. This means that Ottawa cannot require new builds to meet a certain level of energy performance. The City of Toronto uses the planning approvals process, site control and rezoning agreements between city and developers as the mechanism to require increased energy performance.

Municipalities in Ontario have the same legislative authority to require sustainable performance measures found in the TGS under section 41 of the Planning Act. These powers can only be implemented if both the Official Plan and a Site Plan Control Bylaw contain relevant provisions. Ottawa has not yet included provisions in its Official Plan to enable such agreements and must therefore include provisions for sustainable design elements in the Official Plan prior to developing a Green Standard.

While designers can specify the thermal performance of buildings, it is more challenging to definitively influence the behaviour of building occupants. Various strategies have been proposed to address behavioural occupants including energy ambassadors, real time energy monitors and sophisticated building control systems. The energy performance of equipment is regulated federally and is not within the City's sphere of influence.

Expertise and capacity are likely barriers; few architects and engineers are experienced in net zero energy and emissions design, although this is changing due to requirements in Vancouver and Ontario and the rest of the world.

Buildings are already being constructed to net zero energy and emissions in Canada and elsewhere, so there are no technological or design limits to achieving this level of performance. However, net zero buildings are new, and are still associated with higher costs than conventional buildings. While net zero energy and emissions projects are likely to have a positive net present value over their lifetime, in most cases the entity that constructs the building is not the entity that will receive the operational savings. Incremental investments must therefore be justified based on the ability of the building to attract increased rents or supported by incentives and other financing strategies. The TGS is supported by an incentive program that helps address the incremental costs. Another strategy is to use a Property Assessed Clean Energy program to provide the incremental upfront capital and apply future payments to the building occupants commensurate with the energy savings. Recent Ontario legislation allowed program structures through local improvement charges.

Uptake projections

The results of each of the three uptake scenarios is presented in Table 5, as evaluated against the Business as Planned (BAP) scenario. Note that the conservative projection, which holds energy consumption constant, results in an increase in GHG emissions and energy consumption in comparison to the BAP scenario. In the BAP scenario, new buildings experience a 10% improvement in energy efficiency every year as a result of enhanced building codes.

Table 5: Results of the uptake projections.

Scenario	Parameter	Cumulative emissions reductions 2018-2050 (kt CO2eq)	Emissions reductions 2050 (kt CO2eq)	Cumulative energy reductions 2018-2050 (TJ)	Energy reductions 2050 (TJ)
Conservative	Building energy intensity levels held constant (2016)	-1,554 (emissions gain)	-107 (emissions gain)	-39,330 (energy use gain)	-2,813 (energy use gain)
Moderate	Implement a Green Standard, delayed by five years in relation to Toronto's timeline	190	11	2,423	274
Aggressive	Implement a Green Standard in accordance with Toronto's timeline	1,834	74	43,503	1,890

Ways to advance this pathway

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

1. In order to implement a Green Standard under current municipal and provincial regulatory environment, Ottawa will need to amend its Official Plan to include sustainable provisions under site plan control, subdivision and other planning processes.
2. Financing tied to the building asset could be used to offset capital costs of new efficient buildings, although it is more likely it will be used instead for existing building retrofits.
3. The City has made strides in the energy efficiency of its own building inventory, through the passing of its Green Buildings Policy that informs the sustainability of municipal buildings and through its programs under the Building Engineering and Energy Management section. Multiple city buildings are LEED certified. The City could require even further stringent new building policies, such as a requirement for new municipally owned buildings to be Zero Carbon or Passive House certified.
4. On large development proposals with multiple buildings, encourage designs that maximize passive solar gain, maximize potential for on-site renewable energy, or reach higher targets for building performance such as Zero Carbon or Passive House.
5. Finally, provide awareness on the benefits of zero emission buildings. The community could develop a clearinghouse of information on green buildings and provide awareness through information campaigns and through its ongoing relationships with the building and construction industry. There could also be training and workshops for zero emissions building construction principles. Building benchmarking programs, while more applicable to existing buildings, can highlight the costs of energy loss in inefficient buildings. This can indirectly incentivize the construction of zero emission buildings.