Switching Lanes

The potential of laneway housing in reducing greenhouse gas emissions in Toronto, Canada

Will Baigent

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A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science (30hp/credits)

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Abstract:

Conflicting dynamics are taking place in urban areas. Global climate change has necessitated that cities drastically reduce their greenhouse gas emissions while still accommodating rising urban populations. Innovative solutions are needed to remedy this complex problem. This thesis assesses the use of laneway housing as a tool for alleviating these issues. Four main research questions are posed that aim to address the prevalence of the use of laneway housing by cities as a resource for sustainable development and the potential it can have over time in reducing urban emissions in the building and transportation sectors in Toronto, Canada. A variety of quantitative methods are utilized to answer these questions, including text analysis of Canadian municipal documents, geospatial analysis of the potential spaces for this housing development, and projections of the potential emission reductions across multiple constructed scenarios when compared to 1990 levels. It was found that the linkage between laneway housing and sustainable development is underdeveloped in municipal documents. The geospatial analysis concluded that over 36,000 properties are eligible to build laneway housing, and an additional 11,875 could become eligible with future changes to municipal by-laws. It can also be concluded that the stock of potential laneway houses can satisfy future low-rise residential building levels while also reducing transportation and building emissions from this subsector of housing. The findings of this thesis support the increasing interest in laneway housing development in Toronto. Laneway housing has promising potential in helping to accommodate steadily rising urban populations while lowering the impact these new residents will have on greenhouse gas emissions in the building and transportation sectors. Further research is needed to see how these findings can aid similar types of development in other cities.

Keywords: laneway housing, emission reductions, urban densification, population growth, urban sustainable development, GIS

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Two years ago, I made the decision to start a master's degree in a subject and country both of which I knew next to nothing about. At the time it had the potential to be one of the worst decisions I had ever made. However, the classmates I have met here have made it one of the best. I was able to be a part of a group that few can say they ever found in their lives. The opportunity to learn and laugh with you all every single day has been incredible to say the very least. To the LUMES family, the biggest thank you for an unforgettable two years.

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1. Introduction

Urban spaces are currently taking centre stage in the pursuit of realizing both the short- and long-term well-being of the planet and the people inhabiting it. The populations of urban areas have seen a steady rise in recent decades. In 1950, 751 million people (30% of the global population) lived in urban areas. This number climbed to 4.2 billion (55%) in 2018 and is projected to rise to 6.5 billion by 2050 at which point it will amount to two-thirds of the global population (Elmqvist et al., 2018; United Nations, 2018; Intergovernmental Panel on Climate Change, 2014). Various reasons can help explain this large-scale movement. Urban areas offer a greater abundance of opportunities for education, employment and higher salaries and thus the possibility of increased well-being for those living in cities (Alvarez-Cuadrado & Poshke, 2011; Lucas, 2004). However, this trend has also resulted in urban areas becoming an alarming area of concern in the context of energy use and carbon emissions.

Urban areas are gaining notoriety for their alarming levels of energy usage and emissions. Cities are estimated to be responsible for the consumption of over 66% of the world's energy while also accounting for greater than 70% of the globe's CO_2 emissions (C40, 2019). Part of this can be attributed to changes in the infrastructural layout of these cities as they attempt to accommodate the influx of people. The demands for space from the billowing populations has necessitated that urban spaces increase greatly in size. Urban areas are projected to triple in global total land cover between 2000 and 2030 (Seto, Guneralp & Hutyra, 2012). The need to expand urban land cover to create buildings that provide housing and jobs has a number of negative environmental impacts including biodiversity loss, air pollution, loss of green spaces, and stormwater runoff (Concepción, Moretti, Altermatt, Nobis, & Obrist, 2015; Angel et al., 2016; AlAwadhi & Scholl, 2013). Urban sprawl also results in an increased need for vehicular travel and fuel consumption (Brownstone & Golob, 2009). The process of urban sprawl and land use change are only a couple aspects of the consequences of growing cities. Another warranting great concern is the environmental impacts of the buildings being erected.

Buildings account for over 33% of global energy consumption (60% from urban areas), more than 55% of global electricity demand and approximately 40% of the world's CO_2 emissions (IPCC, 2018; International Energy Agency, 2018). These numbers are expected to rise as energy demands in the building sector are projected to increase by 30% in the next 40 years. Meanwhile, the global building stock will need to reduce its CO_2 emissions by 80-90% from 2010 levels by the year 2050 in order to align itself with the 1.5-degree global warming pathway outlined by the Intergovernmental Panel on

Climate Change (IPCC, 2014). The strategies undertaken to accommodate increasing urban populations are particularly important as built infrastructure has long shelf lives. This makes buildings susceptible to energy and emissions lock-in (IPCC, 2014). The subsequent retrofitting of a building is a solution to increase its energy efficiency and reduce the emissions it produces, however, it has drawbacks in that it is financially costly and represents a missed opportunity for energy and emission savings in the preceding years of the building's life cycle.

In North America, laneway housing is one solution that has gained traction as a remedy to the problems of urban sprawl, and increased demand for housing in cities (Soules, 2014). Laneway housing is a term used for dwellings built at the back of a residential lot that are adjacent to laneways (see Figure 1). These buildings are detached from the main house and have their own cooking and cleaning amenities as well as their own front entrance on the laneway side rather than the main street. These secondary suites can then be used to accommodate additional residents on the property, and thereby provide additional housing opportunities in cities that struggle to accommodate increasing populations while also providing secondary income to the primary homeowner.

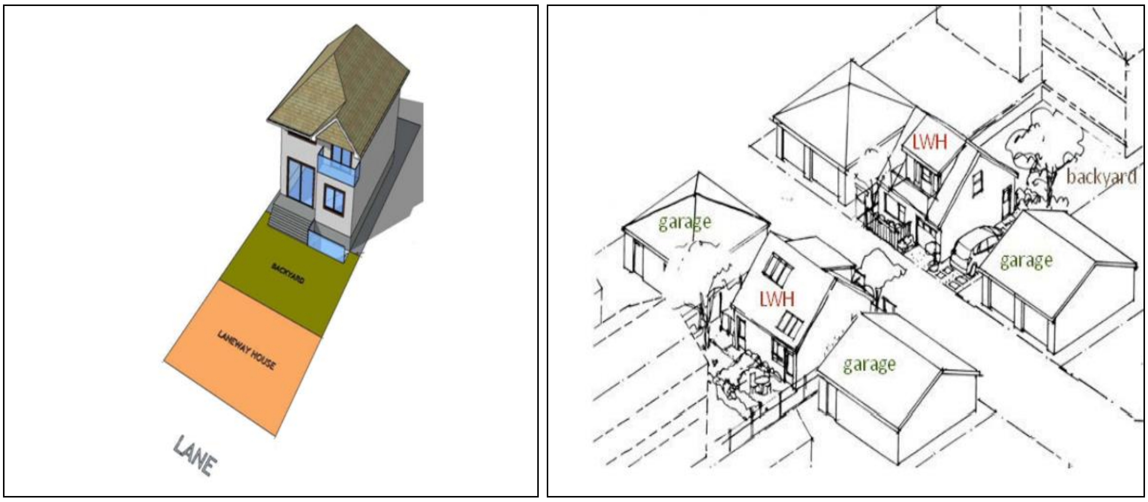

Figure 1. Diagrammed depictions of laneway housing (LWH). These homes can be accessed via the rear laneway in the same way a backyard garage would be. Adapted from City of Vancouver (2018).

There are many variations of, and concepts related to, laneway housing (Appendix A). Similar housing solutions have been created elsewhere such as in the form of "mews" in the UK and "granny flats" in Australia. Within North America, Vancouver is seen as a leader in the field frequently issuing many more building permits for laneway houses than in other cities (Koones, 2019). However, laneway houses are banned in many cities or are inhibited by municipal by-laws that place restrictions on their size and occupancy (Kirk, 2018).

Toronto, Canada, is one city in which the concept of laneway housing is deeply ingrained in the discussion around housing solutions as the city has just recently made changes to their by-laws regarding this form of development (City of Toronto, 2018a). Toronto also finds itself embracing the approach of finding innovative ways to lower its greenhouse gas emissions in order to reach its self-determined 2030 and 2050 climate goals while still accommodating large increases in the city's population (City of Toronto, 2017a). These conditions make Toronto an excellent choice as a case study for investigating the potential of laneway housing in reducing urban greenhouse gas emissions.

Numerous barriers exist to the building of laneway housing especially in Toronto. This thesis poses four main research questions to investigate the disconnect between laneway housing and sustainable development, and the potential of this form of housing to reduce greenhouse gas emissions.

1.1 Research Questions

A number of dissertations have been published on the topic of laneway housing within Canada. However, their scope has focussed on their importance to matters of affordable housing and urban density, the legal and practical barriers they face, the physical characteristics of the laneways that house them, and their relation to parking policies rather than their link to sustainable development (Terpstra, 2012; Cubitt, 2008; Whitehead, 2014; Thumm, 2015). In addition, academic literature linking laneway housing, or other secondary suites, to sustainable development also appears to be widely missing. This section will outline the research questions posed in this thesis and the motivations for asking them. For an overview of the research questions and subtopics covered in this thesis see Table 1.

Table 1. Overview of research questions and subtopics.

Research Question	Subtopic
1. How extensive is the linkage between sustainable development and secondary housing in Canadian municipal documents?	1.1 Prevalence in municipal documents
2. What is the potential capacity of laneway housing to meet the City of Toronto's housing needs?	2.1 Number of properties eligible to build laneway housing
	2.2 Number of properties to be built in upcoming years
3. What is the potential capacity of laneway housing to reduce emissions in the City of Toronto?	3.1 Transportation-related emissions
	3.2 Building-related emissions
4. To what extent can the stock of potential laneway housing fluctuate over time?	4.1 Proportion of potential laneway houses built
	4.2 Properties ineligible for laneway housing

1.1.1 RQ1: How extensive is the linkage between sustainable development and secondary housing in Canadian municipal documents?

Research has previously been conducted on the topic of laneway housing within Canada. However, in many cases an argument was made that laneway housing is an important addition to municipal spaces based on its ability to increase the affordability and diversity of a city's housing stock. Scholarly research has tended to focus on the on the supply side of laneway housing and secondary suites, and the role of current housing market conditions (Goodbrand & Hiller, 2018). More specifically, their promotion is seen as a way to help homeowners and landlords create additional revenue streams. Commonly, the linkage between this form of housing being able to help a city achieve its sustainability goals is absent. Therefore, it is important to determine if municipalities themselves are making this linkage or are instead squandering a pathway in which they can reduce emissions.

1.1.2 RQ2: What is the potential capacity of laneway housing to meet the City of Toronto's housing needs?

Laneway housing is a niche form of secondary housing that will not be able to completely satisfy the housing requirements of a rapidly growing city such as Toronto. However, it is then imperative to evaluate to what extent laneway housing can aid in satisfying the city's housing requirements. This then requires two questions to be answered. First, what is the total number of properties eligible to construct a laneway suite? Or, in other words, how many laneway homes can be built? Second, how many residential buildings are expected to be built in the coming years and could laneway suites accommodate this addition? 2030 is used as a future reference point due to it having been chosen by the City of Toronto as a target year by which to have substantially reduced their emissions compared to 1990 levels by 65 percent (City of Toronto, 2017a).

As cities grow, so too do the options of the physical types of housing available. Toronto is in the midst of a condominium boom with the number of condo units being developed in the city reaching record numbers (Dingman, 2018). Mid to high rise buildings such as condominiums and lofts will play a huge role in accommodating the city's increasing population. However, mid and high-rises, defined as being buildings of 4 or more stories (Freedman, 2009), have very different energy usage characteristics and demands from low-rise rise residential buildings. In a review of literature on the topic, Touchie, Binkley and Pressnail (2013) found that some of this can be explained by obvious factors such as the ownership structure, height, size, and floorspace of high-rise buildings as well as the heating system and degree to which the building is only used for residential accommodation. Therefore, it is problematic to compare compact laneway homes to units found in mid, and high-rise buildings, thus low-rise residential buildings will be the specific focus of this study.

1.1.3 RQ3: What is the potential capacity of laneway housing to reduce emissions in the City of Toronto?

Laneway housing has the potential to cut Toronto's emissions in two large sectors, transportation and buildings. This is especially important as these two sectors account for 80% of the city's greenhouse gas emissions as calculated for 2016 (Figure 2, City of Toronto, 2019a). Within emissions from transportation, 80% of this is attributed to personal vehicle usage . Therefore, personal vehicle use accounts for 28% of Toronto's total GHG emissions. Meanwhile, buildings make up the largest portion of Toronto's emissions at 45%. As these two sectors represent the biggest culprits for emissions it stands to reason that potential solutions for reducing their footprint should be investigated. Laneway housing has the ability to cut the emissions from newly constructed low-rise residential buildings of both sectors in Toronto. However, previous research on the extent of these reductions has yet to be carried out thus warranting the following question be asked. What is the potential capacity of laneway housing to reduce emissions in Toronto? This question will be answered in terms of looking at this potential with regards to transportation-related and building-related savings.

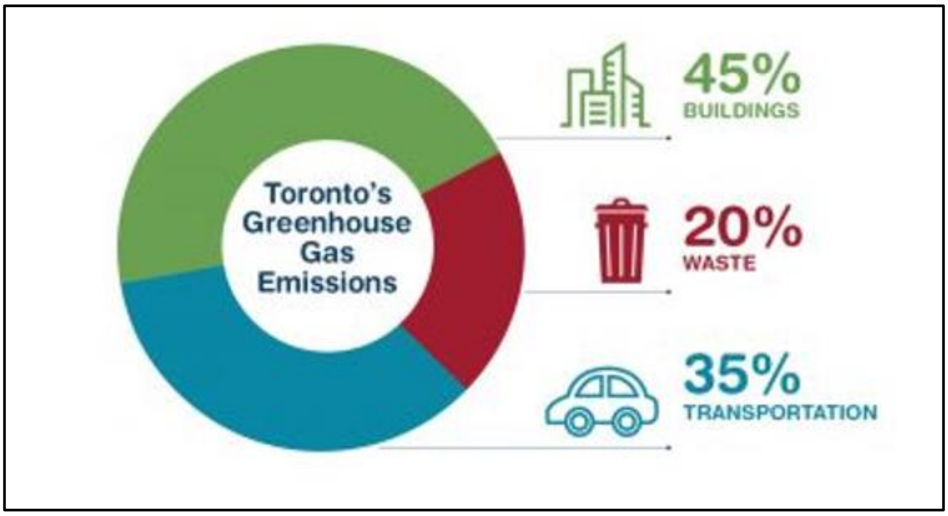

Figure 2. The City of Toronto's greenhouse gas emissions by sector (2016). Image from City of Toronto (2019a).

1.1.4 Research Question 4: To what extent can the stock of potential laneway housing fluctuate over time?

The municipality-imposed barriers to laneway housing development have been previously outlined. The major barriers addressed in previous research questions have revolved around the requirements that laneway housing only be built in the Toronto and East York community council and that primary homes have at least one wall that is detached so as to allow for emergency access to the laneway house. These requirements will lower the number of properties that are eligible for this type of housing development. This in turn will affect the level of impact laneway housing can have in lowering emissions from newly built low-rise residential housing. Therefore, multiple factors warrant investigation. First, under the multiple chosen scenarios, how long will the potential stock of laneway housing last? Next, what number of properties could be potentially added to the stock by removing the largest spatial barriers for laneway housing?

1.2 Situating the research within sustainability science

This thesis aims to stay in line with the overarching principles and objectives of sustainability science. In particular, the research questions and methods have been structured so as to seek 'creative solutions' to sustainability issues, a main characteristic of sustainability science (Jerneck et al., 2011). In doing so, this thesis has attempted to incorporate both the natural and social sciences in investigating the particular analyzed solution. The need to find innovative solutions to lower greenhouse gas emissions is pursued while still taking into consideration the wider societal effects a new solution could have. Once again, this is a characteristic of sustainability science which has been described as a "vibrant arena" incorporating these many disciplines (Clark & Dickson, 2003). From a natural science perspective, an exploration of greenhouse gas emissions reducing solutions was present. Meanwhile, the social science requirements have been satisfied in analyzing public perception of this type of development and the barriers in the economic, social, and political spheres to the development of laneway housing. Lastly, sustainability science aims to analyze all related impacts to new proposed solutions, both positive and negative. Special attention has been paid to this within the discussion section.

2. Background

This section of the thesis will provide an overview of the geography, climate and socioeconomic conditions of the City of Toronto and its policies as they apply to laneway housing.

2.1 Overview of study site: Toronto, Canada

Toronto is a large sprawling metropolis with a population just under 3 million, making it the largest city in Canada and the fourth largest in North America (City of Toronto, 2019b). There are an additional 3.5 million people in the city's surrounding regions. Attributing to the large population are Toronto's numerous employment opportunities across multiple sectors. The city is Canada's financial capital, while also being home to several industrial operations, media and tech companies, and acting as an advantageous location for start-ups. The city's GDP is $168 billion, and the average household income is just under $100,000 CAD (City of Toronto, 2019b).

Toronto's climate can be described as continental (National Geographic, 2018). Average daily temperatures drop as low as -3.7 °C in January and reach as high as 22.3 °C in July (Government of Canada, 2018a). However, in the winter, temperatures can dip below -25 °C while rising to over 30°C in the summer (City of Toronto, 2019b). Therefore, residential homes are exposed to a high variance in climatic conditions and must often employ both cooling and warming systems.

2.1.1 Changing population and emissions

In line with the global trend in cities, Toronto is expected to see swift population growth in the coming decades. Within the Province of Ontario, the Toronto area is projected to be the fastest growing region. Toronto's population is expected to rise by 33.5% to 3.91 million in the next two decades (Ontario Ministry of Finance, 2018).

Yet, as the city grows it also looks to shrink, with regards to its carbon footprint. In 2017, Toronto City Council unanimously passed the 'TransformTO' climate plan (Cruickshank, 2017). The action strategy outlines the goals and strategies for reducing greenhouse gas emissions in the city in the coming decades. Specifically, the plan sets reduction levels of 65% by 2030 and 80% by 2050 in relation to 1990 (City of Toronto, 2017a).

Results of a detailed, city-wide, greenhouse gas emission inventory for 2016 were prepared by Toronto in preparation for its climate action plan. The building sector accounts for the largest portion of the city's emissions at 45% followed by the transportation sector at 35%, of which 80% is directly attributable to private vehicle usage. The City of Toronto finds itself at a difficult crossroads. The city must find a solution to accommodating an increasing population while lowering emissions from sectors that will only be exacerbated by the increase in the number of people living in the city.

2.1.2 Policies regarding laneway housing and building development

The City of Toronto has allowed for the building of laneway homes since 2000 although, until just recently, the city did not have a detailed plan of their rules and regulations regarding them. The city's decision to look more closely into the issue stemmed from their goal of promoting the creation of secondary units and the success other Canadian municipalities, such as Vancouver, have had with this form of housing. This culminated in Toronto publishing a staff report in 2018 detailing their by-laws relevant to laneway housing and their plan for the form of housing moving forward (City of Toronto, 2018a).

Toronto has several stipulations regarding the development of laneway housing which can act as a limiting factor for their development. An exact estimate on the number of laneway houses in the city is unknown. However, some have estimated the total to be in the "dozens" (Lanescape & Evergreen, 2017). Currently, they are 1) only permitted to be built in one of the city's four 'community council areas', 'Toronto and East York' (see Figure 3). This roughly 100 km^2 area encompasses the city's downtown core, and much of its higher density, low-rise residential neighbourhoods. 2) The property must also have a detached wall to allow for emergency access, or in the case of properties with two attached walls, be located in close proximity to the entranceway of a laneway. Toronto also has requirements for the form and size of the laneway house as 3) it cannot be built higher than two storeys and must be smaller than the primary property while leaving enough room for the required amount of landscaped space between the two buildings. Some homeowners have been able to navigate all these requirements in the past and well-known examples of laneway houses do exist in Toronto (see Figure 4). The city is also using this form of housing to promote its goal of developing strategies that reduce dependency on private vehicles as, unlike with other forms of new homes, parking space permits will not be required to be allotted to newly constructed laneway houses.

City of Toronto policies outline two factors that were chosen in this thesis as being key to laneway housing potentially being able to have lower emissions compared to other forms of newly built low-rise residential housing. The first is with regards to private vehicle usage. The City of Toronto has specified that new laneway suites will not be automatically granted parking spaces in a measure to reduce the strain on residential street parking and to encourage the use of public and self-reliant transportation (City of Toronto, 2018a). Whether or not residents would feel the need to own a car and make alternative arrangements for parking is unknown. However, the fact that laneway suites are currently only permitted in the central Toronto and East York community council districts creates a closer proximity to shops, schools, and places of work and makes it very plausible to get by without a car.

The second factor relates to the emissions from the physical home. The Toronto Green Standard is a set of building performance measures designed by the city to help ensure new developments aid in reaching the city’s climate goals. The most recent edition of the system, number III, has four tiers (City of Toronto, 2017b). The first tier is mandatory whereas levels two to four are voluntary. It is however estimated that permit applications will have a much higher probability of being approved if they meet tier 2 standards. Tier 1 and 2 standards have different requirements when it comes to energy efficiency and performance. Unlike tier 1, tier 2 requires that new residential buildings are constructed to be in line with version 17 of Energy Star, a program designed to promote and label energy efficient construction materials, building practices, and appliances. Energy Star homes are meant to have high efficiency heating and cooling systems, as well as have complete thermal enclosure (Energy Star, n.d.). The Toronto Green Standard was also designed to align itself with the current LEED (Leadership in Energy and Environmental Design) standard.

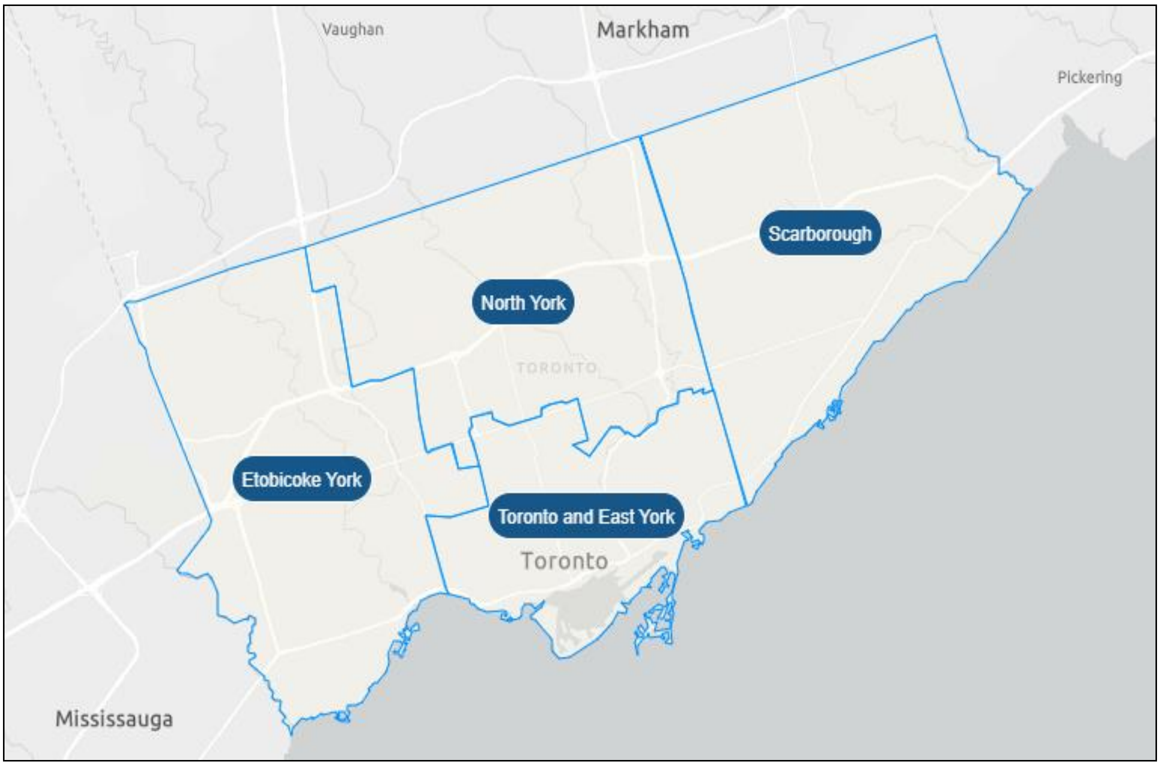

Figure 3. Toronto's four community council areas. Image retrieved from City of Toronto (2019c).

Figure 4. Laneway houses constructed in Toronto, Canada. Image retrieved from Google Street View (2018).

3. Methods

This section of the thesis will outline the methods used to answer each subtopic related to the four main research questions posed. Table 2 provides a summary of the methods used during the research.

Table 2. Summary of methods.

Research Question	Subtopic	Methods
1. How extensive is the linkage between sustainable development and secondary housing in Canadian municipal documents?	1.1 Prevalence in municipal documents	Text analysis of municipal documents
2. What is the potential capacity of laneway housing to meet the City of Toronto's housing needs?	2.1 Number of properties eligible to build laneway housing	GIS analysis
	2.2 Number of properties to be built in upcoming years	Data analysis, scenarios
3. What is the potential capacity of laneway housing to reduce emissions in the City of Toronto?	3.1 Transportation-related emissions	Data analysis, scenarios
	3.2 Building-related emissions	Data analysis, scenarios
4. To what extent can the stock of potential laneway housing fluctuate over time?	4.1 Proportion of potential laneway houses built	Data analysis
	4.2 Properties ineligible for laneway housing	GIS analysis, data analysis

3.1 Municipal document analysis

A list of the 20 most populous cities in Canada (see Appendix B) were compiled based on Government of Canada data (Government of Canada, 2018b). The building and residential sections of each city's website were examined. Planning documents, by-laws, guidelines, reports, and reviews were all analyzed. If one of the aforementioned documents contained information about the city's policy or rationale behind their allowance, or disallowance of "secondary suites", "laneway houses" or "accessory units" then the document was analyzed to see if any linkage was made between these forms of housing and sustainability. Documents were scoured for mention of the terms "environment", "energy", "emissions", "greenhouse gasses" (alt. "GHG"), and "climate change". Documents from cities in Québec, a predominantly French-speaking province in Canada, were less readily available in English. Therefore, these were analyzed using the comparable French terms “durable”, “durabilité”, “énergie”, “émissions”, “gaz à effet de serre”, and “changement climatique” and were also translated to English and analyzed again with English keywords so as not to miss any linkages. French cities included Montréal, Québec City, and Sherbrooke.

3.2 Potential capacity of laneway housing to meet Toronto’s housing needs

3.2.1 GIS analysis of suitable properties for laneway housing

ArcGIS was used to determine the number of properties in Toronto that would be eligible for building laneway housing. Shapefiles (see Table 3) were downloaded from the City of Toronto’s open data catalogue (City of Toronto, n.d.). An additional layer was created to isolate the laneways across the city. This was done by opening the attribute table of the “Centreline” shapefile and using the “Select by Attribute” feature. All items that fell under the description “FCODE_DESC” = ‘Laneway’ were highlighted. Next, using the “Export Data” function an additional shapefile was created and added that contained only the laneway polygons. A visual overview of the residential properties and laneways in a small portion of one residential neighbourhood can be seen in Figure 5.

Figure 5. A visual overview of the residential properties and laneways within one Toronto neighbourhood. The map represents a snapshot of the shapefiles worked with while using ArcGIS. Own illustration.

Laneways were given a 6-metre buffer, as laneways in the city range from 3 to 6 metres in width (The Laneway Project, 2019; Lanescape & Evergreen, 2017). Upon examination, within the laneway layer, laneway lines did not always fall directly in the middle of polygons that were laneway spaces meaning a 6-metre buffer would be able to compensate for this. Using the selection by location feature, shapefiles (properties, municipal zones, and laneways) were selected to only include the data that fell completely within the Toronto & East York (TEY) community council districts. These were then made into their own layers and added to the map. This is the only district in which laneway housing is currently eligible to be built.

Table 3. Shapefiles used in GIS analysis

File Name	Source	Description
Zoning_MTM3	City of Toronto (2014)	City of Toronto zone boundaries as outlined by Zoning By-law 569-2013.
Property_BNDS_GCC_MTM3	City of Toronto (2018)	Outline of area of all properties in City of Toronto.
Address_Points_MTM3	City of Toronto (2018)	Point symbols for all addresses in City of Toronto.
TW_Fire_Hydrants_MTM3	City of Toronto (2017)	Location of all fire hydrants in City of Toronto.
Centreline_MTM3	City of Toronto (2018)	Linear features depicting all streets, walkways, rivers, railways, highways and administrative boundaries in City of Toronto.
Community_Council_MTM3	City of Toronto (2018)	Outline of the four service districts within the City of Toronto.

Within Toronto's zoning by-laws laneway houses are allowed in the R, RD, RM, RS and RT zones (see Table 4). Two new layers were created, one for merging the RD, RM, and RS zones and one for merging the R and RT zones. As not all properties within the R and RT zones are eligible to build laneway housing, further analysis of the number of properties intersecting laneways was needed.

Table 4. A description of the residential zones in Toronto in which laneway housing is eligible to be built.

Zone	Description	Properties within zone eligible for laneway housing
R	Residential zone allowing for multiple building types including townhouses, detached and semi-detached houses as well as larger dwellings such as duplexes, triplexes and fourplexes.	Not all
RD	Residential zone allowing for only detached houses	Yes
RM	Residential zone allowing for detached and semi detached houses, as well as larger dwelling such as duplexes and triplexes.	Yes
RS	Residential zone allowing for detached and semi detached houses.	Yes
RT	Residential zone allowing for townhouses, detached and semi-detached houses.	Not all

Data on the proportion of different types of houses within Toronto (see Table 5) was based on census data retrieved from the Government of Canada (2017). Townhouses are often ineligible to build laneway housing due to their lacking a side entrance and access from their backyards to a fire hydrant. This is due to townhouses having a shared wall on both sides of the property. They are allowed to still build a laneway house if they are within a 45-metre distance of a fire hydrant as accessed through the laneway, but this has previously been estimated to be a minimal number of eligible properties (Lanescape & Evergreen, 2017). Therefore, the proportion of townhouse properties in the R and RT zones were calculated based on census data and excluded from the number of properties eligible to build laneway housing.

The number of properties eligible for laneway housing were calculated using the selection by location feature to isolate only the residential properties that intersected with the laneway buffer layer and met the other aforementioned criteria. A data table showing the selected features indicated the number of properties meeting these conditions.

Table 5. A breakdown of Toronto's single-family dwelling housing stock. Data retrieved from the Government of Canada (2017).

Type of House	Number of Houses	Share of Total (%)
Detached	846,405	71%
Semi-detached	158,820	13%
Townhouse	195,245	16%

3.2.2 Projecting future low-rise residential building development

To predict the number of residential buildings that were likely to be constructed in the future, data on the buildings previously built was accessed. Cleared building permit records were downloaded from the City of Toronto's "Open Data Catalogue". Data was available from 2001-2018. Permits were filtered to specific permit types issued for new residential buildings. Conditional permits, permits issued, were excluded from the data set. This was due to the uncertainty regarding whether or not conditions would be met in the future that allowed for the final construction of the building (Romeo-Beehler, 2017).

For the sake of comparison only new residential buildings that were meant for long term housing were included. This means that newly built hotels and hostels were excluded from the total. Forms of housing that clearly indicated the number of families they were able to accommodate were included. These were detached and semi-detached houses, townhouses, duplexes, triplexes and two-unit buildings.

Mid- and high-rise residential buildings such as apartment buildings, student residences, and "3+ unit" buildings, as well as categories of buildings which were ambiguously described, such as "Other (new housing)" were excluded from the analysis for multiple reasons. First, they exhibit different energy usage characteristics from other low-rise residential buildings due to differences in size, occupancy and use, thus making their comparison more difficult. Next, there was no data on the average number of units in each apartment building, making it problematic to compare between single family dwellings and these larger buildings. Lastly, these buildings made up a very small portion of each annual data set of buildings cleared for construction with the average proportion being 1.2% allowing for confidence that their absence would not significantly affect the analysis.

Using the data from 2001-2018 projections were made for the number of future low-rise residential units constructed in the future. This was done using the “trend” function on Microsoft Excel which predicts future values based on the previous values in a series. This was used instead of the “forecast” function as the trend function is meant for series rather than random samples. The future projection period was set as the 10-year period leading up to 2030, the target year of Toronto’s next substantial climate goals.

3.3 Emission reducing potential of laneway housing

3.3.1 Transportation-related emissions

Per capita private vehicle emissions data was retrieved from Statistics Canada (2012). Data on the per capita emissions from the average Canadian citizen was available from 1990 to 2007 and for the average person living in Toronto for 2007. The emissions per Torontonian were smaller and this percentage was extrapolated to estimate the per capita emissions for someone living in Toronto for the rest of the time series (1990-2007). Using this newly created time series, the ‘trend’ function on Microsoft Excel was utilized to forecast what the annual per capita emissions of someone living in Toronto could be for the upcoming 10-year period of study (2020-2029). Graphs from the Toronto Atmospheric Fund (2017) on per capita transportation emissions from someone living in Toronto was used to verify that the estimate from the trend function was accurate.

To calculate per household private vehicle emissions, based on per capita levels, data on the average number of persons per Toronto household was used. Census data reported by Statistics Canada and the City of Toronto provided these values for the years 1991, 1996, 2001, 2006, 2011 and 2016 (Statistics Canada, 1991; Statistics Canada, 2016; City of Toronto, 2015; Statistics Canada, 2017). These data points were used to forecast future household sizes for the years 2020-2029. Projected annual per capita private vehicle emissions were multiplied by projected household size values to estimate what the private vehicle emissions savings per household and across all newly built low-rise residential buildings would be from laneway housing.

Five scenarios were created to investigate the potential of laneway housing in reducing emissions from new low-rise residential properties compared to 1990 levels. In the scenarios penetration rates were set at 0, 5, 15, 25 and 100%. The 0% scenario was representative of a business as usual approach in which none of the new low-rise residential homes being built were laneway houses whereas the 100% scenario was meant to analyze what the maximum potential impact could be from laneway houses. In this maximum scenario all newly built low-rise residential housing would be in the form of laneway houses. The middle scenario penetration rate values were set at 5, 10 and 15% so as to cover the range from estimates that between 100 to 300 laneway homes are likely to be built per year (City of Toronto, 2018a).

3.3.2 Building-related emissions

In this analysis laneway homes are projected as being constructed to Energy Star standards as this would increase the likelihood of their building permits being approved. When comparing buildings constructed to Energy Star standards with those that have not, increases in energy efficiency have been projected at 20% (Natural Resources Canada, 2017). The average annual GHG emissions from energy consumption for different types of households in the Province of Ontario were retrieved from Natural Resources Canada (n.d.). Data was given for detached households as well as those that share at least one wall with a neighbouring home. Natural Resources Canada data was verified by comparing it to data produced by Fercovic and Gulati (2016) on household greenhouse gas emissions across Canadian cities. Using the future residential building projections described in section *3.2.2* it could be estimated how many detached and non-detached homes are to be built in the coming 10 years. Once again, 2030 was used as the cutoff point. Laneway homes can be built in the form of detached or attached properties. Examples of attached laneway homes in Toronto exist such as that seen in Figure 4. The same steps were taken as in section *3.3.1* to investigate the potential of laneway housing to reduce building related emissions from new low-rise residential buildings compared to 1990 levels under different penetration rate scenarios.

Data on the number of residential buildings that received building permits between the years 2001 and 2018 was available from the City of Toronto's 'Open Data Catalogue' (n.d.). Information for applications before 2001 was not available as Toronto previously tracked them on multiple systems where data collection standards and techniques varied (City of Toronto, n.d.). Results were filtered to analyze only residential buildings that fell into the detached, semi-detached, or townhouse categories. Semi-detached houses and townhouses were combined into one category as both were used in the category of 'households with one shared wall' as listed by Natural Resources Canada (n.d.)

3.4 Fluctuations in the stock of potential laneway houses over time

3.4.1 Proportion of stock used under different projected scenarios

The test scenarios previously outlined will utilize the potential stock of laneway houses at varying rates. Microsoft Excel was used to calculate the projected residual levels of laneway houses at the year 2030 under different scenarios. This was done by totalling the predicted number of laneway houses built annually and subtracting the amount from the total stock. Values were expressed as the proportion of the total eligible laneway houses that were used up under each scenario.

3.4.2 Number of ineligible properties

Using ArcGIS, the three remaining community council districts were isolated. From the attribute table the three districts were selected, and an additional layer was created. The same steps were taken to isolate the properties, laneways, and residential zones that were located within these districts. In a similar methodology to that undertaken in section 2.2 1, two additional property layers were created, one for those in the R and RT zones in which not all properties are eligible and one for those found in residential zones RD, RM and RS. Once again, a 6-metre buffer was created around the laneways and the number of properties intersecting this buffer was identified.

The proportion of townhouses in the R and RT zones were calculated based on data from the Government of Canada (2017) and excluded from estimates of the number of properties eligible for laneway housing. In order to calculate the number of ineligible properties based on this requirement this value was found for properties both within and out of the Toronto and East York district. Estimates for the number of ineligible properties were found both for the two separate requirements as well as in addition to one another.

4. Results

The results section of this thesis has been divided into portions covering the findings from each analyzed research question and subtopics.

4.1 Prevalence of linkage between sustainable development and secondary housing in Canadian municipal documents

Documents relating to secondary forms of housing were found for 19 of the 20 most populous cities in Canada. Of the 19, one single municipality, the amalgamated region of Kitchener-Cambridge-Waterloo, does not allow for any form of accessory buildings. Of the 18 cities allowing for secondary housing, 10 made no linkage between sustainability and alternative forms of housing based on findings of the review. Of these cities, three were among the seven most populated in the country, Ottawa, Calgary, and Winnipeg.

The explained rationale for creating alternative forms of housing differed between municipalities. In both cases where documents did and did not make a linkage to sustainability the majority emphasized that secondary housing was beneficial in its ability to provide increased and a greater diversity of housing options. This was the prevailing rationale throughout analyzed documents. If a connection was made to secondary suites being able to help a municipality reach its environmental goals it often came after reasons related to housing opportunities such as was the case with documents retrieved from the City of Vancouver.

The City of Toronto is among the municipalities that makes a direct linkage between secondary forms of housing and sustainability. Within Toronto's report on laneway housing a section is dedicated to sustainability in which it is explained that the city sees strategic land and infrastructure use as a way to meet its emission and energy reduction targets (City of Toronto, 2018a). More specifically, the city is targeting new approaches to help achieve this development, and views laneway housing as a tool to do this due the environmental benefits of increased densities in neighbourhoods, and the ability to add green building technology to the suites. Within the regulations on laneway housing it is also stipulated that new suites are "encouraged to include green roof areas, solar panels and other sustainable building technologies" (City of Toronto, 2018a).

4.2 Calculated potential capacity of laneway housing to meet Toronto's housing needs

4.2.1 Findings from GIS analysis of suitable properties

A substantial 36,714 properties were found to have the physical characteristics required to add a laneway suite after accounting for other factors (see Table 5). The vast majority of eligible properties (91.8%) are in the R and RT zones. The significant proportion of townhouses (Government of Canada, 2017) in the Toronto housing stock meant that 16% of the properties that abutted laneways would likely be ineligible to build laneway housing and thus the number of eligible properties could be larger.

Table 6. The number of properties eligible to build laneway housing in Toronto. Data based on own calculations.

Zones	Number of Properties Intersecting Laneway Buffer	Total Eligible Properties
R, RT	40,268	33,719
RD, RM, RS	2,995	2,995
Total	43,263	**36,714**

4.2.2 Future and past building of low-rise residential housing

Residential building permits were issued for a variety of housing types over the time period that building permit data was available for. These included detached, semi-detached homes, and townhouses as well as apartment buildings, duplexes, triplexes, multiple unit buildings and student residences. Between 2001 and 2018 a total of 34,510 units were cleared to be built in low-rise residential buildings. Of these, 34,185 (99%) were in traditional 'single family dwellings' (townhouses, detached, and semi-detached homes). Detached homes were the most commonly constructed building over this timespan (see Figure 6) making up 60% of the total over the period. Semi-detached homes and townhouses were less common at 12% and 27%, respectively. Other types of family units made up 1% of the total built.

The overall trend has been a slight decline in the number of homes cleared to be built over the years (see Figure 7). However, the annual number has varied less recently. This slight decline led to a lower projected number of houses being built going forward. 1,630 low-rise residential units are projected to be built annually by 2030 when the city assesses their emission targets. By that point detached houses will make up 67% of houses constructed. In the decade leading up to 2030 a projected 18,715 low-rise residential homes will be constructed. As some of these homes will be in the form of duplexes and triplexes which contain multiple units, the projected number of units created is 18,900. Both totals are well below the projected number of eligible laneway houses calculated in section *4.2.1* (36,714) indicating that laneway housing has the potential to accommodate growth in low-rise residential housing going forward.

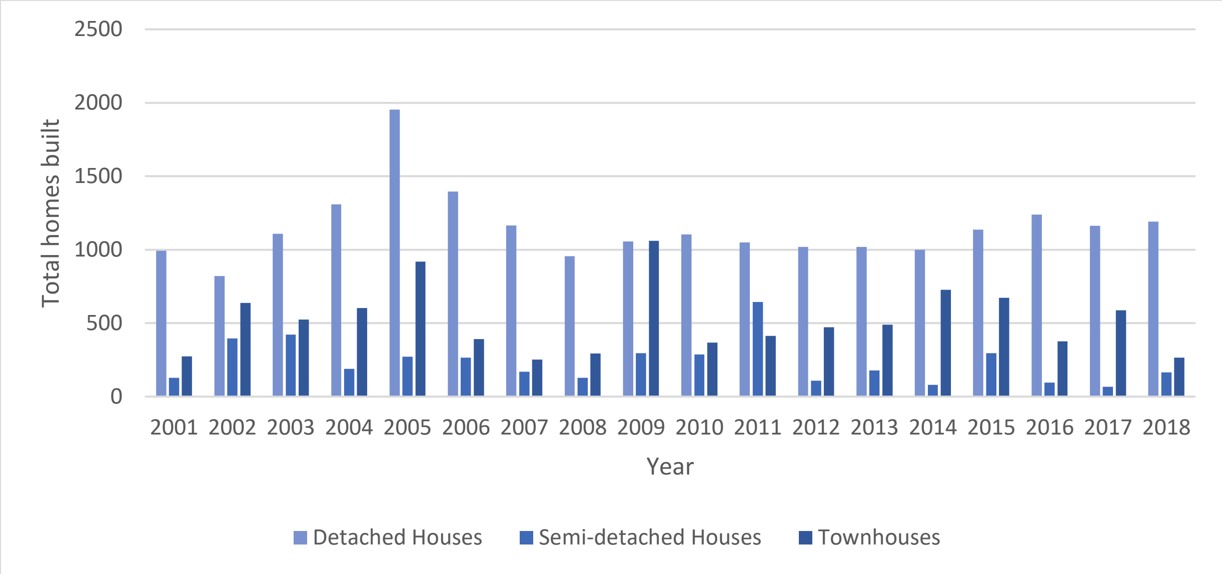

Figure 6. The number of single-family homes cleared to be built between 2001-2018. Own illustration. Data retrieved from City of Toronto (n.d.).

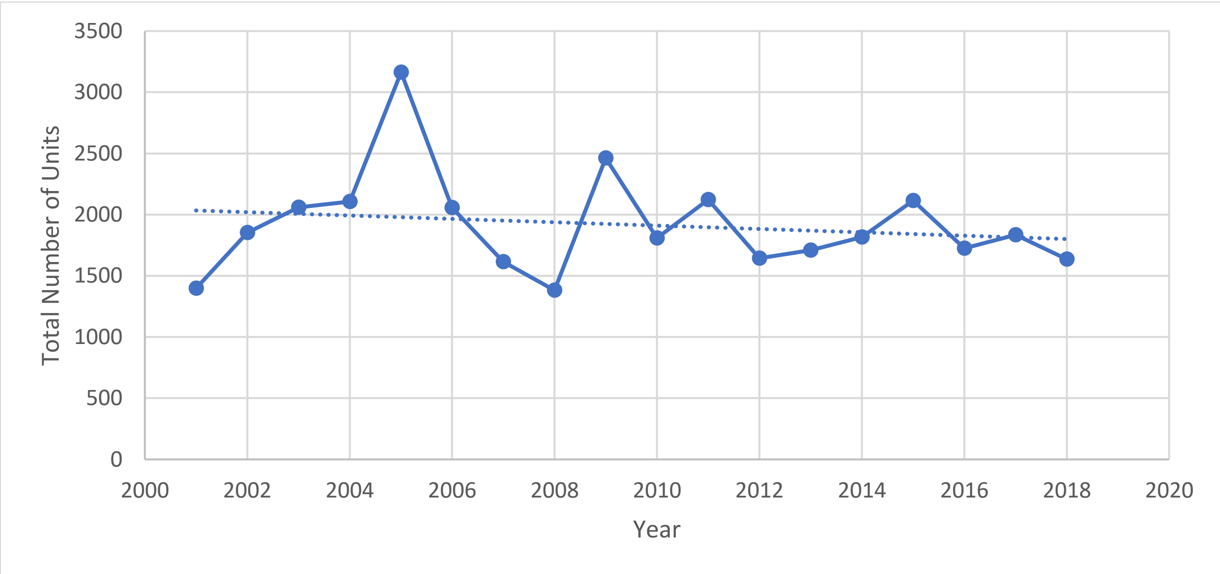

Figure 7. The number of residential building permits annually issued between 2001 and 2018. The trendline shows there to have been a slight decline in the number of permits annually issued over time. Own analysis and illustration. Data retrieved from City of Toronto (n.d.).

4.3 Calculated emission reductions from laneway housing

4.3.1 Changes in transportation-related emissions

Laneway housing was found to have the potential to reduce transportation-related emissions due to imposed regulations that decrease the ease of private vehicle utilization by those living in laneway homes. The total emissions from all newly built low-rise residential housing should decline due to a decrease in the projected number of low-rise residential buildings constructed annually. This was even the case in the minimum scenario in which no laneway houses are built. The three middle scenarios (low, medium and high) saw reductions of 14, 27 and 45%, respectively. However, none of the scenarios produced the desired reduction of 65%. However, the target was achieved in the maximum scenario. As a result of emissions levels from private vehicle use on per capita basis increasing over time, emissions are set to increase on a per household basis under the 0 and 5% scenarios despite the total emissions from all newly constructed low-rise residential buildings being lower.

Table 7. Potential of laneway housing to reduce the total and per household private vehicle emissions from newly built low-rise residential housing ($kgCO_2$ equivalent).

(kg CO2 Equivalent)	Minimum (0%)	Low (5%)	Medium (15%)	High (25%)	Maximum (100%)
1990 Per Household	3,018.1	3,018.1	3,018.1	3,018.1	3,018.1
2030 Per Household	3,641.3	3,459.2	2,940.4	2,205.3	0
% Change Per Household	21%	15%	-3%	-27%	-100%
Change Per Household	623.1	441.1	-77.8	-812.9	-3,018.1
1990 Total New Buildings	6,589,898.7	6,589,898.7	6,589,898.7	6,589,898.7	6,589,898.7
2030 Total New Buildings	5,937,008.8	5,640,158.4	4,794,134.6	3,595,601	0
% Change Total New Buildings	-10%	-14%	-27%	-45%	-100%
Change Total New Buildings	-652,889.9	-949,740.3	-1,795,764.1	-2,994,297.7	-6,589,898.7

4.3.2 Changes in building-related emissions

Greenhouse gas emissions from newly built low-rise residential housing should decrease across both detached and single attached houses regardless of the penetration rate of laneway housing. This is due to the projected decline in the number of annually built low-rise residential houses compared to 1990 levels. On a per household basis, emissions are expected to increase in both detached and single attached households in 2030 in comparison to 1990 due to the increasing trend in household emissions. Laneway houses are projected to help reduce emissions across the various scenarios in which they are built. However, the 20% increased efficiency rate of constructed laneway houses appears to have a rather low impact. In the scenario in which 100% of newly built low-rise residential buildings are laneway houses, emissions from new buildings are only projected to be 23% lower than 1990 levels.

The total stock of newly built detached homes appears to be an area of concern. Due to projected increases in per detached emissions, and the meager decline in the number built, total emissions from all newly built detached homes are only projected to be slightly lower than 1990 levels across the first four scenarios. In the same comparison done for single attached households the reduction is over 20% higher due to a larger projected decline in the number of single attached homes being built.

Table 8. Potential of laneway housing to reduce the total and per household building emissions from newly built low-rise residential housing. Units in Mt of CO_2 equivalent.

(Mt of CO2 Equivalent)	**Minimum (0%)**	**Low (5%)**	**Medium (15%)**	**High (25%)**	**Maximum (100%)**
1990 Detached Households	15,874.6	15,874.6	15,874.6	15,874.6	15,874.6
2030 Detached Households	15,749.5	15,591.9	15,276.9	14,961	12,599.6
% Change Detached Households	-1%	-2%	-4%	-6%	-21%
Change Detached Households	-125.1	-282.6	-597.6	-912.6	-3,275
1990 Per Detached Household	13.1	13.1	13.1	13.1	13.1
2030 Per Detached Household	14.4	14.3	14	13.7	11.5
% Change Per Detached Household	10%	9%	7%	4%	-12%
Change Per Detached Household	1.3	1.2	0.9	0.6	-1.6
1990 Single Attached Households	2,040.4	2,040.4	2,040.4	2,040.4	2,040.4
2030 Single Attached Households	1,516	1,500.8	1,470.5	1,440.2	1,212.8
% Change Single Attached Households	-26%	-26%	-28%	-29%	-41%
Change Single Attached Households	-524.5	-539.6	-569.9	-600.2	-827.6

1990 Per Single Attached Household	2.1	2.1	2.1	2.1	2.1
2030 Per Single Attached Household	2.8	2.8	2.7	2.7	2.3
% Change Per Single Attached Household	34%	33%	30%	28%	8%
Change Per Single Attached Household	0.7	0.7	0.6	0.6	0.2
1990 Total New Buildings	17,915	17,915	17,915	17,915	17,915
2030 Total New Buildings	17,265.4	17,092.8	16,747.5	16,402.2	13,812.3
% Change Total New Buildings	-4%	-5%	-7%	-8%	-23%
Change Total New Buildings	-649.6	-822.2	-1,167.5	-1,512.8	-4,102.7

4.4 Calculated fluctuations in the stock of potential laneway houses over time

4.4.1 Calculated proportion of stock used under different projected scenarios

Laneway housing appears to be a resource that can be utilized to lower emissions from newly built low-rise residential buildings for quite some time. The highly improbable maximum penetration rate scenario, in which all newly built low-rise residential housing is in the form of laneway housing, is projected to use up half of the stock within the 10 year study period and would likely use it all by 2040 depending on fluctuations in the rate of newly built housing. However, under more probable scenarios, the stock should last much longer as only 13% of all eligible laneway houses would be built under the 25% scenario. These estimates would improve if changes are made to the by-laws regarding laneway housing construction as analyzed in section *4.4.2.*

Table 9. Evaluation of the depletion of the stock of laneway housing under different scenarios.

	Minimum (0%)	Low (5%)	Medium (15%)	High (25%)	Maximum (100%)
Total Built by 2030	0.0	945.0	2,834.9	4,724.9	18,899.6
% of Total Eligible Stock Used	0%	3%	8%	13%	51%

4.4.2 Calculated total of ineligible properties

A substantial number of properties have been ruled ineligible for the development of laneway housing based on spatial requirements. A total of 11,875 properties that abut a laneway do not satisfy the requirements of having a side access to the backyard and being located in the Toronto and East York community council district. The side access requirement is the more restrictive of the two as it eliminates 1,823 more properties than does the district location. The total number of ineligible properties make up of 24% of all properties abutting a laneway in Toronto. In other words, 76% of residential properties abutting a laneway in Toronto are eligible to build a laneway house.

Table 10. The number of properties rules ineligible for laneway housing in Toronto due to not satisfying the city's spatial requirements for development.

Requirement not Satisfied	Number of Properties
House Type	6,849.3
Community Council District	5,025.9
Total	**11,875.2**

5. Discussion

The following discussion section has been guided by the main research questions and related sub-questions posed in this thesis. The following subsections will link the findings of this thesis to larger trends in housing, urban sustainable development, urban planning, and building certification schemes.

5.1 Urban sustainable development in Canadian municipal documents

The absence of a connection between sustainability and secondary housing in Canadian municipality documents can be attributed to multiple factors. Documents varied in scope and length across municipalities. Cities vary widely in their operating budgets (Canadian Federation of Independent Business, 2015). Thus, it is possible that this affords a city to be able to put more resources into the planning and production of these documents. Toronto's position as one of the municipalities making a clear linkage supports this idea as Toronto's operating budget is the highest of all Canadian cities (City of Toronto, 2018b). In the case of Toronto, the enthusiasm to deploy the building of laneway housing as a tool to increase sustainable development seems disconnected when analyzing the numerous barriers in place preventing the development of these suites. This is a point that will be further discussed in section *5.4.*

Most municipal documents analyzed were effective in praising secondary forms of housing, outlining the other benefits they have. Among these linkages were the increase in housing options for citizens and the positive effect it may have on housing prices, and the ability for homeowners to create additional revenue streams. These examples may indicate that a municipality values the social aspects of sustainability to a higher degree than emissions and energy use, or that these are simply seen as more pressing issues or better selling features. This could also be indicative of a municipality attempting to appease the values of its citizens. A lack of data has made it difficult to determine trends in the values of Canadians living in urban areas (McGrane, Berdahl & Bell, 2017). However, the level of urbanization in a Canadian area has been linked to the political and social preferences of its residents (Walks, 2004). Moving forward, it would be useful to isolate additional factors, such as city size and density, in the municipal document analysis carried out in this thesis to determine what role they may have in impacting how laneway housing is presented to the public.

The finding that many municipal documents regarding secondary suites and laneway housing fail to make a linkage to sustainability is in line with previous research on the topic. There are no rules regarding how sustainability initiatives must be integrated within municipal documents thus helping to account for some of the variation in depth between documents. This is not exclusive to Canada as the issue of a lack of integration of sustainability in Canadian documents is consistent with global findings (United Nations Environmental Program, 2012). It has been suggested that this failed linkage can be attributable to a lack of empirical evidence to draw from (Stuart, Collins, Alger & Whitelaw, 2016). Research findings, such as those produced by this thesis, should help to close this gap.

Research question 1 aimed to investigate the prevalence of the linkage between laneway housing (and other forms of secondary suites) with urban sustainable development. In terms of how this connection is portrayed, findings concluded that this is an underdeveloped linkage in Canadian municipal documents supporting similar conclusions regarding sustainability in municipal documents elsewhere (UNEP, 2012). This thesis speculates this could be associated with municipal operating budgets, the decision to emphasize other benefits of laneway housing, or aiming to target the values of citizens.

5.2 Potential capacity of laneway housing to meet the City of Toronto's housing needs

The results of section *4.2* determined there to be a substantial number of properties eligible to build laneway housing and helped to identify important trends in residential property development since the year 2001. In the following subsections the results will be discussed in their relation to societal standards for housing size, the control over housing development in Toronto, and individual sustainable behaviour.

5.2.1 Societal standards for housing size

It should be acknowledged that many families may prefer not to live in laneway suites due to them being below the average size of other family homes, having to share space with the primary homeowner or lacking storage space (Leach, 2012). However, changing standards of housing size and space is is an ongoing battle in many large growing cities. As we saw is the case in Toronto in section 4.2.2, the preference when building low-rise residential homes has been to build detached, single family homes rather than homes in closer proximity to one another or with multiple units. Societal standards for unneeded amounts of space makes it more difficult to accommodate growing populations. In spite of this, many benefits of downsizing do exist. For example, living in smaller spaces can help to save money on housing costs and utility bills (Doteuchi, 2008) and is seen as some to be a stress relief (Leach, 2012). In addition, living in smaller homes is an effective way to decrease energy consumption (Huebner & Shipworth, 2017) as larger homes tend to use more energy (Druckman & Jackson, 2008).

The ability of homeowners in Toronto to adopt the notion of living in smaller spaces may be more likely than once thought. While many North American cities have undergone rampant de-urbanization over the past decades Toronto has managed to upkeep a highly dense centre (Lehrer, Keil & Kipfer, 2010). The trend of post-World War II suburban family living accompanied by large front lawns and cookie cutter homes never fully latched on in Toronto. Therefore, reimagining how much space a family needs in a city that never fully diverted away from dense living is more plausible when compared to the same scenario in other North American cities. This plausibility could be amplified by the finding in section *4.2.1* that the number of low-rise residential homes being built has declined which could indicate a lack of space to build. We may be seeing evidence of this already as Toronto has an extremely robust condominium stock with people across age, class and status demographics living in these smaller condo units (Lehrer, Keil & Kipfer, 2010). Laneway housing stands to check off many of the same boxes as condos in that they can be located within the city core, require less upkeep than a traditionally sized home, and are more affordable. In all, the seeming lack of obsession over the amount of residential space in Toronto bodes well for the acceptance of laneway housing moving forward. However, further research will be needed to determine if Toronto's unique physical layout and renter tendencies make it a better candidate for laneway housing development than other North American cities going forward.

5.2.2 Claiming public control over housing

Laneway housing has the potential to help reverse an alarming trend in the Toronto housing landscape. As discussed, Toronto's housing needs are being increasingly met by condominium development. The initial boom of this form of housing in the 1970s was followed up by a, still ongoing, wave that began in the 1990s (Lehrer, Keil & Kipfer, 2010). However, this was accompanied by what has been found by Rosen and Walks (2013) to be a movement of power dynamics in favour of the private sector away from the public. Some scholars see this phenomenon as being so extreme that it is the private sector developers, rather than the city's urban planners, who build our cities (Coiacetto, 2000). If it is indeed the private developers that are in control, then it is important to consider their motivations. Unfortunately, more often than not it lacks a social conscience and is based on "profit-driven considerations" (Rosen, 2017). In an interview conducted by Rosen (2017) with the president of one large-scale Toronto-based development company, the president was quoted as saying about their motivations: "We're very capitalistic in our viewpoint of the world. We're not savers. Our whole thing is to turn capital and make money". In a city with residents spanning a wide range of incomes (Contenta, 2018) it is problematic that housing development is controlled by developers that give no thought to who will have an opportunity to live in their buildings.

The development of laneway housing has the added benefit of potentially swinging the housing power dynamic back towards a portion of the public. It will be the choice and responsibility of citizen homeowners whether or not they decide to build a laneway suite in their backyard. In this sense laneway housing development provides an opportunity for citizen engagement in shaping the spatial fabric of the city. As Maiello, Christovão, Nogueira de Paiva Britto, and Frey (2013) point out, defining what makes for successful citizen led urban transformation is difficult as it is often context specific. In this particular case it is unclear if an individual's rationale for the development of a laneway suite is the same as the one described by the president of a large-scale development company, "very capitalistic". In addition, this case of citizen led urban transformation could be seen as less successful as it is controlled by the citizens who are wealthy enough to own a property. However, this must be balanced with the idea that decreasing the concentration of profit from a few mega-developers (Rosen, 2017) to at least a portion of the public could also be considered a form of success.

5.2.3 Laneway housing's role in overcoming financial barriers to sustainable behaviour

When further considering the success of citizen involvement in urban sustainable development it should be noted that knowledge of sustainability should not have to precede engagement in a sustainability transition as engagement can still be passive and vary in level. This is especially true in a case like this where the linkage between sustainability and laneway suites is underdeveloped. Thus, this thesis provides added benefit in that it can further the discussion and knowledge base surrounding laneway housing and perhaps alter the reasons homeowners decide to build a suite in their backyard.

The idea that laneway housing development can contribute to increased personal sustainable behaviour is an interesting discussion. Several common barriers exist to individual sustainable behaviour. Among these are financial constraints (Joshi & Rahman, 2015). However, in this particular case, participation in the transition to a more sustainable housing stock is in the economic interest of the homeowners as they can provide themselves with an additional revenue stream in the form of rent collected from the laneway home. This represents another incentive to sustainable building development (Olubunmi, Xia & Skitmore, 2016). Whether or not the emissions reductions from this form of housing is less meaningful if it is profit-driven is an important question to ask. Cutting greenhouse gas emissions is paramount to avoiding the irreversible surpassing of planetary boundaries. However, capitalistic pursuits are also at the root of our planet's environmental issues. Although, this latter fact should not be ignored there is a case to be made that the urgency of the first issue should take precedence and financial incentives to sustainable building development and behaviour are in the climate's best interests.

5.3 Cutting emissions

The results of section *4.3* revealed that adding a number of smaller homes within Toronto will not radically overhaul the building and transportation sector's respective greenhouse gas emissions to 65% below 2030 levels. They will however lower each new household's footprint. The city faces a challenge in accommodating population growth and the added emissions that will come with more homes and vehicles, while aiming to reduce its total footprint and reach its climate targets. Reductions will need to come from major cuts in other areas of each sector. Recommendations for how to accomplish this will be made in section *5.6*.

The following subsections of the discussion will elaborate on the findings of the section *4.3* while situating them in the larger contexts of urban green space, compact cities, individual energy consumption, and building certification schemes.

5.3.1 Laneway homes and transportation

Reductions in transportation-related emissions from newly built low-rise residential housing are projected to fall short of the city's climate goals. This is the case despite working under the unrealistic assumption that those living in laneway homes will have no emissions from private vehicle usage. Although they are projected to be substantial, these results should serve as notice that larger changes are needed to private vehicle usage. Incentives for electric car usage and fuel taxes are possible ways to alleviate this issue (Chandra, Gulati & Kandlikar, 2010; Liu & Cirillo, 2016).

The observed projected emissions savings from laneway houses without private vehicles are not the only benefit with regards to transportation. Citizens in Toronto have previously been surveyed to review their thoughts and preferences for finding low-carbon transportation options in the city (City of Toronto, Live Green Toronto & Toronto Atmospheric Fund, 2017). The surveys revealed that people felt it was most important to reduce the number of cars on the road, increase the use of public transit, and increase active transportation. Improving public transit and the infrastructure in place for cyclists were seen as the best ways to do this. New measures to eliminate private vehicle use, such as not granting a parking space to laneway homes, would seem to be seen as favourable to the public in that it would stand to increase public transit ridership and active transportation. However, it is unclear if the public would be in favour of this type of regulation as it was not present in survey responses. Laneway housing driven public transit ridership would be beneficial as use of the city's transit has been stagnant since 2014 and authorities are looking into ways to change this (Spurr, 2018).

An outcome of high-density urban areas is the creation of what has been described as "compact cities". Compact cities refer to what Neuman (2005) outlines as low polluting and energy efficient areas resulting from the close proximity of citizens to local amenities. High density areas in North America are meant to target transportation related emissions, as almost 60% of greenhouse gas emissions in this sector come from private vehicle use in the U.S. (Environmental Protection Agency, 2018). Gaigné, Riou and Thisse (2012) point out that new initiatives are needed to tackle these issues. Laneway housing fits into this category. In the interim constructing urban spaces of increased density seems to have its share of benefits (Stone, Hess & Frumkin, 2010; Shi, Yang & Gao, 2016).

Yet, compact cities appear to not be without their drawbacks. Gaigné et al. (2012) do envision potential negative scenarios in which compact cities produce higher pollution levels and the dispersion of jobs. Shi et al. (2016) echo this sentiment outlining that compact cities tend to be at risk for increased congestion and pollution. Although, in the scenario outlined in this thesis, laneway housing driven compactness should have less congestion. Nonetheless the concerns regarding compact cities are meaningful. It is unclear what level of density Toronto would have to surpass to begin exacerbating these issues.

5.3.1.2 Laneways as green alleys

The conversion of spaces that have traditionally been used to accommodate parking will help to begin to open up a city's laneways to be more pedestrian and cyclist friendly. This was emphasized in the City of Montréal's plans where the city envisions the creation of green alleys that can be used as community and commuting friendly spaces (La Ville de Montréal, 2018). This vision has been duplicated to much success elsewhere. Zelinka and Beattie (2003) found that laneways can provide a space to increase citizen movement and activity, while at the same time creating positive relationships within a neighbourhood (Wolch et al., 2010). A number of environmental benefits to this form of green pathway has also been identified. Green alleys in particular have been beneficial in regards to stormwater runoff, recharging groundwater levels, combatting the heat island effect and providing additional habitat for wildlife (Wolch et al., 2010) The benefits of green alleys also extend to the health of the citizens living in these urban spaces.

There are numerous added benefits to the creation of green spaces within a city especially with regards to physiological and psychological health effects (van den Berg et al., 2015). An overview of health benefits provided by Lee and Maheswaran (2011) where they identify positive effects on osteoporosis, colorectal cancer, diabetes as well as mental health and overall well-being. These areas become increasingly desirable when coupled with the findings that living in urban spaces leads to a higher risk of mental illness as well as increased prevalence of mood and anxiety disorders (Lederbogen et al., 2011). The fact that green alleys can contribute positively in so many ways should be utilized as an additional selling feature of laneway housing development in the future.

5.3.2 Building-Related Emissions

The projected emissions savings from laneway suites, in comparison to other low-rise residential housing options, could turn out be higher than calculated. When projecting building-related emissions, the size of the houses was not taken into consideration. Toronto by-laws stipulate that laneway suites are required to be smaller than the main properties they are adjacent to. Smaller buildings have been found to be less energy intensive in the past (Guerra Santin, Itard & Visscher, 2009). Thus, in theory, laneway homes should emit less than projected. Although, some of these savings could be lost in that most laneway suites will likely stand as homes with no shared walls to other properties. As discussed, homes with at least one wall attached produce far fewer emissions (United States Environmental Protection Agency, 2019).

The development of energy efficient homes in high density urban areas does not ignore the role of individual consumption patterns in reducing energy usage in the building and transport sectors. However, it does acknowledge that numerous factors make individual reductions difficult for some such as heating and cooling necessities and the cost of rent within urban areas. Energy efficient buildings allow individuals to be able to make more meaningful reductions in their energy usage. Within the building sector, individual reductions in energy consumption alone cannot have us reach our climate goals align if our homes do not provide us with the efficiency capabilities to do so.

There is a lack of evidence that individual consumptions habits play the most important role in a building's energy consumption. Guerra Santin, Itard and Visscher (2009) found that when comparing household energy consumption for space heating only 4.2% of the variation across households could be explained by occupant behaviour. Meanwhile the type and size of the building explained 10 times more of the variation at 42%. The differences in strength of explanatory variables when it comes to space heating is important in a cold climate city like Toronto where the majority of building related emissions are from heating indoor spaces (City of Toronto, 2019a). Meanwhile, Touchie et al. (2013) found that variation in energy efficiency in Toronto residential properties could be most widely attributed to the ratio of windows to walls in a building and the efficiency of the building's boiler. As Steemers and Yun (2009) suggest, the largest role occupants play in the energy consumption of a building is the actual building they choose to live in. Although it is abundantly clear that individual behaviour plays a huge role in greenhouse gas emissions (Wynes & Nicholas, 2017) this may not apply to the same extent with regards to residential buildings.

5.3.2.1 Critiquing the dominant building certification systems

Certification schemes intend to increase the sustainability of production. In the case of buildings certification schemes, such as the Leadership in Energy and Environmental Design (LEED) and Energy Star, they aim to increase the energy efficiency of certified infrastructure. These programs were heavily influential in the creation of the Toronto Green Standard and, therefore, will play a large role in the construction of laneway housing. Thus, their flaws will be discussed, and it will be considered if better alternative systems exist.

LEED certifies buildings to different levels based on the proposals and calculations of its lifecycle performance submitted by developers. LEED focuses more on the construction of these buildings, failing to follow up on the performance of a building once it is erected. This is problematic as 80 to 85% of the energy that a building consumes is used during the occupation phase of its lifecycle (Sharma, Saxena, Sethi, Shree & Varun, 2011). In addition, buildings have been shown to operate at lower energy efficiency when compared to their proposed values (Marchio & Rabl 1991; Branco, Lachal, Gallinelli & Weber, 2004). Meanwhile, LEED-certified buildings have been found to demonstrate the same trend (Flows, 2014; Cater, 2010). Part of this could be explained by the principle, known as the rebound effect, in which an individual can act less sustainably due to knowledge that preemptive measures were already taken to increase sustainability (Boyle, Peake & Everett, 2012). There is a concern that the Energy Star program also runs the risk of enabling individuals to consume beyond necessary means as they place a large emphasis on labelling office and home products such as electronics, major appliances and office equipment with their logo. In the process Energy Star ignores the whole system at play when it focuses on small components that can be plugged in and unplugged (Brown, Webber & Koomey, 2002).

The LEED certification system is also often simply too narrow in its focus. Due to the increased financial costs of reaching upper levels of the certification system many developers opt to aim lower, settling for achievement levels that are the most convenient and cost-efficient (Sandoval & Prakash, 2016). As Rosol (2013) explains, in some situations LEED has been discredited by municipal planning bodies during developments due to the underwhelming requirements of its lower levels.

5.3.2.2 Finding an alternative to the dominant building certification schemes

Other building schemes exist that aim to decrease energy use in the building sector. One example of this is the "Passive House" standard. First created in Scandinavia, the standard voluntarily requires that the passive heat input from solar radiation and heat given off by electrical appliances will provide all the warmth needed to keep the building at a comfortable air temperature (Wang, Kuckelkorn, Zhao, Spliethoff & Land, 2017). Numerical requirements are also given for the annual energy consumption, and heating/cooling rates, as well as the rate of air infiltration. When compared to other building standards the energy requirements of Passive House are far stricter (Wang et al., 2017). However, the Passive House standard does not place the same emphasis on the construction phase of a building's life cycle that LEED does, indicating that some form of integration between the two schemes would be beneficial.

A database provided by the Passive House Institute shows that no buildings have been created that fit these standards in Toronto (Passive House Institute, 2015). However, some are under construction and others exist in similar climate areas such as Ottawa and Montreal indicating that the Toronto's climatic conditions are not prohibitive to this type of house being built (Chung, 2017).

5.4 Evaluating potential fluctuations in the stock of laneway housing over time

5.4.1 Assessing policies prohibitive to laneway housing development

The results from sections *4.4* indicate that the risk of completely using up the stock of laneway houses is low. If laneway homes were to be built at rates faster than those projected in the scenarios created in this thesis, the stock of potential laneway houses would be able to accommodate this. However, reassessing the by-laws which regulate the eligibility of properties to build laneway housing would still be in the best interests of the city. Increasing the stock of eligible properties for laneway housing would help to increase the probability of them being built. As it currently stands, prospective home builders looking to build low-rise residential housing outside of the Toronto and East York community council districts cannot even consider developing laneway housing. If eligibility was to expand into the surrounding community council districts, we could expect to see an increase in the penetration rate of laneway housing moving forward.

The City of Toronto decided that only properties within the Toronto and East York community council district would be eligible for laneway housing for the foreseeable future while they researched the outcomes of this form of development. The decision to only choose the one district stemmed from the consideration given to the character of neighbourhoods. As outlined in the city's official plan, Toronto aims to be "sensitive" and "gradual" in making changes to the physical character of a neighbourhood (City of Toronto, 2017c). This is likely in the best interests of the inhabitants of a neighbourhood. However, it juxtaposes with the city's climate goals illustrating a point made in section *4.3* that emission reductions from newly built low-rise residential homes are projected to be short of Toronto's emission targets. If Toronto is to view its residential neighbourhoods as being assets in its goal of drastically reducing the city's emissions, then it will need to change its stance that changes in these physical areas must be "sensitive" and "gradual". Alternatively, the city could have already decided that compensation for insufficient reductions in emissions from newly built low-rise residential housing will need to be made in other subsectors. Changing the by-laws regarding the districts in which homeowners are eligible to build laneway houses would increase the number of potential laneway homes and thus the possible emissions savings. However, this may not be the most impactful revision the city could make.

Section *4.4.2* revealed that the number of properties analyzed to be ineligible to build a laneway house from lacking a side access to the backyard was greater than the number ruled ineligible due to their location being outside of the Toronto and East York community council districts. It is difficult to determine if the policy of avoiding the development of laneway houses behind townhouses could ever be reversed. The rationale for this policy is for safety reasons. Side access from the front of the property to the laneway house is seen as necessary in the chance that firefighters or emergency responders need to quickly access the laneway home. Additional reasoning is that a side access would allow for the waste bins to be brought to the front street to be disposed of by garbage collectors. One way to overcome this obstacle would be to access the laneway home via the laneway. However, Toronto laneways vary in width and not all would be able to accommodate vehicles as large as fire trucks, ambulances, or garbage trucks. However, some laneways may be able to fit these larger vehicles in which case townhouses applying to build laneway housing should be considered on a case-by-case basis.

5.4.2 Incorporating public feedback in laneway housing development

In preparation for the City of Toronto's "Changing Lanes" (2018a) report, online surveys and in-person consultations were completed with members of the public (Lanescape & Evergreen, 2017). The majority of participants are in favour of the development of laneway houses moving forward. However, a clear trend was that people saw the regulations and financial requirements for development to be overly restrictive. It was requested that these be softened going forward. As it currently stands the development charge to build a laneway house is $41,251 (CAD). Sustainability was a common thread throughout survey responses and consultations with many respondents suggesting that rebates or other financial incentives be awarded to those properties that aimed to reach certain building standards or manage their green space. The inclusion of the public in the conversation around laneway housing development should be seen as a benefit and is part of positive trend in incorporating socially oriented trends to urban planning (Stuart, Collins, Alger & Whitelaw, 2016).

Most members of the public involved in consultation on Toronto's proposed laneway housing study viewed the project favourably. However, 9% did not and it is important to consider what factors may negatively affect public perception of laneway housing. Living in alternative forms of housing, such as secondary suites in basements or smaller properties, is a common transitional period for many renters living in cities who lack the finances to purchase their own properties such as students and lower income residents (Goodbrand & Hiller, 2018). However, preconceived notions and stereotypes about the individuals who would live in these spaces are common among opponents of secondary suites. A fear that these less financially secure renters will impact the character of a neighbourhood has been cited as a prevalent concern (Goodbrand & Hiller, 2018). Members of the public were also conscious of the perceptions surrounding laneways as being “unsafe” as they can be used for “illegal” and “questionable” activities (Lanescape & Evergreen, 2017). Laneway homes have the potential to alter public perceptions of these overlooked spaces within a city. Situating renters who are unfairly stereotyped in these spaces could stand to create and reinforce negative views of laneways in the eyes of those opposing laneway housing. However, positive narratives could also be created, and the ramifications of this scenario should be considered.

The idea that societal views of secondary suites may change for the better could lead to alleviation of stress by renters who were previously made to feel undesired. However, this occurrence can also represent a common precondition for gentrification, resulting in these same renters being forced out from experiencing these newfound benefits. Secondary suites do not appear to reduce housing prices but can reduce the rate of increase (Rosol, 2013). A scenario in which secondary suites sparks the chance of amplifying the rate of increasing housing prices. Indeed, this will likely vary on a case to case basis as is true with increases in housing prices (Guerrieri, Hartley, & Hurst, 2013). As was mentioned when discussing the struggle for control over housing development in section *5.2.2*, a focus on which members of the public are benefitting and being disadvantaged by laneway housing development should be a key component of the evaluation of its usefulness as a tool for sustainable urban development. Gentrification and housing prices are additional layers acting to necessitate this focus.

5.5 Limitations of this study

The limitations of this study should be acknowledged. This thesis represents the first research attempting to quantify the potential emissions reducing impacts of laneway housing. Although, it is the hope that these findings will have a positive impact on the scale of laneway housing development going forward it should be recognized that immediate widespread acceptance and adoption of a type of housing that is relatively underdeveloped, and unknown is still unlikely. Further amplifying this unlikelihood is the previously discussed stronghold the private sector has on housing development in Toronto. Even without quantifying the chance of this many laneway houses being built, it can be said with confidence that the odds of their large-scale development across the city is low. However, this study has instead served as an exercise in investigating the potential positive impact this form of housing could have, and in the process contributing to the discussion on why it is important that these living spaces be further pursued going forward.

Other factors further decreasing the chance of rampant and prompt laneway housing development must also be mentioned. Many properties applying for laneway housing development will likely encounter problems deeming them ineligible based on factors that could not be accounted for in the GIS analysis. Geospatial data on the dimensions and proportional land use of properties was not available. This means it was not possible to filter eligible properties down to the ones that would not have to remove large backyard trees and have the necessary space required between the main and secondary buildings. A way to estimate what proportion of properties would fail these criteria was not found.

The time it takes for a laneway house to have its building permit cleared and be subsequently built was also not effectively accounted for. An estimate of the time it would take for this process to be completed is not clear. Calculations on potential energy and transportation related emissions savings were done starting in the very near future however it could be the case that this is too soon of a start date.

Further questions regarding emissions calculations stem from having had to project future low-rise residential development and the uncertainty around the accuracy of these projections. The likelihood of these projections coming to fruition could be affected by factors outside of the scope of the calculations. Toronto could offer increased financial incentives increasing the rate of laneway housing development. On the other hand, public perception could also be negatively swayed by negative impacts of their construction or the logistical constraints of the application and development process. With regards to transportation-related emissions savings, projections were done with the idea that those living in laneway homes would not own a private vehicle which is unlikely as car ownership occurs in 72% of Toronto households (Harris, 2018).

These represent a mere fraction of factors that could play a role. Further research should aim to account for differences in building size, projected emissions savings from an increased transition to a renewable energy supply, and variations in transportation needs based on the location in the city of laneway homes.

This thesis also lacked engagement with relevant actors in the field. This will be overcome once the thesis is published and can be shared with those within in the related network. In particular, it will be sent to several relevant departments within the City of Toronto such as the environment and energy, city planning, and building divisions. The research will also be sent to environmental NGOs and real estate companies collaborating with the city in laneway housing research such as Evergreen, and Lanescape.

5.6 Summary of Recommendations

The City of Toronto will need to address several factors if it hopes to have newly built low-rise residential buildings not be a large detriment to the city reaching its climate goals. As it currently stands, emissions from energy usage in homes are not decreasing at a fast-enough rate. This problem will only become more dire once 2030 is surpassed and the more substantial 2050 goals must be met. Meanwhile, further transportation-related emissions will also need to be addressed. As discussed, standards for newly built homes are not improving their performance at a high enough rate. Although it has the potential to result in substantial reductions, the Energy Star standards are not ambitious enough. The city's goals of having more new buildings be 'net-zero' needs to be pushed for sooner. Shifting from a reliance on flawed standards such as those of Energy Star and LEED to a more stringent one, Passive House, would be a step in the right direction. With regards to transportation, it will be reiterated here that incentives for electric vehicle usage and fuel taxes can both be useful policy tools for lowering emissions in this sector.

The emissions of a building are related to more than just its energy performance. Also important is the makeup of the energy supply that powers the building. From an environmental perspective, the Province of Ontario has done a commendable job in closing multiple coal plants and eliminating the use of coal in its electricity supply (Government of Ontario, 2019). However, the wind and solar energy subset of the renewable energy supply is still quite low only comprising 9% of the province's energy supply. Within Toronto, this is an area that could be focussed on.

The physical requirements of a laneway house are, of course, inherent to having an adjacent laneway on which to build from. However, as outlined in Appendix A, many variations of the housing concept do exist which do not require a laneway. The environmental benefits of downsizing and higher density urban areas are not exclusively attributable to laneway housing. Other forms of secondary suites can have the same impact. Due to the timeliness of the topic and the geospatial characteristics of laneway houses, this particular form of secondary housing in this specific city was logical to research for this thesis. Thus, it should be noted that this research could be duplicated and applied to other urban areas.

6. Conclusion

In conclusion, laneway housing has the potential to greatly reduce the emissions from newly built low-rise residential housing. Urban areas are a key focus in the attempt to reduce global greenhouse gas emissions. As it currently stands, cities are responsible for greater than 70% of the world's emissions. The pursuit of immediate reductions to urban emissions is complicated by the fact that urban populations are expected to rise to 6.5 billion by 2050. This rise will lead to increases in emissions from the building and transportation sectors which are among the largest emitters. This thesis has shown laneway housing to be an immediately available and effective tool to reducing building and transportation-related emissions despite this linkage to sustainability being underdeveloped in Canadian municipal documents. In the particular case of Toronto, laneway housing, in its current iteration of requirements, will not amount to the pursued targets of emission reductions when comparing newly built low-rise residential housing with those built in 1990. Although, reductions were still found to be substantial across the projected scenarios. However, being aware of this will be important in making further reductions in the sub-areas of other sectors and more effectively managing the stock of potential laneway housing which could increase with changes to by-laws which render many properties ineligible for this type of development. Improvements to building standards, incentives for electric vehicle usage, and fuel taxes are proposed as some of the recommendations that would help to further lower the footprint of those living in homes in Toronto.

The repercussions of not reaching the world's vitally necessary greenhouse gas emission targets are incredibly daunting. Sustainability scientists have an obligation to both the environment and society to do all that they can to address our planet's sustainability issues. These stakes are readily apparent and well known to them. While the psychological risks of this burden can be potentially harmful, there should be at least some reassurance from knowing that, sometimes, solutions can be found in our own backyards.

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Appendix A. Alternative and related terms for laneway housing.

Term	Unique Characteristics	Source
Accessory Apartments	Tend to be within the primary dwelling.	(City of Guelph, 2019)
Accessory Dwelling Units	"A small self-contained dwelling, typically with its own entrance, cooking and bathing facilities, that shares the site of a larger, single-unit dwelling."	(Brown & Watkins, 2012; City of Santa Cruz, 2003)
Accessory Unit	Similar characteristics.	(Brown & Watkins, 2012)
Ancillary Unit	Similar characteristics.	(Brown & Watkins, 2012)
Backyard Cottages	Can be contained within a side lot.	(City of Seattle, 2010)
Carriage Houses	Some municipalities allow for carriage houses to be created from previously existing garages.	(City of Penticton, 2012)
Casita	One and two room wood frame structures. A common architectural style in the Carribean.	(Sciorra & Cooper, 1990)
Garden Suite	Similar characteristics.	(Hvozdanski, 1997)
Granny Flats	Small, inexpensive living spaces designed for elderly tenants to live close to their relatives. Term is more commonly used in Australia.	(Folts & Muir, 2002)
In-law Unit	Similar physical characteristics. Intended for extended family.	(MSRC, 2018)
Secondary Dwelling	Similar characteristics.	(Brown & Watkins, 2012)
Secondary Unit	Similar characteristics.	(Brown & Watkins, 2012)

Appendix B: The 20 most populous cities in Canada based on 2017 data retrieved from the Government of Canada (2018b).

City	**Population**	**City**	**Population**
Toronto	6,346,088	London	521,756
Montréal	4,138,254	Halifax	431,701
Vancouver	2,571,262	St. Catharines - Niagara	416,539
Calgary	1,488,841	Oshawa	402,399
Edmonton	1,411,945	Victoria	377,414
Ottawa - Gatineau	1,377,016	Windsor	344,747
Winnipeg	825,713	Saskatoon	244,193
Québec City	812,205	Regina	202,481
Hamilton	787,195	St. John's	186,067
Kitchener - Cambridge - Waterloo	527,765	Sherbrooke	195,028