

Barriers and Drivers to Sustainable Residential Home Construction in Ontario, Canada:

Perspectives from the Construction Sector

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Over the past few decades, the province of Ontario in Canada has seen significant growth in its regions and townships, especially in suburban developments. These developments are within towns and more prominent cities, causing considerable suburban sprawl, in contrast to mid-rise and high-rise developments. The suburban neighbourhood has become more attractive for homebuyers because of the space, privacy, and relatively reduced living expenses while being close enough to major cities for convenient amenities and facilities. The construction industry has taken some initiative to develop more sustainable buildings; however, the focus is mostly on non-residential buildings or residential high-rise developments, but there is limited information on sustainable single-home residential construction. This study aimed to understand the barriers and drivers to sustainable residential construction in Ontario, including knowledge, awareness, familiarity and interest in sustainable residential construction by those who are involved in the sector. A survey was developed based on Rogers' Theory of innovation adoption and included both closed (yes, no, and Likert scale) and open-ended questions. The survey was sent to Ontario companies that are involved in residential construction and included questions on sociodemographic characteristics and the length of time in the industry, as well as questions on knowledge and awareness of existing sustainable construction standards and interest in future sustainable applications within the industry. Findings show that construction industry professionals generally possess the necessary experience, knowledge, and interest in sustainable construction. They identified barriers such as costs of sustainable housing, lack of materials, and lack of homebuyer interest. Drivers included government financial incentives and local by-laws and material availability. Recommendations for promoting sustainable residential home construction include developing a database on sustainable materials, developing green standards at the local level, upgrade the Ontario Building code, and provide life cycle cost benefits of sustainable housing to homebuyers.

Keywords: sustainable homes, neighbourhood developments, third-party sustainability certifiers, residential construction industry, Ontario

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Chapter 1: Introduction

Suburban growth has become prominent throughout Ontario's municipalities and townships (Avantini, 2022). For homebuyers, suburban homes are more attractive than apartments due to the space, safety and privacy they offer for growing families (Booi & Boterman, 2020; Ottensmann, 2020; Pisman et al., 2011). On the social side, these residential developments provide a service for those residents who need a sense of independence and land ownership, making low-density, suburban, detached, semi-detached, or townhouse dwellings with a yard more favoured than high-density living (Norman et al., 2006; Senior et al., 2004). These spacious and private lots make the homeowner feel that they have control and can regulate interpersonal relations amongst neighbours (Senior et al., 2004). Nevertheless, these suburban residential developments also create negative social externalities, such as heavy dependence on cars, where other modes of transportation are unavailable by municipalities or are inefficient due to sprawl, creating additional transportation-related pollution and emissions while increasing human inactivity (Bagley & Mokhtarian, 2002; Craig et al., 2002). Thus, residential housing must be designed to be more sustainable from a social, economic, and environmental perspective.

There are standards that govern residential developments of single detached homes to prepare for home construction. Plots of land are stripped of ecosystems and their associated native species, affecting biodiversity (Rome, 2001, p. 181). Furthermore, the preparation of land for residential properties introduces geographic recontouring, and once built, are comprised of unnatural settings through manicured gardens and lawns (Li et al., 2010; Vimal et al., 2012; Wilson & Chakraborty, 2013). In addition to the direct impacts on the natural environment, the continuous construction of roadways, rooftops, and parking lots has increased stormwater runoff and the runoff of oils, chemicals and other toxins discharged into water sources (Gartner, 1987; House-Peters & Chang, 2011; Wilson & Chakraborty, 2013). There are few mechanisms for mitigating and re-establishing displaced ecosystems. Instead, these drastic changes result in a loss of the natural environment and ecosystem services, and where the natural flora is replaced with a perfect visual aesthetic, requiring chemicals and additives (Gartner, 1987; Vimal et al., 2012; Wilson & Chakraborty, 2013).

This thesis focuses on the barriers and drivers to building sustainable residential housing in Ontario, Canada, specifically single detached homes. The rest of this chapter provides background information on concepts of sustainability in residential housing, as well as existing legislation and practices related to building codes and design.

Defining sustainability in the residential construction industry

The original and long-standing definition of sustainable development is from the Brundtland Report: “Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development (WCED), 1987), which has been interpreted to mean environment protection, social well-being and economic prosperity for all, now and in the future.

Based on a literature review, a list of criteria and principles of sustainable construction definitions is summarize (Table 1.1) categorized across all three pillars of sustainability. Sustainable construction should consider the complete life cycle of construction, from the extraction of raw materials through the planning, design and construction of buildings and infrastructure until their deconstruction and management of residual waste in ways that reduce resource use and waste, use renewable materials, and protects the biosphere (Table 1.1) (Abidin, 2010; Chang et al., 2016; Tan et al., 2011). Further, sustainable construction should be a holistic process aimed at restoring and maintaining harmony between the natural and built environments while creating settlements affirming human dignity and encouraging economic equity’ by equally applying the principles of sustainable development (Du Plessis, 2002, p. 6; Mensah et al., 2020; Zimmermann et al., 2019).

It could be argued that current practices in the residential housing sector are not broadly sustainable; instead, they emphasize those features and principles that provide economic benefits, such as energy efficiency technologies and material and resource efficiencies to reduce costs. There is some evidence of environmental protection, most notably seen in practices that consider the embodied energy of materials, ensure healthy air quality, and prevent biological and ground contaminants (Agyekum et al., 2019; Hammond & Jones, 2008; Hill et al., 1994; Jacobs et al., 2007; Steinemann et al., 2017; Uhde & Salthammer, 2007; Wilson & Chakraborty, 2013; Zhang et al., 2019). However, the construction industry has not yet holistically adopted sustainable construction principles.

Table 1.1: Principles and criteria of sustainable construction based on the three pillars of sustainability: environmental protection, social well-being and economic prosperity (Abidin, 2010; Ahn, 2011; Ahn et al., 2013; Pearce et al., 2017)

Environmental Protection	Social Well-being	Economic Prosperity
• Protecting air, water, and land ecosystems • Conserving natural resources (fossil fuels) • Preserving animal species and genetic diversity • Protecting the biosphere • Using renewable natural resources • Minimizing waste production or disposal • Minimizing CO₂ emissions and other pollutants • Maintaining essential ecological processes and life support systems • Pursuing active recycling • Maintaining the integrity of the environment between humanity and nature	• Improving the quality of life for individuals and society as a whole • Alleviating poverty • Satisfying human needs • Incorporating cultural data into the development • Optimizing social benefits • Improving health, comfort, and well-being • Having concern for inter-generational equity • Minimizing cultural disruption • Providing education services • Promoting harmony among human beings and between humanity and nature • Understanding the importance of social and cultural capital • Understanding multidisciplinary communities	• Improving economic growth • Reducing energy consumption and costs • Raising real income • Improving productivity • Lowering infrastructure costs • Decreasing environmental damage costs • Reducing water consumption and costs • Decreasing health costs • Decreasing absenteeism in organizations • Improving Return on Investments (ROI)

1.1.1 Building Certifications and Sustainable Construction Standards

Although the construction industry in Canada has not yet adopted holistic sustainable construction, there are voluntary third-party certifications used in Canada over the past three decades to support more sustainable construction practices (Appendix A: Third-party certifier's areas of focus of sustainable construction practices). The purpose of a third-party certifier is to provide additional support to the construction and renovation of buildings within a multifaceted sustainability framework, aiming to define, assess, verify, and promote sustainable building practices (Afroz et al., 2020; Zimmermann et al., 2019). The role of third-party certifiers in promoting sustainable construction is to enhance the sustainability of the built environment by establishing, assessing, and verifying green building standards (Zimmermann et al., 2019). Each third-party certifier has independent standards and methods to evaluate sustainability and subsequently award buildings on

how well they measure to their certifier standard. An example of a well-known certification is Leadership in Energy and Environmental Design (LEED), providing general frameworks for building sustainably, but it has been criticized for being process and not performance-based (Afroz et al., 2020); that is, it uses a checklist approach instead of evaluating the performance. Energy Star is a well-known label used heavily in energy efficiency practices such as appliance energy efficiency and works closely with Natural Resources Canada to encourage renewable energy sources and reduce overall building energy consumption (Afroz et al., 2020; Government of Canada, 2021a). Examples of lesser-known and newer certifiers are Living Building Challenge, ambitious regenerative buildings that promote the natural surrounding native environment and are self-sufficient within their site (Fahmy et al., 2019; Rios et al., 2015) or International WELL Building Institute working in alignment with the UN's Sustainable and a significant focus on social well-being (Goubran & Cucuzzella, 2019; United Nations, 2015; Zimmermann et al., 2019). Despite the proliferation of building certification, they are still only optional to implement.

1.1.2 Defining the Construction Industry

For this thesis, 'construction industry' refers to those involved in developing properties, from land purchase to home finishing. The literature does not define construction industry members; however, (Lechner, 2015) provided examples of who these individuals might be (Figure 1.21 **Error! Reference source not found.**), and how they might work together to achieve sustainable housing. Those involved in the construction industry range from architects, who determine the overall design of housing, to engineers who ensure the design is technically feasible, to the suppliers and contractors who build the house.

1.2 Ontario's Residential Construction Industry: Current trends and regulations

Simple light-frame construction is the predominant and preferred type of residential home construction in Ontario, and has been maintained and accommodated for many decades (Branco et al., 2021), which limits and hinders the alternative methods to build sustainable residences. The following highlights the current building types and legislative frameworks guiding residential building construction in Ontario.

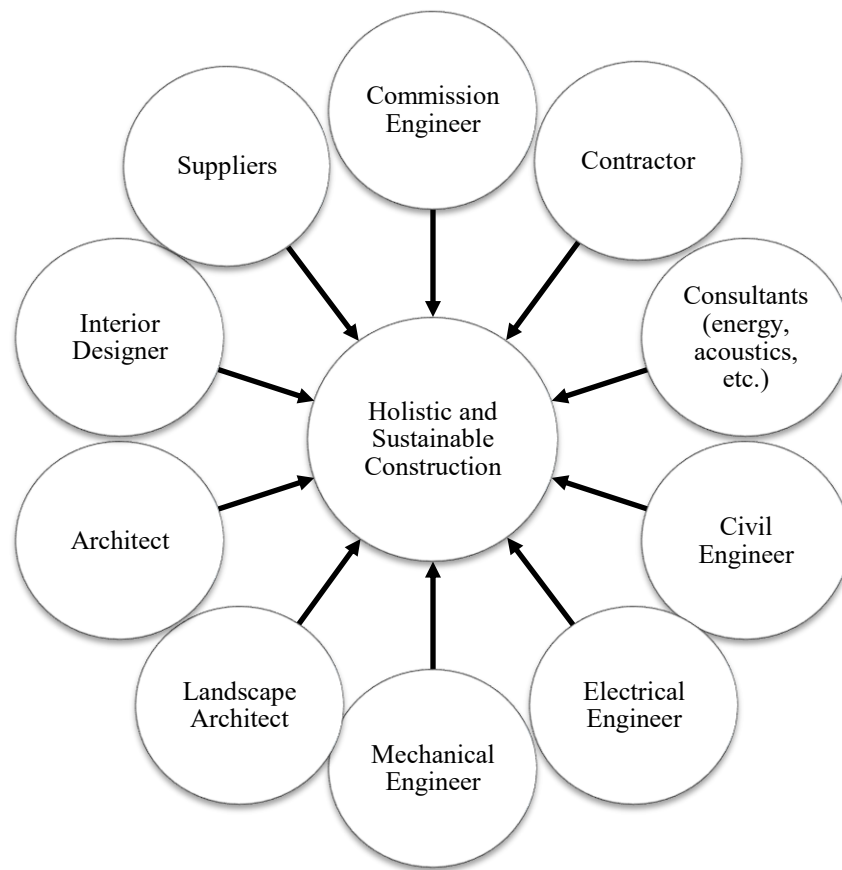


Figure 1.1: Key construction industry members required to implement holistic and sustainable construction (Lechner, 2015)

1.2.1 Residential Land Development in Ontario

Ontario's residential development has continued to contribute to suburban sprawl. Although there is an increase in condominium apartments (Table 1.2), such as in Toronto's Census Metropolitan Areas (CMAs) (59.0%), the preference is still for single detached houses and townhouses in Ontario (Government of Canada, 2021b), making this the most common property type in Ontario. However, this share is gradually declining, especially in highly urbanized downtown cores (Government of Canada, 2021b).

An analysis of the Kitchener-Waterloo area in Ontario shows that from 2005 to 2017, 22,320 residential properties were built (specifically single-detached, semi-detached and townhouses) and 2719 non-residential properties, but only 16 residential properties and 65 non-residential-properties were certified (CaGBC National Office, 2018; Canada, 2017; Geographic Information System (GIS) services of University of Waterloo, 2018b, 2018a). Although there may be sustainably built homes that are not certified, it is unclear whether they exist, or if there is a demand for them, or if the residential construction industry is even thinking about sustainability. Thus, to ensure that sustainable construction is more accessible and normalized (Goubran & Cucuzzella, 2019), it is essential to understand the barriers and drivers to sustainable construction in Ontario.

Table 1.2: Ontario’s Initial Composition in 2019 and net increase of housing stock from 2019 to 2020 (Government of Canada, 2021b)

Property Type	Initial Stock, 2019 (%)	Stock Increase, 2019-2020 (%)
Single-detached	68.2	32.5
Semi-detached	6.7	4.1
Townhouse	9.6	24.6
Condominium Apartment	11.8	38.8
All other property types	3.7	0.0

1.2.2 Current Construction Industry Legislation and their Sustainability Measures

Two principal legislature and programs affect or could guide sustainable building in the construction industry: the Building Code Act; and Ontario’s construction waste diversion program.

The Building Code Act, 1992 (BCA) lays out the legislative framework governing Ontario’s construction, renovation, demolition, and change of building use regulations. The BCA regulation sets technical and administrative requirements, such as standards for public health and safety, fire protection, structural sufficiency, energy conservation, water conservation, environmental integrity, and barrier-free accessibility of buildings. The Building Code Act also allows municipalities to adopt municipal property bylaw standards (Roseland, 1992; Turvey, 2017), which can include standards for maintaining properties within or part of the municipality. The current BCA edition, the 2012 Building Code, was enacted in January 2014. The amendments in 2016, and the most significant updates that encourage sustainability, provide measures for: structurally “solar-ready” roofs and conduits; reduced

trade-offs between the building envelope and heating systems for energy efficiency compliance; heat or energy recovery units in all buildings; greywater reuse systems; proper (passive) ventilation; radon mitigation, and moisture control (Building Code Conservation Advisory Council et al., 2016; Environmental Commissioner of Ontario et al., 2017; Natural Resources Canada, 2012; Wodchis, 2017). The amendments in the Ontario Building Code (OBC) reflect government priorities, innovations in construction and design, changes in jurisdictions, emerging issues, and Coroner's jury recommendations (OBC, 2016). These updates reflect various stakeholder perspectives, including those in the construction industry, and signify the province's preparedness for the future and making homes ready to be "net-zero" (Government of Ontario, 2016). Nevertheless, these are optional aspects of the building code.

A closely related program is Ontario's construction waste diversion program (Environmental Protection Act, 1999). Homebuilding generates substantial quantities of waste, including both hazardous and non-hazardous materials. As of 2016, Ontario generated approximately 14.2 million tonnes of waste attributed to construction, renovation, and demolition activities, resulting in the emission of nearly 2 million tonnes of carbon dioxide. (Government of Canada, 2020). Though this waste is collected, 88% of it is disposed at landfills, and only 12% is diverted (Government of Canada, 2020). Many construction materials are mixed, coated, or sealed with other materials, making it harder to separate and recycle the raw material (concrete with steel reinforcing bar).

1.3 Problem Statement and Research Approach

The Planetary Boundary framework shows that we are approaching or exceeding limits in terms of land use, water, climate change, and biodiversity loss (Steffen et al., 2015). The building sector, from cradle-to-grave, is responsible for a large contribution to exceeding planetary boundaries, through land change, fossil fuel use, etc. There are many opportunities to build more sustainable single-detached residential buildings in Ontario, from available technologies and design to guidelines from certifications and the Building Code, yet this is not common practice in Ontario. Thus, this thesis aims to investigate the barriers and drivers to achieving sustainable single-detached housing through the perspectives of the residential construction sector. The barriers and drivers are both internal (e.g. characteristics of individuals, practices) and external (consumers, government) to the sector. The following sections provide the theoretical framework and research contributions of the study.

1.3.1 Theoretical Framework for Research and Rogers' Theory of Diffusion of Innovation

The theoretical framework used in this research, described in the following sections, is Rogers' Theory of Diffusion of Innovation, specifically the five stages of the innovation-decision process. An innovation is any concept, practice, or object perceived as new by an individual or group adopting it (Rogers, 1983). According to Rogers, an innovation is an idea, practice, or object perceived as new by an individual or other adoption unit (Rogers, 1983). For the purposes of this thesis, this definition could include everything from materials, technologies and practices within sustainable construction, as an innovation (Ahn et al., 2013).

Generally, Rogers' Theory of Diffusion of Innovation explains how, why, and at what rate innovations (e.g. new ideas, programs, practices, or technologies) are adopted (Rogers, 1983). Adopters are individuals (or other decision-making units) that have decided to try and adopt an innovation (Meyer, 2004; Rogers, 1983, 2003). According to the theory, diffusion is the process by which an innovation is adopted over time through specific communication channels among individuals within a social system (Rogers, 1983, 2003). Communication channels are the means by which information about the innovation is shared among individuals (Rogers, 1983, 2003). Communication can lead to either convergence or divergence among individuals when discussing an innovation (Rogers, 1983, 2003). Rogers defines convergence as the process where people align their perspectives or opinions from the shared information with each other, while divergence occurs when differing opinions cause them to drift apart. This process is interactive, emphasizing that communication is a two-way exchange rather than just message delivery (Rogers, 1983, 2003).

Everett Rogers initially conceptualized the diffusion of innovation theory to understand the adoption and implementation of new ideas, processes, products, or services (Lundblad, 2003; Rogers, 1983; Sahin, 2006). Roger's Theory of Diffusion of Innovation helps capture a broad idea of what knowledge is to be adopted by individuals and has been applied and tested in various fields such as sociology, education, psychology, geography, and others (Orr, 2003; Straub, 2009). This theory looks specifically at trends and innovations, the individuals who are the first to adopt them, and how society acts and reacts to these changes (Rogers, 1983; Sahin, 2006). Although Rogers originally conceived of the theory for an individual (of a 'decision-making unit' to consider decisions made at the household level), the theory was eventually developed to understand innovation adoption in

organizations. The following sections highlight the main ideas from the theory for each of these situations.

1.3.1.1 Innovation for Individuals: Five Stages of Innovation-Decision Process

The innovation-diffusion process is the process through which an individual (or other decision-making units) passes from getting knowledge of an innovation to forming an attitude toward the innovation (persuasion) to a decision to adopt or reject the innovation, and then finally to implementation of the innovation and confirmation (seeking reinforcement of an innovation-decision that has already been made, but they may reverse this previous decision if exposed to conflicting messages about the innovation) for decision-adoption or rejection of innovation (Rogers, 1983, 2003).

The preliminary stage and the five stages of Roger's' Innovation-Decision Process are briefly mentioned here and described in detail in the following sections. Before the five stages, there is the concept of "Prior Conditions". In stage one, an individual becomes aware of the innovation and learns more about it. The individual's characteristics, such as socioeconomic status, personality variables, and communication behaviour, determine when an individual might adopt an innovation. In the second stage, persuasion, an individual gains enough knowledge about the innovation's characteristics and advantages and judges whether to consider it. Stage three portrays the outcome of the individual's choice, whether they adopt or reject the innovation. The innovation is then implemented in stage four. Stage five closes out the process with confirmation through each individual's reflection on their implementation decision and evaluates their decision to continue or discontinue the innovation adoption (Rogers, 1983; Straub, 2009).

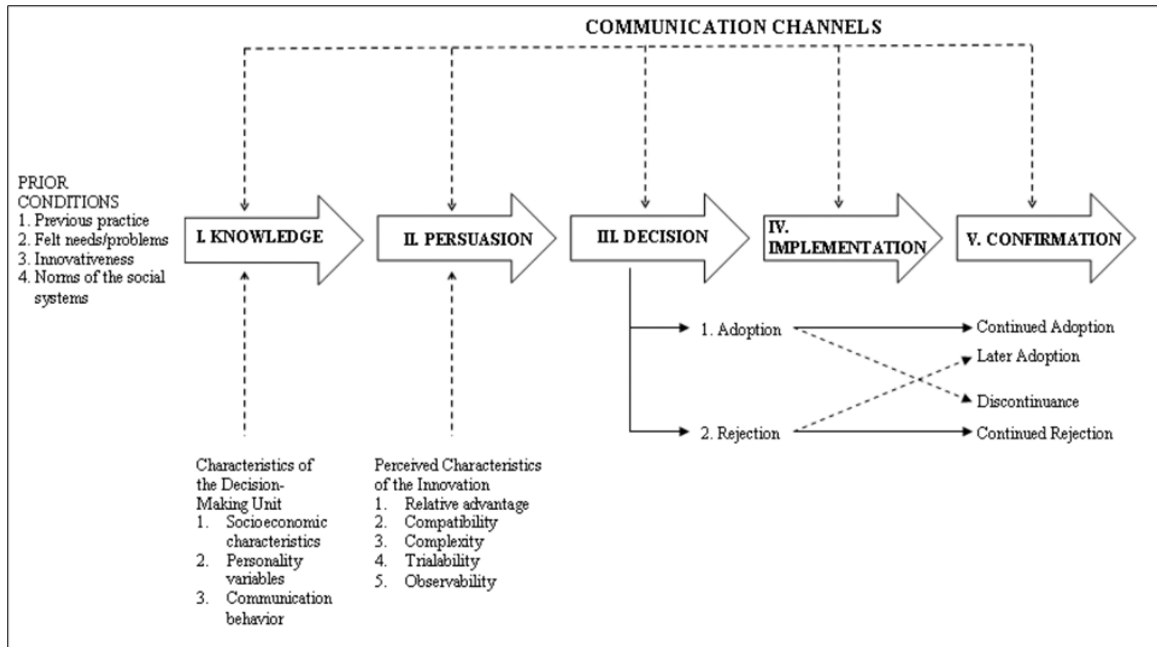


Figure 1.2: A Model of the Five Stages in the Innovation-Decision Process (Rogers, 1983, 2003).

For the purposes of this research, only the ‘Prior conditions’, and Stage 1 (Knowledge) and Stage 2 (Persuasion) are described further, as this research is exploratory in trying to understand the barriers and drivers to adopting the ‘innovation’ of ‘sustainable residential construction’ by the construction sector.

1.3.1.1.1 Prior Conditions

A major precursor and strong influencer on adoption is the concept of ‘prior conditions,’ which refers to the existing conditions faced by the decision-maker, including what the decision-maker already does (previous practice), whether the existing system is performing well (felt needs/problems), the innovativeness of the decision-maker, and the norms of the social system (Rogers, 1983). Previous practice refers to the existing behaviours, methods, or technologies that individuals or groups are accustomed to before introducing an innovation (Rogers, 1983, 2003). Felt needs or problems are the perceived deficiencies or challenges experienced by individuals or groups within a community or society (Rogers, 1983, 2003). Rogers also mentions that needs or problems are subjective and therefore are difficult to measure. Finally, social norms are established behaviours, beliefs, values, and expectations that guide the conduct of individuals within a particular social group or community (Rogers, 1983, 2003). These norms serve as informal guides that govern acceptable or appropriate

behaviour within the social context (Rogers, 1983, 2003). Social norms significantly influence adoption; for example, innovations more aligned with prevailing norms are accepted, while those conflicting with norms are more likely to be rejected (Rogers, 1983, 2003).

Table 1.3 defines the elements of the prior conditions and provides examples of what each might look like in the construction industry. It is important to note that the literature examples did not use Rogers' Theory of Diffusion of Innovation, but rather were used to provide examples of prior conditions within the construction industry. Innovativeness is the degree to which an individual or unit adopts new ideas earlier than other system members (Rogers, 2003; Tellis et al., 2009). By establishing this foundation, the decision-making process starts to move forward into the five main stages.

Table 1.3: Rogers' Diffusion of Innovation Theory: Examples of prior conditions associated with the construction industry.

Prior Condition	Examples
Previous Practices	(Afshari et al., 2016) evaluated barriers to greening existing buildings using LEED. They addressed existing and traditional construction as well as the behaviours that provide a baseline for achieving renovated buildings to a green standard comparable to sustainably constructed buildings.
Felt Needs or Problems	Abdelaal & Guo (2021), Ahn et al. (2013) and Darko & Chan (2017) each independently report the negative impact that current buildings have on the environment in terms of construction and performance- thereby identifying a need or problem to start addressing ways to build more sustainably.
Innovativeness	In their study, Da Silva and Ruwanpura (2009) observed Canadian building projects pursuing LEED certification. They noted that achieving specific LEED points, especially those requiring advanced technologies or innovative approaches, can be particularly challenging. Industry members who choose these complex credits demonstrate innovativeness by pushing boundaries to adopt sustainable construction methods effectively (Da Silva & Ruwanpura, 2009).
Established Social Norms	(Darko & Chan, 2017) stated that a barrier to adopting sustainable construction practices is the lack of importance attached by the leaders. Leaders serve as change agents who influence workers' behaviours toward adopting sustainable construction practices. Within the same domain, (Ahn et al., 2013) state that project managers and superintendent-leaders should seek ways to motivate their subcontractors to adopt sustainable practices during the construction project and in their daily lives.

1.3.1.1.2 Stage 1: Knowledge

In this stage an individual becomes aware of an innovation and learns how it works (Rogers, 2003). The types of knowledge related to innovation-diffusion are: awareness knowledge (knowing an innovation exists); how-to knowledge (knowing how to appropriately use an innovation); and principles knowledge (knowing why a strategy works) (Henderson, 2005; Rogers, 1983, 2003).

During the knowledge phase of the innovation-diffusion process, there are three characteristics of decision-making units that are important in determining whether they will adopt or reject the innovation in the following stages (Rogers, 1983, 2003).

In the knowledge stage of the decision-making process, there are three characteristics of an adopter-an individual or other decision-making unit: (1) socioeconomic characteristics, (2) personality variables, and (3) communication behaviour (Rogers, 1983, 2003). Since the knowledge stage only introduces the individual to innovation, these characteristics determine the type of adopter (Rogers, 1983, 2003). Rogers bases these characteristics on previous research where behaviour patterns were recorded and summarized as “generalizations” (Rogers, 1983, 2003).

The socioeconomic characteristics of adopters can help impact the adoption of innovations. Generalization 7-5 states that those with more education and higher social status have a more favourable attitude toward innovations (Rogers, 1983). For example, (Symes & Pauwels, 1999) conducted a study on the diffusion of innovations in urban design and the sustainability of the Hulme development guide and found that if an idea came from university research, junior or younger members of the profession were more likely to be early adopters, while some of the older planning committee members in the local authority would be laggards. Due to the uncertainty of measuring personality variables such as innovativeness and opinion leadership, which include variability in individuals' perceptions and biases (Rogers, 1983; Valente & Pumpuang, 2007), these variables were not further researched or included in this study.

Communication behaviour refers to how individuals (or other decision-making units) share, receive, and process information about an innovation (Rogers, 1983). An example of communication behaviour is Generalization 7-24, which states that early adopters are highly interconnected in social systems, seek information about innovations more actively, have more advanced knowledge, and have higher opinion leadership than later adopters (Rogers, 1983). Adopters who are considered by their social group to be opinion leaders have significant influence over the attitudes, beliefs, and behaviours of others within a particular social group or community (Rogers, 1983, 2003). As an example, (Ahn et al., 2013) found that project managers within the construction industry were driving innovation adoption, not only seeking more information on sustainable construction themselves but also urging further education of their subcontractors. Although understanding the communication

behaviours of individuals in the construction industry is important to understanding the knowledge phase, this aspect was not considered in this research.

1.3.1.1.3 Stage 2: Persuasion

During the persuasion stage, the important aspects are the perceived characteristics of the innovation, which are those attributes that potential adopters use to evaluate whether to adopt an innovation (Rogers, 1983). By this stage, the individual knows about and is interested in the innovation and actively seeks information and details about the benefits of the innovation (Rogers, 1983). The characteristics of innovations are (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability.

Relative advantage refers to the degree to which an innovation is perceived as superior to the idea it replaces. Relative advantage can be measured economically, but social prestige, convenience, and satisfaction also play crucial roles (Rogers, 1983). For instance, this might involve implementing sustainability measures to enhance the efficiency of buildings, leading to long-term cost savings (Darko & Chan, 2017; Singh et al., 2019). It has also been found that construction industry members may embrace sustainable practices to elevate their status or enhance their public image (Abdelaal & Guo, 2021; Oke et al., 2019; Ruparathna & Hewage, 2015).

Compatibility is the degree to which an innovation is perceived as consistent with potential adopters' values, experience, and needs (Rogers, 1983, 2003). Innovations that align with a social system's values and needs are adopted more quickly than incompatible ones (Rogers, 1983, 2003). According to (Rogers, 1983), adopting an incompatible innovation may require the prior adoption of a new value system. (Ahn et al., 2013) discuss the fear of changing standard construction schedules and practices, disrupting their experience, when implementing innovations in sustainable construction. The authors also noted that most respondents/participants viewed less drastic shifts in current construction schedules favourably, making it possible to introduce sustainable practices seamlessly into the new standards.

Complexity is the degree to which an innovation is perceived as challenging to understand and use. Depending on prior conditions and the type of innovation, it may be easy or more challenging to adopt an innovation, affecting the likelihood that it will be adopted quickly, if at all (Rogers, 1983). In the construction industry, newer and innovative materials and sustainable construction methods require special skills, more learning and practice for installation, maintenance and use, which will

cause disadvantages relative to existing products and practices (Koebel et al., 2015; Sanderford et al., 2015).

Trialability refers to the degree to which an innovation can be experimented with on a limited basis. Innovations that can be tested in stages are usually adopted faster than those that cannot (Rogers, 1983). The case study by (Bristow & Bristow, 2017) focuses on retrofitting sustainable versions of average homes, including energy supply, greenhouse emissions and transportation. Homeowners could compare the impact of a "battery electric vehicle" versus their standard "internal combustion engine car" on energy use and emission production (Bristow & Bristow, 2017). In this case, high costs currently hinder adoption, but the approach used in the study explains that to overcome this barrier, further demonstrations and trials showcase that these retrofits are cost-effective and beneficial in the long run (Bristow & Bristow, 2017). In another study, (Singh et al., 2019) tried to understand the barriers to adopting net-zero energy homes by 271 participants in a net-zero energy housing demonstration project in Toronto, Canada. This study found that one of the main reasons future homeowners hesitated to purchase a net-zero home was that they did not know anyone who already had a net-zero home to influence them in making such a significant financial decision.

Observability refers to the extent to which an innovation's outcomes are apparent to others- the more visible an innovation's results are to individuals, the more likely they are to adopt it. This visibility encourages peer discussions about a new idea as friends and neighbours of an adopter seek information about how the innovation has performed (Rogers, 1983). A study by (Rehkopf et al., 2016) assessed the societal impact of the eco-home in Kitchener, Ontario, known as the Residential Energy Efficiency Program (REEP) House for Sustainable Living. By making places like this accessible to the public and providing educational materials, exhibitions and tours, prospective homebuyers and homeowners can comprehend the environmental impact of their homes before making any upgrades and allow them to visualize their potential impact on the environment (Pinkse & Dommisse, 2009).

1.3.1.2 Innovation in Organizations

Although innovation adoption can be evaluated on the scale of an individual, a group or an organization, there are distinct differences when analyzing individual and organizational decisions related to innovation adoption. Rogers defined an organization as a stable system of individuals who work together to achieve a common goal through the hierarchy of ranks and a division of labour

(Rogers, 1983). There are two major aspects of innovation in organizations: 1) the concept of organizational innovativeness, or the characteristics associated with innovation adoption in organizations; and 2) the process by which organizations adopt. Since this thesis is not considering the adoption process itself, but rather trying to understand the lack of sustainable practices in the Ontario construction sector, a brief explanation of only organizational innovativeness is provided.

There are unique aspects of organizations that determine how innovative they are. The degree to which power and control in a system are concentrated in the hands of a few individuals, or centralization, negatively affects innovation (Figure 1.3) (Rogers, 1983, p. 360). Complexity refers to the degree to which an organization's members possess a reasonably high level of experience, formal training, professionalism and competence in various occupational specialties and is usually positively associated with innovation (Rogers, 1983, p. 360).

Other organizational characteristics have parallels with characteristics found in innovative people and innovative organizations (Rogers, 1983, p. 356). For example, larger companies were more innovative, because they have more financial resources, similar to higher incomes being associated with innovative individuals (Darko & Chan, 2017; Rogers, 1983, p. 356). Another organizational characteristic, system openness-defined as the degree to which members of a system are connected to other individuals outside the system was found to be positively related to organizational innovativeness (Rogers, 1983, p. 356), similar to Generalization 7-24, which states that individual early adopters are highly interconnected in social systems.

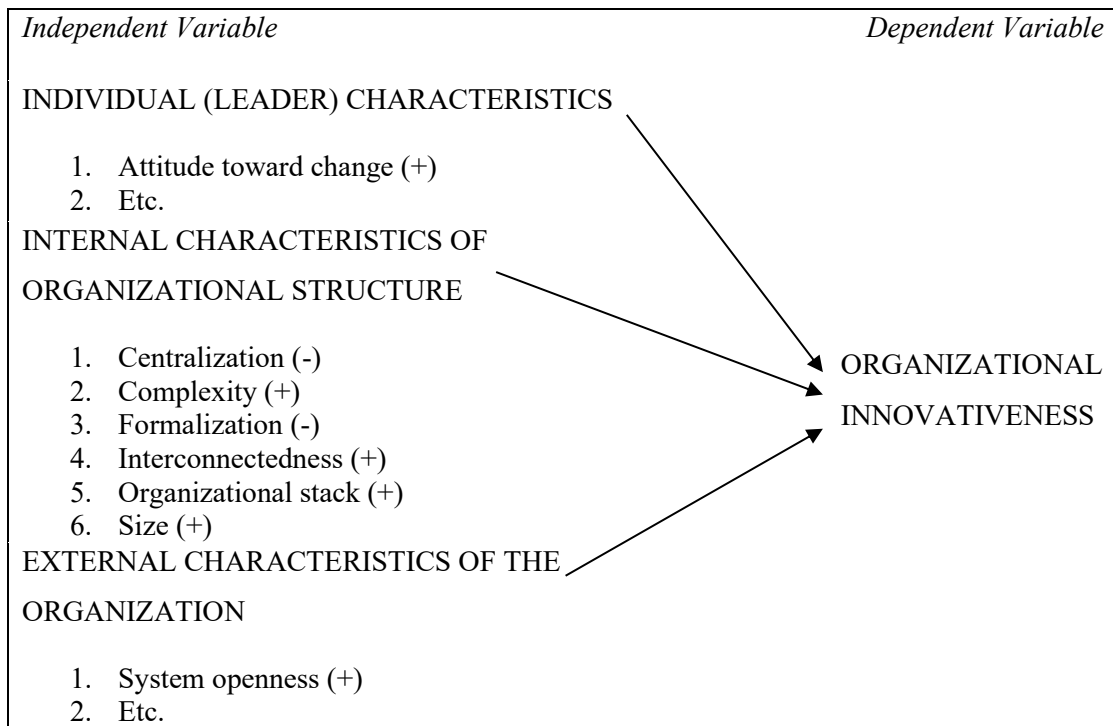


Figure 1.3: Independent variables related to organizational innovativeness (Rogers, 1983). A positive relationship between the characteristic and organizational innovativeness is indicated with a plus (+), while a minus (-) sign indicates a negative relationship.

1.3.2 Research Contribution and Objectives

This research contributes to knowledge of practices and perspectives of the residential construction industry on sustainable construction of residential buildings in Ontario. The aim of this study is to understand the barriers and drivers associated with constructing more sustainable new-build residential homes in southern Ontario. This research has the following specific objectives:

1. To identify the sustainability practices/methods currently implemented in the residential home construction sector (Prior Conditions);
2. To determine the level of awareness/knowledge of sustainability practices and features in the residential home construction sector (Knowledge) and relate this to socioeconomic characteristics;
3. To identify communication channels used to obtain knowledge and information of sustainability knowledge and practices in the residential home construction sector; and

4. To determine factors (barriers and drivers) affecting the implementation of sustainability in residential home construction (Persuasion: Perceived Characteristics of the Innovation)

1.4 Thesis Structure

Chapter 2 of the thesis is a literature review summarizing three essential topics relating to applying theory to this study of Ontario's current sustainable development practices and the sustainable construction market barriers and drivers. Chapter 3 describes the methodology used to achieve the aims of this study. The study results are presented in Chapter 4 and discussed in Chapter 5. The final chapter (Chapter 6) summarizes the thesis's impacts and provides suggestions for future work.

Chapter 2: Literature Review

This literature review covers: 1) factors that can affect the adoption of sustainable residential home construction based on previous studies with diverse geographical locations, market limitations, policy support, and various industry members with differing knowledge, attitudes, and sustainable construction practices; and 2) studies broadly related to sustainable housing within Canada.

This section covers factors related to adopting sustainable construction. Each factor can be seen as either being a barrier or driver depending on whether it prevents or promotes the adoption (Pitt et al., 2009). Based on (Saleh & Alalouch, 2015) table of classifications of the significant potential challenges to sustainable construction in Oman, the factors were organized into categories (Table 2.1), and additional potential factors were added and renamed based on a review of additional studies into the following categories: Financial, Sector Capacity / Professional, Technological and Material and Societal. The remainder of the literature review addresses how each factor affects the adoption of sustainable construction practices.

Table 2.1: Breakdown of factors adapted from categories and challenges identified by Saleh & Alalouch (2015) and modified based on additional literature.

Category	Factors	Additional References
Financial	Upfront costs and investment	(Hwang et al., 2018; Pham et al., 2019; Saleh & Alalouch, 2015)
	Slow return on investments (long payback period)	(Hwang et al., 2018; Saleh & Alalouch, 2015)
	Financial incentives or mechanism	(Gupta et al., 2017; Hwang et al., 2018)
Sector Capacity / Professional	General knowledge of sustainability	(Abdelaal & Guo, 2021; Gupta et al., 2017; Hwang et al., 2018)
	Quantitative evaluation tools	(Saleh & Alalouch, 2015)
	Building codes and regulation	(Saleh & Alalouch, 2015)
	Professional capacity	(Saleh & Alalouch, 2015)
	Human resources and specialists in sustainable construction	(Pham et al., 2019)
	Adopting new practices, methods, processes, and scheduling risks	(Gupta et al., 2017; Hwang et al., 2018; Pham et al., 2019)
Technological and Material	Availability of sustainable materials, resources, and technology availability	(Pham et al., 2019; Saleh & Alalouch, 2015)
	Understanding and training of sustainable technology and practices training	(Pham et al., 2019; Saleh & Alalouch, 2015)
Societal	Government (Local) support or promotion	(Gupta et al., 2017; Hwang et al., 2018)
	Stakeholder awareness and knowledge	(Hwang et al., 2018; Saleh & Alalouch, 2015)
	Demand	(Pham et al., 2019)
	Coordination and communication among stakeholders	(Pham et al., 2019)

2.1.1 Financial Factors

Cost is one of the most reported barriers to sustainable construction adoption. For example, Singh et al. (2019) examined the adoption of net-zero homes in Ontario, through a survey of 271 potential

homeowners viewing a net zero energy housing demonstration project in Toronto, Canada. A major barrier to homeowners was the extra upfront cost compared to a conventional home. The additional costs related to sustainable building technologies include installation that conforms to design specifications, and higher labour costs for specialists and certification (Darko & Chan, 2017). It has also been suggested that most investments in sustainable construction are made in procuring new equipment and educating the current workforce to be skilled and knowledgeable in sustainable construction (Ahn et al., 2013; Darko & Chan, 2017). Furthermore, developers still hesitate to invest in sustainable construction practices due to the lack of research on the financial benefits and slow return on investment (Afroz et al., 2020; Ahn et al., 2013; Bond, 2011). Serpell et al. (2013) suggest that these initial investments may result in a loss of their profit margin for construction firms, and affecting the return on investment, even though in the long run, these features could reduce cost of operation for the homeowners (Bond, 2011; Singh et al., 2019). According to (Afroz et al., 2020), overcoming this barrier requires analyzing the financial benefits of sustainable construction that can be presented to developers to understand the long-term return on investment.

Because of the high upfront cost and return on investment, financial incentives or financing mechanisms are provided to ease the financial strain on the construction industry (Hwang et al., 2018; Pitt et al., 2009; Ruparathna & Hewage, 2015; Singh et al., 2019). Hwang and Tan (2012) identified that financial incentives could encourage developers to invest in sustainable construction practices. The literature is vague on the exact source of such mechanisms, with only a few stating that the government should provide incentives or financing (Abdelaal & Guo, 2021; Zou & Yang, 2014). Furthermore, Gupta et al. (2017) suggest incorporating financial incentives into building codes to promote sustainable construction practices. Studies do not provide further insight into any source of financing but still view it as a significant factor in sustainable construction.

2.1.2 Sector Capacity and Professional Factors

One factor affecting the adoption of sustainable construction is the capacity or professional capability to collaborate towards a common goal of developing sustainable homes. Addressing knowledge gaps and ensuring a shared understanding of sustainability among members of the construction industry, such as project managers (Hwang & Ng, 2013) and governments, can lead to greater sustainability and increased public support for sustainable development initiatives (Atmoko et al., 2019; Hwang & Ng, 2013). Other studies also note that knowledge gaps can hinder sustainability, where the lack of

understanding of the term 'sustainable' can lead to confusion and misunderstandings primarily among members of the construction industry (Abdelaal & Guo, 2021; Gupta et al., 2017) and also with governing bodies and homebuyers (Herremans & Reid, 2002). Knowledge gaps can hinder the development of sustainable housing (Bond, 2011; Issa et al., 2010), create unsustainable solutions (Chang et al., 2018; Samari et al., 2013) or lead to inconsistent implementation of sustainable urban development initiatives (Herremans & Reid, 2002; Hwang & Ng, 2013; Oke et al., 2019; Ololade & Rametse, 2018; Zou & Yang, 2014).

Through sharing knowledge and practice, third-party certifiers may help the construction industry adopt sustainable construction practices. Afshari et al. (2016) studied the greening of existing buildings using the Leadership in Energy and Environmental Design (LEED) rating system and emphasized the importance of regulations in promoting green building practices in Canada. However, these systems are voluntary. Sustainable building codes and regulations can incentivize developers to incorporate sustainable features into their newly built residential suburban neighbourhoods (Hwang & Tan, 2012). As such, construction standards could, by law, incorporate sustainability aspects in these certifications, such as net zero or lean construction, making sustainable building a requirement (Singh et al., 2019). Furthermore, various studies have suggested that governments promote third-party certifiers who have researched and developed frameworks, benchmarking and assessment tools for their sustainable construction method (Hwang et al., 2018; Oke et al., 2019), and that green building practices in Canada undergo third-party certification systems to maintain the credibility of sustainability (Da Silva & Ruwanpura, 2009; Issa et al., 2010).

Professional capacity may depend on the company's size. Company size is significant to adopting sustainable construction practices, though not extensively addressed. Some studies have shown that larger companies are more likely to implement sustainable construction practices due to their greater access to resources and ability to invest in research, technology and development (Chang et al., 2018; Darko & Chan, 2017). Additionally, larger companies can influence industry norms and standards, which can impact the adoption of sustainable practices across the industry (Serpell et al., 2013). Because of these advantages, larger companies have more expertise and knowledge about sustainable construction practices, which can be shared with other companies and construction industry members. However, Darko and Chan (2017) also argue that smaller companies may have advantages in adopting sustainable practices, as they may have more flexibility and agility to adapt to changes in the industry. Smaller companies may also focus more on sustainability due to their closer ties to the local

community and greater attention to customer needs. The availability of trained human resources and specialists in sustainable construction is essential for successfully implementing sustainable construction practices. Sustainable technology and practices training can equip these specialists with the skills and knowledge to implement sustainable construction practices effectively (Abdelaal & Guo, 2021; Afshari et al., 2016; Hwang et al., 2018). This training can include how to use sustainable materials and resources, achieve energy efficiency, waste reduction, and implement green building certification programs (Bond, 2011; Choi, 2009; Ololade & Rametse, 2018; Pham et al., 2019). By training specialists in sustainable construction, the construction industry can promote the adoption of sustainable construction practices and contribute to the development of sustainable new build residential suburban neighbourhoods (Darko & Chan, 2017; Herremans & Reid, 2002; Hwang & Ng, 2013; Oke et al., 2019).

Leadership is also essential for sustainable adoption and project success. Effective leadership can further influence the workforce's adoption of sustainable building practices (Choi, 2009; Oke et al., 2019). Leadership can also play a critical role in implementing sustainable construction practices, but leaders must possess the necessary skills and knowledge to achieve sustainability goals (Atmoko et al., 2019; Zhang et al., 2019). Darko and Chan (2017) note that leadership is a critical success factor in adopting sustainable construction projects.

A major challenge is that adopting new practices, methods, and processes can require significant changes to project schedules, often leading to delays and increased costs (Afshari et al., 2016; Pham et al., 2019). In addition, Hwang et al. (2018) and Nahmens and Ikuma (2012) point out that the learning curve associated with adopting new sustainable construction practices can further extend project timelines. These scheduling risks may be exacerbated by the need for specialized training and human resources and the potential for compromises in visual aesthetics in favour of functional sustainability. Despite these challenges, the potential benefits of sustainable residential construction make it a worthwhile endeavour for those willing to navigate the associated scheduling risks.

2.1.3 Technological and Material Factors

Training workers mitigates sustainable development challenges by equipping them with skills for informed decisions on sustainable technologies (Darko & Chan, 2017). Adopting sustainable construction strategies requires training on the use of their materials and resources for effective

implementation (Bond, 2011; Hwang et al., 2018; Nahmens & Ikuma, 2012). Nonetheless, access to materials, resources, and technology for sustainable construction, as well as training and education in sustainable practices, is crucial for the effective use of these materials and technologies (Abdelaal & Guo, 2021; Afshari et al., 2016).

The availability and accessibility of sustainable materials and resources are essential because they can help to meet green building standards, reduce the carbon footprint of buildings, and promote a circular economy (Armstrong et al., 2018; Bond, 2011). Additionally, the use of sustainable materials and resources can lead to reduced energy consumption (Hwang & Ng, 2013), improved indoor air quality, increased occupant satisfaction (Pham et al., 2019), and enhanced productivity (Samari et al., 2013), among other benefits. However, there is a risk of achieving sustainability at the cost of aesthetics, which can reduce the attractiveness of sustainable homes (Darko & Chan, 2017). Striking a balance between visual aesthetics and sustainability is crucial for the success of sustainable newly built residential suburban neighbourhoods (Hwang et al., 2018). This can be achieved by carefully considering materials and design choices, as well as utilizing sustainable construction practices and technologies (Hwang et al., 2018). Ultimately, balancing visual aesthetics and sustainability requires a holistic approach to sustainable construction that considers the needs of the environment, occupants, and the broader community.

2.1.4 Societal

Societal factors heavily determine whether sustainable construction is adopted. Societal barriers encompass three significant stakeholders groups in the construction development industry: construction sector members, homebuyers, and policymakers. This section focuses on the latter two. People with varying backgrounds, experiences, and attitudes have different levels of understanding and compliance with sustainable construction (Abdelaal & Guo, 2021; Ololade & Rametse, 2018). Many studies emphasize the importance of construction stakeholder engagement in developing sustainable residential communities (Abdelaal & Guo, 2021; Armstrong et al., 2018; Chang et al., 2018; Hwang et al., 2018). When stakeholders are aware of and interested in sustainability initiatives, they are more likely to engage in the development and implementation of such projects, actively leading to increased stakeholder participation and collaboration (Abdelaal & Guo, 2021; Afshari et al., 2016; Hwang et al., 2018; Hwang & Ng, 2013; Saleh & Alalouch, 2015). Thus, addressing

knowledge gaps and ensuring a shared understanding of sustainability among stakeholders should lead to greater sustainability and increased public support for sustainable construction initiatives.

Since governing bodies create construction regulations, government support and promotion are significant factors in sustainable construction. Policies rewarding sustainable initiatives can positively influence knowledge and attitude toward green building design and assessment (Abdelaal & Guo, 2021; Hwang et al., 2018; Hwang & Tan, 2012). There is also an emphasis on the importance of local governments supporting and promoting sustainable residential construction, as they may have more flexibility and autonomy in implementing policies and providing incentives to promote sustainable building practices (Hwang & Tan, 2012). For example, local governments cover smaller, tighter communities that influence construction industry members and homebuyers to gain interest and adopt sustainable construction. Local government support and promotion can significantly enhance sustainable residential construction by offering incentives like tax credits, grants, and rebates to developers incorporating sustainable features into their projects, enforcing sustainable building codes and regulations, and advocating for third-party certifiers, as evidenced by studies from various countries, including Chile (Serpell et al., 2013), Oman (Saleh & Alalouch, 2015), Zambia (Oke et al., 2019), and Indonesia (Atmoko et al., 2019), which underscore the importance of government support and sustainability policies as vital components for developing policy strategies that support sustainability of both public and residential buildings (Abdelaal & Guo, 2021; Atmoko et al., 2019; Darko & Chan, 2017; Gupta et al., 2017; Hwang et al., 2018; Hwang & Tan, 2012; Oke et al., 2019; Olanipekun et al., 2017; Samari et al., 2013; Serpell et al., 2013; Zhang et al., 2019; Zou & Yang, 2014). Finally, Zhang et al. (2019) surveyed the status and challenges of green building development in various countries, including Canada, and suggested the need for supportive government policies to promote sustainable construction development.

(Armstrong et al., 2018) suggest that the problem is an information deficit when homebuyers are often critical of the information they receive about sustainable housing and, therefore, reject sustainable housing. Thus, understanding stakeholder demand can contribute to developing more sustainably successful communities (Abdelaal & Guo, 2021; Afshari et al., 2016; Bond, 2011; Zou & Yang, 2014). Demand can be generated by educating the public about the importance of sustainable construction development (Hwang & Tan, 2012), while demand can lead to increased awareness of social and environmental issues (Hwang et al., 2018). Stakeholder demand for sustainable homes can heavily influence their adoption, and educating the public about the importance of sustainable

housing should generate greater demand while increasing awareness of social and environmental issues.

Sustainable residential construction development depends on a high level of coordination, collaboration and communication among construction industry members (Oke et al., 2019).

However, it is essential to engage other stakeholders- homebuyers, as it can lead to greater social and economic sustainability (Ahn et al., 2013; Armstrong et al., 2018; Choi, 2009; Pham et al., 2019).

Hwang and Ng (2013) also add that stakeholder participation can lead to more significant public support for sustainable development initiatives. Engaging future homebuyers in the development and implementation of sustainable communities can lead to greater sustainability and increased public support for sustainable development initiatives.

The location of residential developments is a factor in adopting sustainable practices. Suburban locations are often associated with sprawl and dependence on automobiles, which can lead to high energy consumption and greenhouse gas emissions- while urban locations may be more sustainable due to their proximity to public transit and amenities, which can reduce energy consumption and promote a more sustainable lifestyle (Afshari et al., 2016). The location also determines whether the project can access sustainable materials, resources and technologies (Darko & Chan, 2017). For example, the closer a suburban project location is to urban areas, the greater access to sustainable building materials and technologies is which due to their proximity to suppliers and manufacturers (Darko & Chan, 2017).

A sustainable neighbourhood's success depends on the type of building constructed. The varying types of buildings have different energy consumption patterns and environmental impacts (Afshari et al., 2016). In contrast, this research looks at one type of building within the suburbs; various residential units may impact the environment differently. For example, multi-unit residential buildings may have lower per-unit energy consumption than single-family homes due to shared walls and more efficient heating and cooling systems (Afshari et al., 2016).

2.2 Adoption of Sustainable Construction

Multiple studies on adopting sustainable construction methods have explored barriers and drivers. A review of these studies reveals commonalities that encourage further exploration and identify gaps, thereby presenting an opportunity to explore the barriers and drivers of sustainable residential construction in Ontario from the perspective of the construction sector.

Many studies have explored construction industry stakeholders' perceptions of barriers and/or drivers to adopting sustainable construction methods, for example in North Carolina (Ahn et al., 2013) and Australia (Bond, 2011; Zou & Yang, 2014). There are also studies specific to residential construction, namely in Singapore (Hwang & Ng, 2013; Hwang & Tan, 2012), Johannesburg, South Africa (Ololade & Rametse, 2018), Chile (Serpell et al., 2013), Malaysia (Abidin, 2010) and China and Hong Kong (Darko et al., 2017; Darko & Chan, 2017). (Darko et al., 2017) emphasize that the local context of the various countries must be considered; however, exploring green building drivers can provide stakeholders with insights into implementing green buildings. (Serpell et al., 2013) recommend diagnosing the current situation in each country, considering its socioeconomic situation and the construction industry practices. This can also be seen in a study of 49 worldwide green building standards and applications of green building technologies in 70 countries to understand how other countries understand the concept of green buildings (Zhang et al., 2019).

On the consumer side, (Bond, 2011) and (Zou & Yang, 2014) both address sustainable residential development in Australia. (Bond, 2011) focused on the attitudes of building practitioners towards sustainable development, identifying the barriers and drivers in adopting sustainable building practices and (Zou & Yang, 2014) investigated homeowners' motivations and behaviours concerning energy savings. Although the study took place in Australia, reviewing the same topic from both practitioners' and consumers' perspectives is valuable to gain a comprehensive understanding of the barriers and drivers to adopting sustainable construction.

Consequently, studies on other countries provided a solid foundation for understanding the barriers and drivers. Nevertheless, there are still few such studies in Canada. Issa et al. (2010) studied Canadian practitioners' perceptions of research on green buildings' cost premiums, long-term expenses, and health and productivity benefits. They conducted a web-based anonymous survey and analyzed data from 1,200 LEED-accredited professionals in Canada to evaluate practitioners' awareness and confidence in research regarding these aspects. The study found that many Canadian practitioners are unfamiliar with this research, often perceiving the existing literature as overly simplistic and not reflective of real-world complexities. Da Silva & Ruwanpura (2009) also reviewed LEED points obtained by Canadian buildings and identified the gap in existing research on sustainable development, specifically with further LEED implementation in Canada since more research is conducted in the United States. While third-party certifiers such as LEED can support

sustainable construction, this study will examine other third-party certifiers and additional factors concerning the adoption of sustainable construction, specifically in the residential sector.

Ruparathna & Hewage (2015) reviewed sustainable procurement initiatives in the Canadian construction industry through questionnaire surveys, document reviews, and semi-structured interviews, covering the three pillars of sustainability—environmental, economic, and social. The study found that sustainable procurement initiatives are underutilized and lack sustainability criteria in bid evaluations (especially in the social and economic criteria), and standardized procurement methods are absent in Canada. While this is an essential step of construction, it is one of many areas that are looked at in the construction industry.

Afroz et al. (2020) examined case study data concerning post-certification performance and criteria for green building certification programs, pinpointed inconsistencies in data infrastructure and archiving methods, and formulated recommendations for standardizing data infrastructure to facilitate data-driven building operation strategies across Canada. This study revealed a significant number of certifications recognized in Canada, although many specialize in the infrastructure industry (which includes, but is not limited to, office buildings, schools, commercial buildings, industrial facilities, and multi-unit residential properties) rather than the residential sector. It has influenced certifiers' policy exploration and awareness strategies, affecting post-certification activities and enabling data-driven building operation and maintenance strategies.

(Afshari et al., 2016) investigated barriers to greening existing buildings using LEED in Winnipeg and (Bristow & Bristow, 2017) researched retrofits to existing homes in Waterloo. Both looked at efforts needing to be made to turn the existing buildings into sustainable ones. The relevance of this research context is significant; however, it prompts the inquiry as to why sustainable practices are not integrated from the onset in the execution of new construction projects.

A Canadian study explored the understanding of barriers to adopting net-zero energy homes, surveying 271 homeowners in a net-zero energy housing demonstration project in Toronto, Canada (Singh et al., 2019). This study revealed that the additional cost compared to traditional home construction and operation, unfamiliarity with the technology linked to net zero energy homes, and not knowing someone with a net zero energy home hindered the acceptance of such homes. While this study gives the perspective of homeowners, it's also important to address the existing gaps in end-user needs to reside and operate in sustainable homes.

Bin and Parker (2012) and Rehkopf et al. (2016) conducted case studies on the REEP House in Kitchener, Ontario. Bin and Parker (2012) examined the life cycle environmental impacts of the home through life cycle assessment (LCA), while Rehkopf et al. (2016) focused on societal impacts and assessment methods, surveying visitors. These studies explored various topics such as long-term performance and life cycle assessments, material choices and their impacts, long-term behavioural changes and the effectiveness of educational programs, systematic assessment frameworks, and comparisons with other green demonstration homes through this example of a single sustainable home. Over time, the energy impact of a poorly performing initial house surpassed the embodied impacts, while for an efficient house, the embodied impact is greater (Bin & Parker, 2012). Rehkopf et al. (2016) found that retrofits reduced electricity, water, and gas consumption. The REEP House programs taught visitors about these improvements and how to retrofit their homes. The research established a framework for assessing green homes, emphasizing the need for better assessment methods to boost societal impact (Rehkopf et al., 2016). The REEP home is an example of trialability that addresses gaps in reducing the housing sector's environmental impact and promoting sustainable residential construction in Ontario and Canada, but it may not accurately reflect the larger-scale development of sustainable homes.

2.3 Conclusion

There is a significant gap in research concerning Ontario's community and neighbourhood residential home builders regarding their knowledge, awareness, familiarity, and interest in holistic, sustainable construction. The Ontario Building Code (OBC) establishes minimum construction standards, making it essential to assess the province's progress in adopting sustainable practices through its initiatives or by influencing changes to building code standards. The literature highlights that effective industry leadership is crucial for the implementation of sustainable practices, particularly through the lens of Rogers' Theory of Diffusion of Innovation, which emphasizes the need to engage industry decision-makers with diverse skills and perspectives (Rogers, 1983, p. 231). Moreover, the factors affecting the adoption of sustainable construction practices—categorized into financial, sector capacity/professional, technological and material, and societal—further suggest that understanding these builders' perspectives will be vital in overcoming barriers and driving sustainability advancement in Ontario's residential sector. Therefore, acknowledging these dimensions and

exploring this unexplored area of research is essential for fostering a more sustainable future in the province.

Chapter 3: Methodology

This thesis evaluates the barriers and drivers to sustainable residential neighbourhood developments by investigating Ontario's construction industry members' knowledge and awareness of sustainable practices in the industry. This chapter explains the research design used to achieve this goal, the data collection procedures, and the statistical tests and qualitative analysis techniques used to analyze the data. To reiterate, the objectives of this thesis are:

1. To identify the sustainability practices/methods currently implemented in the residential home construction sector (Prior Conditions);
2. To determine the level of awareness/knowledge of sustainability practices and features in the residential home construction sector (Knowledge) and relate this to socioeconomic characteristics;
3. To identify communication channels used to obtain knowledge and information of sustainability knowledge and practices in the residential home construction sector; and
4. To determine factors (barriers and drivers) affecting the implementation of sustainability in residential home construction (Persuasion: Perceived Characteristics of the Innovation)

3.1 Research Approach

A survey approach was used for this research because: 1) similar studies have used surveys (e.g. (Ahn et al., 2013) and (Darko et al., 2018)); and 2) surveys are an efficient way to gather various opinions from a large number of people. The questionnaire was developed to target those working in the residential construction industry (i.e., project managers, project coordinators, designers, architects, engineers, technical experts, client service advisors, accommodation managers, acquisition/ supply officers, and specialists).

3.1.1 Survey Design

The survey consisted of 21 questions (Table 3.1). The questions were developed using Rogers' Theory of Diffusion of Innovation's Generalizations of socioeconomic characteristics, personality variables, and communication behaviour of innovativeness and adopters (Rogers, 1983). These questions were divided into three sections: 1) Socio-demographic and academic characteristics, 2) Prior Conditions, and 3) Knowledge: Respondents' Awareness of Sustainability in the Sector. The questions were also developed using a review of other studies (GhaffarianHoseini et al., 2013; Hwang

& Ng, 2013; Mahpour, 2018; Serpell et al., 2013; Singh et al., 2019). Seven of these questions provided additional opportunities for open responses for respondents to provide additional information related to the topics covered in the survey. Appendix F provides sources for the full survey development.

Five members working in the industry reviewed and tested the survey before its distribution. Minor changes to word choice in questions and Likert scale options were made before ethics approval and survey distribution.

Table 3.1: Final Survey Design

<u>Survey Eligibility (Screening Questions)</u>
1. Confirming the individual is 18 years or older 2. Confirming current place of employment, complete residential home community
<u>Socio-Demographic & Academic Characteristics (Part 1)</u>
3. Job title 4. Highest level of education relating to the current employment position 5. Educational background in construction (follow-up to the previous question) 6. Years of experience in the industry
<u>Prior Conditions</u>
7. List of sustainable standards, practices, and features a) Individual's awareness of the industry's current sustainable standards, practices, and features in recent and current projects b) Individual's level of interest in the industry's potential and desire to apply sustainable standards, practices, and features to future projects 8. Significance of barriers to sustainable home development 9. Importance of drivers to sustainable home development 10. Familiarity with third-party sustainable certifications 11. Frequency of the use of sustainable third-party certification within the industry 12. Individual knowledge of the company's sustainability application efforts
<u>Knowledge of Future Potential and Applications</u>
13. Individuals concerned about changes in current work routines 14. The individual is concerned about the time it will take to adapt to the change 15. Individual's enthusiasm to share and deliver sustainability efforts 16. Individual's belief in the residential industry not harming the environment 17. Individuals believe that homebuyers are not interested in sustainable homes 18. Individuals believe that sustainable development is a temporary market 19. Methods of knowledge retention of sustainable trends, innovations, and education.
<u>Socio-Demographic & Academic Characteristics (Part 2)</u>

- | |
|--|
| 20. The number of companies the individual has worked for is related to the construction industry.
21. Section for additional comments and thoughts |
|--|

3.1.1.1 Geographical Scope

Due to its growth in residential construction, Ontario was selected specifically for homes and neighbourhood developments- “suburban sprawl” or “low-density residential” (Norman et al., 2006; Ottensmann, 2020). The initial geographical scope was Southwestern Ontario; however, due to low response rates, surveys were sent to companies throughout all of Ontario. Many companies share on their websites and social media that they have also completed projects between regions and cities outside of their own, although still in Ontario.

3.1.1.2 Survey Administration

The survey was developed on Qualtrics XM, an experienced management software, where the survey link was later generated for distribution. A recruitment email with the Qualtrics link was emailed out between May 2021 and July 2021 to represent members or contacts provided by each construction company.

The company email and name list were generated through the Ontario Homebuilders Association and local association (regional) websites (*The Ontario Home Builders' Association (OHBA)*, 2025). The Local Homebuilders Association groups of Brantford, Chatham Kent, Cornwall, Durham Region, Greater Dufferin, Greater Ottawa, Grey-Bruce, Guelph and District, Haldimand-Norfolk, Haliburton County, Kingston Frontenac, Lanark-Leeds, London, Niagara, North Bay and District, Peterborough and The Kawarthas, Quinte, Sarnia Lambton, Simcoe Country, St. Thomas -Elgin, Stratford and Area, Sudbury and District, Thunder Bay, Waterloo Region, West End, and Windsor Essex. Greater Toronto's association list, known as Bild, was also used in the study (*Building Industry and Land Development Association - BILD*, 2025). Each association's website was different; however, each had a list of members available to the public and some contact information. Nevertheless, each company's website was visited to ensure they specialized in community neighborhood residential developments and to attain an email address if unavailable on the local Homebuilders Association website. If a company did not have an email address or a website, they were excluded from the study. If an email address was available, but the email bounced back, or the email address was invalid, they were not included in the study. All companies listed on a local association website were part of the residential neighbourhood development industry.

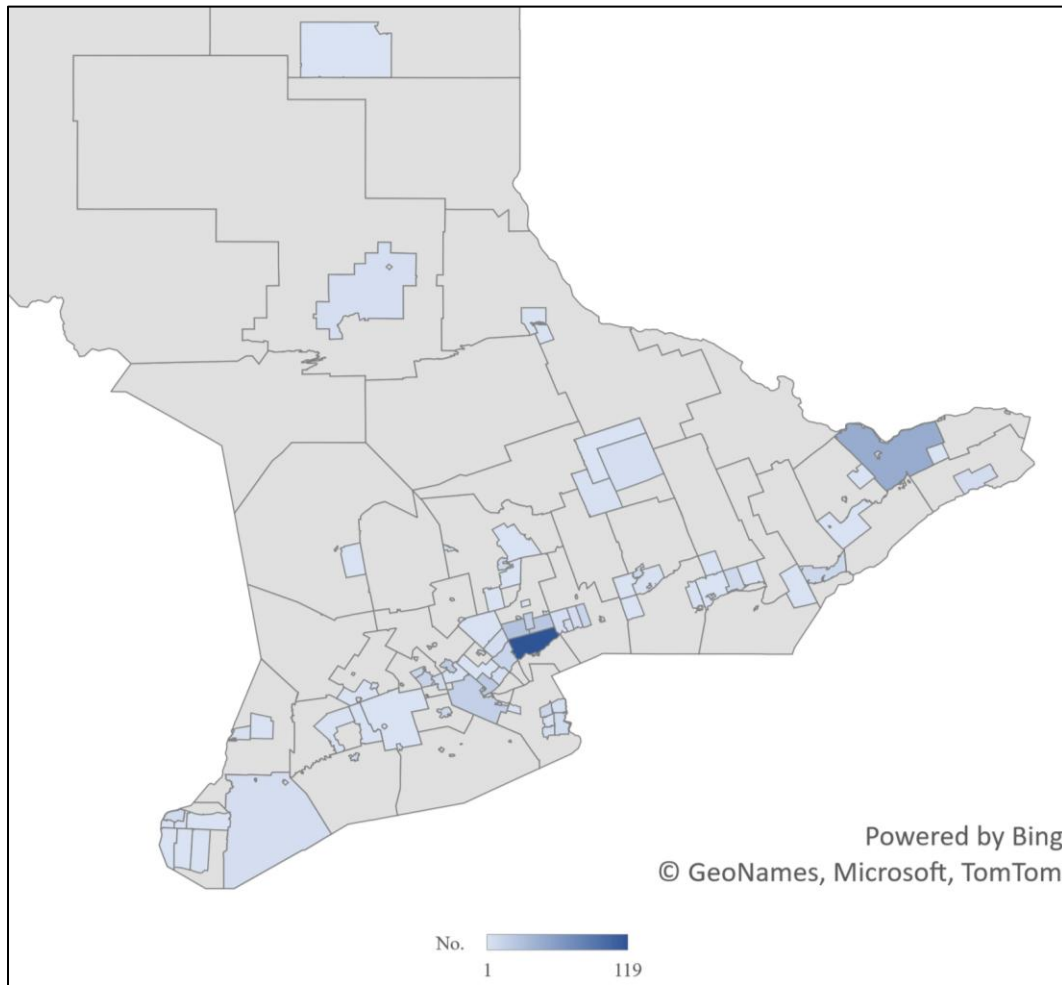


Figure 3.1: Populated Residential Homes Developers Contacted of Cities and Towns in Ontario

Emails were sent to individual company representatives, directly addressing them and explicitly asking them to also distribute them throughout their company to gain a range of construction industry members expertise. A total of 735 emails were sent out during this time, and 693 companies were contacted throughout Ontario. Two of the companies are in Quebec, but have completed projects in Ontario.

3.1.2 Data Analysis

The analysis was completed in two parts. The initial descriptive statistics of the survey were analyzed through SPSS (Statistical Package for Social Sciences). Inferential statistics were applied to meet Research Objective 4. This analysis is further described in the following sections.

3.1.2.1 Survey Analysis

Once the survey was closed, it was downloaded, filtered, and organized. The survey results were filtered for further analysis using the following exclusion criteria:

1. The responses were from someone who were not working in the residential neighbourhood development industry or were under 18. (Preliminary conditional responses to the survey)
2. Survey was less than 35% complete.

3.1.2.1.1 Statistical Analysis

In addition to descriptive statistics, frequency tables breaking down the survey results and statistical tests run through SPSS help view and understand the survey's outcomes.

Descriptive statistics were generated for the responses and presented as frequency tables and bar graphs in Microsoft Excel. Since most data were ordinal and nominal, those data sets' central tendency measure was the median. Even though the mean is not a reliable measure of central tendency for ordinal data, particularly for Likert scales with less than 7 degrees, it is still presented alongside the median, including the standard deviation (SD) to gain insight into the data variability. The interquartile range (IQR) was calculated for the ordinal data to measure the variability in the data where it was applied.

One of the research's objectives includes identifying the social demographic influence on knowledge of sustainable development practices in the construction industry in Ontario. The following variables were required to test the hypotheses (examples provided in Table 3.2**Error! Reference source not found.**):

- Age, job title, the highest level of education achieved, educational background, years of experience, and number of places of employment; and
- Knowledge and awareness of sustainable construction practices, barriers, drivers, third-party sustainable certifiers, and opinions on sustainability in construction.

Null hypotheses were generated when the statement was used in statistical testing to indicate that there is no effect or no difference between variables (Creswell, 2014). If the two variables are statistically independent, the results do not help to predict or understand the results of the other variable's results (McHugh, 2013).

Table 3.2: Sample Tests Used with Survey Questions and their Null Hypotheses

Test Used	Null Hypothesis	Independent Variable	Dependent Variable
Kruskal Wallis or Wilcoxon-Mann-Whitney Test	The years an individual has worked does not affect their perception of barriers to homebuyer interest and knowledge in the industry.	Continuous: Years of Experience in the Industry	Ordinal: Barrier hindered the construction – Homebuyer interest and knowledge (8a)
Kruskal Wallis or Wilcoxon-Mann-Whitney Test	The years an individual has worked do not affect their familiarity with third-party certification organizations.	Continuous: Years of Experience in the Industry	Ordinal: Familiarity with third-party sustainable certifications
Kruskal Wallis or Wilcoxon-Mann-Whitney Test	The number of companies '2an individual has worked for does not affect their familiarity with third-party certification organizations.	Continuous: The number of companies the individual has worked for is related to the construction industry.	Ordinal: Familiarity with third-party sustainable certifications
Chi-square - Fisher's Exact Tests	The individuals' highest level of education does not affect their perception of barriers to homebuyer interest and knowledge in the industry.	Categorical: The highest level of education relating to the current employment position	Ordinal: Barrier hindered the construction – Homebuyer interest and knowledge
Chi-square - Fisher's Exact Tests	The individuals' highest level of education does not affect the experience of drivers to promote sustainability through company knowledge and awareness.	Categorical: The highest level of education relating to the current	Ordinal: Drivers used to encourage construction – Company

Test Used	Null Hypothesis	Independent Variable	Dependent Variable
		employment position	knowledge and awareness
Chi-square - Fisher's Exact Tests	The individuals' job positions do not affect the frequency with which third-party sustainable certification organizations are used in the residential industry.	Categorical: Job title	Ordinal: Frequency of the use of sustainable third-party certification within the industry

Because many of these survey questions use the Likert scales better to capture the respondents' opinions in the survey, since the Likert scales are ordinal, their response choices have a meaningful order. However, the numbers themselves are not meaningful (Bernstein, 2005). Therefore, non-parametric tests are used to statistically analyze this type of ordinal data.

These methods can determine if there is a relationship between survey participants' sociodemographic characteristics and knowledge and awareness of sustainable residential development. This data type cannot be seen through simple descriptive statistics; the Kruskal-Wallis Test, Wilcoxon-Mann Whitney, Chi-square, and Fisher's exact tests were used. These tests were conducted with a 95% confidence interval and a 0.05 significance level.

In SPSS Statistics, a p-value output labelled Asymptotic Significance and Exact Significance indicates the significance of the relationship between the independent and dependent variables. Suppose the test's resulting p-value is less than the established significance level of 0.05, in that case, the test is significant, and the null hypothesis is rejected, indicating a relationship between the independent and dependent variables. If the p-value is higher than the significance level, the null hypothesis fails to be rejected, meaning there is no relationship between the independent and dependent variables.

3.1.2.1.2 Kruskal Wallis Test

The Kruskal-Wallis test is used when one independent variable has two or more levels and an ordinal dependent variable. This test is a non-parametric and a generalized form of the Wilcoxon- Mann-Whitney test method since it permits two or more groups (Ostertagová et al., 2014). The Kruskal-Wallis test has four assumptions:

- The independent variable is a nominal or ordinal variable with more than two expressions;
- The dependent variable is metric or ordinal;
- No relationship between the observations in each group or between the groups themselves; and,
- Knowing whether the distribution in each group has the same shape.

Since the Kruskal-Wallis test does not assume normality in the data and is much less sensitive to outliers, it can be used when these assumptions have been violated (Ostertagová et al., 2014). SPSS Statistics helps carry out the Kruskal-Wallis test to compare the medians of the dependent variables for the different groups of independent variables. However, this test can compare mean ranks if the distributions are different. Similar distributions allow the medians to represent a shift in the location between groups (Ostertagová et al., 2014).

3.1.2.1.3 Wilcoxon-Mann-Whitney Test

The Wilcoxon-Mann Whitney test (Mann-Whitney U test or Wilcoxon rank-sum test) compares two independent population tests where the dependent variable is either ordinal or continuous but not normally distributed (Hart, 2001). The Wilcoxon-Mann-Whitney test can be used on the results of the two populations or in the follow-up of the Kruskal-Wallis to further establish exact relationships between the two populations. Because of this, its four following assumptions are similar in that:

- The dependent variable is continuous or ordinal;
- The independent variable consists of two categorical independent groups;
- No relationship between the observations in each group or between the groups themselves; and,
- Both variables are not normally distributed.

When analyzing the data through SPSS Statistics, a Wilcoxon-Mann Whitney test compares the dependent variable's medians for the two independent variable groups. However, if the two distributions have different shapes, the Wilcoxon-Mann Whitney test can only compare mean ranks and not medians.

3.1.2.1.3.1 Chi -Square Test and Fishers Exact Test

The Chi-square test (also called Pearson's chi-square) and Fisher's Exact Test assess for independence between two variables when comparing independent and unrelated groups. These tests measure the difference between the observed and expected frequencies of the outcomes of a set of variables. The chi-square test has the following assumptions:

- The two variables should be measured at an ordinal or nominal level
- The two variables should consist of two or more categorical independent groups.

A Chi-square test cannot be completed if more than 20% of cells have expected frequencies < 5 ; Fisher's exact test is applied because approximation methods are inadequate (Kim, 2017). The Fisher's exact test runs exact procedures and is applied to smaller samples, though valid for all sample sizes (Kim, 2017).

3.2 Limitations of Research Method

When distributing the survey, we expected a snowballing effect as we requested that the survey link be passed to company members (Creswell, 2014). However, due to the survey's anonymity, we were unable to measure this. This led to sample bias issues, as more people in leadership roles participated and fewer from other job titles in the industry (Creswell, 2014).

Surveys can produce biased answers due to the limited range of options offered and the few open-ended responses, as respondents were restricted to answering within the provided choices. There was a concern that the length of the survey and the time it took to complete it significantly lowered the chances of full completion, and the option to skip responses for all questions further contributed to this issue. Consequently, many surveys likely returned incomplete, leading to inconsistent data collection.

Chapter 4: Results

This research aims to investigate the barriers and drivers to constructing more sustainable new-build residential homes in southern Ontario through the perspective of construction industry members involved in the sector. The results are presented according to the following research objectives:

1. To identify the sustainability practices/methods currently implemented in the residential home construction sector (Prior Conditions);
2. To determine the level of awareness/knowledge of sustainability practices and features in the residential home construction sector (Knowledge) and relate this to socioeconomic characteristics;
3. To identify communication channels used to obtain knowledge and information of sustainability knowledge and practices in the residential home construction sector; and
4. To determine factors (barriers and drivers) affecting the implementation of sustainability in residential home construction (Persuasion: Perceived Characteristics of the Innovation)

4.1 Socio-economic Characteristics of Survey Respondents

There were 104 (14.1%) attempted surveys of the 735 distributed, with 83 (11.3%) qualifying by completing at least 35% of the survey (11 questions). The response rate was 11.3%. The results tables and figures will indicate the number of respondents (n) to a question. Thirty respondents (36.1%) were in the 45-54 age category, and 22 were in the 35-44 age category (26.5%), making up a total of 62.6% of the respondents. Respondents in other age groups comprised the remainder (37.4%) (Table 4.1).

Of 83 respondents, 69 stated their current job titles (Table 4.1). Based on the use of employment databases (Indeed Editorial Team, 2021; Jraisat et al., 2016; Statistics Canada, 2022), respondents' job titles were organized into categories based on similar names and responsibilities:

1. Company Head (e.g., company owners, CEOs, founders, or presidents),

Figure 4.1: Age categories of survey respondents

2. Construction Business and Sales (e.g., sales, contract, marketing managers, or customer relations),

3. Project Managing Team (e.g., projects or operations managers),
4. Construction Trades Specialists (e.g., architect, builder, or developer) and,
5. Property Manager.

Many of the respondents were company owners, CEOs, founders, or presidents (46.4%). The remaining respondents had the following jobs or responsibilities: marketing or customer relations and sales (24.6%); project or operation managers (18.8%); construction trades (8.7%), and one property manager (1.4%).

Table 4.1: Summary of Respondents' Socioeconomic Characteristics.

Description	Frequency	Percentage
Profession (n=69)		
Company Head	32	46.4%
Customer Business and Sales	17	24.6%
Project Managing Team	13	18.8%
Construction Trades Specialists	6	8.7%
Property Manager	1	1.4%
Highest Level of Education (n=83)		
Bachelor's degree	39	47.0%
College credit, no degree	18	21.7%
Master's degree	11	13.3%
High school graduate, diploma, or the equivalent	6	7.2%
Trade/technical/vocational training	4	4.8%
Associate degree	2	2.4%
Other	2	2.4%
Professional Degree	1	1.2%
Doctorate	0	0.0%
Years of experience in the Residential Industry (n=83)		
5+ years	75	90.4%
3-5 years	7	8.4%
1-3 years	1	1.2%

Description	Frequency	Percentage
6-12 months	0	0.0%
< 6 months	0	0.0%
Number of places of employment within the construction industry (n=76)		
2-4 Companies	42	55.3%
1 Company	27	35.5%
5-10 Companies	4	5.3%
10+ Companies	3	3.9%

Many respondents had post-secondary education, specifically a bachelor's degree (47.0%), college credit (21.7%), or a master's degree (13.3%). The remainder had a high school graduate, diploma, or the equivalent (7.2%), trade/technical/vocational training (4.8%), an associate degree (2.4%), other (2.4%) and a professional degree (1.2%). Respondents that had indicated "other" had a college degree or college diploma. A majority of respondents (55.4%) stated that their education was irrelevant to their job/role.

Most respondents (90.4%) have at least 5 years of experience in the residential industry. A small number have 3-5 years (8.4%) and 1-3 years (1.2%) experience in the residential industry. Just over half of the respondents (55.3%) had worked in 2-4 companies, followed by respondents working at one company (35.5%) and the remainder working at five or more companies (9.2%).

4.2 Ontario Residential Construction Industry: Rogers' Five Stages of Innovation-Decision Process

The following results are based on questions related to Rogers' Five Stages of Innovation-Decision Process.

4.2.1 Previous Practice: Currently Implemented Sustainable Practices and Features

Previous practice refers to the existing behaviours, methods, or technologies that individuals or groups are accustomed to before introducing an innovation (Rogers, 1983, 2003). Respondents were asked which sustainability features their companies have implemented in residential construction developments to understand previous practices in the residential building sector. The features listed in

the survey were those in the updated building code and are based on the “above-average building code standard”, meaning that they are not required by law.

The most common features (implemented in over 75% of cases) in residential projects were: ‘Efficient ventilation and humidification’ (96.3%), ‘Efficient use of building materials’ (91.6%), ‘Measures to prevent land contamination’ (85.5%), ‘Smart home systems/appliances’ (79.3%), and ‘Efficient water use’ (75.6%) (Table 4.2). In the open-ended responses, one respondent highlighted that energy efficiency is important for affordability, and implied it would lower operation costs:

I run my own construction company built mostly homes. Have built a 49-unit affordable seniors’ apartment with the intention to keep therefore energy efficiencies was huge. (R7)

Another respondent also mentioned that in addition to costs, saving energy is also important:

Most builders like us would love to do as much as possible (affordably) to increase the level of energy efficiency and sustainability. Innovation that saves money and energy is always welcome.... (R15)

Other sustainability features that were implemented in 60%-75% of recent projects were: ‘Project energy modelling’ (62.2%), ‘Making design and planning decisions based on regional and local sustainability goals’ (60.2%), ‘Ethical or local material sourcing’ (61.0%), and ‘Planning houses’ footprints with ecological and natural features in mind’ (60.5%).

Lastly, the sustainability features that were least implemented in the industry were ‘Building homes to optimize passive energy or other renewable energy sources’ (48.8%), ‘Post-occupancy evaluation’ (45%), ‘Life cycle assessment of homes’ (31.7%), and ‘Design to end-of-use or end-of-life deconstruction’ (18.5%). Six respondents stated that they did not know if the features had been implemented, specifically: ‘Ethical or local material sourcing’ (7.3%); ‘Planning houses’ footprints with ecological and natural features in mind’ (7.4%); ‘Post-occupancy evaluation’ and ‘Design to end-of-use or end-of-life deconstruction’ (7.4%).

One respondent had issues with some of these sustainability features

... do we consider the end-of-life deconstruction recyclability/disposal of the new materials we are using? How can we do that effectively when we do not know what new technologies may be utilized in 30 years which will undoubtedly be better than what we are doing now? (R2)

Table 4.2: Sustainability features implemented in recent projects (7a). The number of responses for each option is given in brackets (n=number of responses). Mode=2 refers to ‘Yes’ answers, and mode=1 refers to ‘No’ answers.

Results Sustainability Features Options (SF)	No = 1	Yes = 2	I do not know	Mode
Homes are built to control ventilation and humidification efficiently (n=82)	3 (3.7%)	79 (96.3%)	0 (0.0%)	2
Efficient use of building materials during construction (n=83)	7 (8.4%)	76 (91.6%)	0 (0.0%)	2
Proper measures to prevent future contamination of land and the surrounding environment (n=83)	9 (10.8%)	71 (85.5%)	4 (3.6%)	2
Homes are built with ‘user-friendly’ Smart home systems/appliances (n=82)	17 (20.7%)	65 (79.3%)	0 (0.0%)	2
Homes are built to use water efficiently (n=82)	18 (22.0%)	62 (75.6%)	2 (2.4%)	2
Project energy modelling (n=82)	30 (36.6%)	51 (62.2%)	1 (1.2%)	2
Making design and planning decisions based on regional and local sustainability goals (n=83)	33 (39.8%)	50 (60.2%)	0 (0.0%)	2
Ethical or local material sourcing (n=82)	26 (31.7%)	50 (61.0%)	6 (7.3%)	2
Planning houses' footprints with ecological and natural features in mind (n=81)	26 (32.1%)	49 (60.5%)	6 (7.4%)	2
Homes are built to optimize passive energy or other renewable energy sources (n=82)	41 (50.0%)	40 (48.8%)	1 (1.2%)	1
Post-occupancy evaluation to better future projects (n=80)	38 (47.5%)	36 (45.0%)	6 (7.5%)	1

Results	No = 1	Yes = 2	I do not know	Mode
Sustainability Features Options (SF)				
Life cycle cost assessment to showcase sustainable home construction options (n=82)	55 (67.1%)	26 (31.7%)	1 (1.2%)	1
Design to consider end-of-use or end-of-life deconstruction with minimum waste (n=81)	60 (74.1%)	15 (18.5%)	6 (7.4%)	1

4.2.2 Felt needs or problems: Interest in applying sustainability features

Felt needs or problems are the perceived deficiencies or challenges experienced by individuals or groups within a community or society (Rogers, 1983, 2003). To determine this, for the respondents who answered ‘No’ or “I do not know” to which sustainability features their companies had implemented in residential construction developments were asked a follow-up question to determine how interested they were in applying the sustainability practices in future projects (using a 5-point Likert scale). In some cases, there were less than 20 people who responded No/I do not know, and although the results are reported in Table 4.3, they are not explained further.

Many respondents (n=56) stated that current projects were not implementing post-occupancy evaluation but 30 (~54%) of them were very or extremely interested in applying this in future projects (mean=3.4 and median=4; Table 4.3). Out of 38 respondents, 15 were moderately interested, and 12 were very to extremely interested in ‘Homes are built to optimize passive energy or other renewable energy sources.’ For ‘Life cycle cost assessment to showcase sustainable home construction options’, 28 were moderately to very interested (Mean=3.0).

There was only slight to moderate interest for the rest of the sustainability features (Mean =2.4 to 3.1, Median=2 to 3), specifically: Making design and planning decisions based on regional and local sustainability goals; Planning houses' footprint with ecological and natural features in mind; Project energy modelling; Ethical or local material sourcing; Design to consider end-of-use or end-of-life deconstruction with minimum waste. In the open-ended responses, one respondent provided an insight as to why these are not implemented:

... do we consider the end-of-life deconstruction recyclability/disposal of the new materials we are using? How can we do that effectively when we do not know what new technologies may be utilized in 30 years which will undoubtedly be better than what we are doing now? (R2)

Table 4.3: Respondents' interest in implementing sustainable features in new residential developments. The number of responses for each option is given in brackets (n=number of responses). “Not interested at all” =1 and “Extremely interested” =5.

Sustainable features	Not interested at all	Slightly Interested	Moderately Interested	Very Interested	Extremely Interested	I do not know	Mean (SD)	Median (IQR)
Post-occupancy evaluation to better future projects (n=56)	5 (8.9%)	11 (19.6%)	8 (14.3%)	19 (33.9%)	11 (19.6%)	2 (3.5%)	3.4 (1.3)	4 (2)
Homes are built to use water efficiently (n=16)	0 (0%)	4 (25.0%)	3 (18.8%)	7 (43.8%)	2 (12.5%)	0 (0%)	3.4 (1.0)	4 (2)
Efficient use of building material during construction (n=6)	0 (0%)	3 (50%)	0 (0%)	2 (33.3%)	1 (16.7%)	0 (0%)	3.2 (1.2)	3 (2)
Homes are built with ‘user-friendly’ Smart home systems/appliances (n=17)	0 (0%)	6 (35.3%)	5 (29.4%)	3 (17.6%)	3 (17.6%)	0 (0%)	3.2 (1.1)	3 (2)
Proper measures to prevent future contamination of land and the surrounding environment (n=9)	1 (11.1%)	2 (22.2%)	3 (33.3%)	1 (11.1%)	2 (22.2%)	0 (0%)	3.1 (1.3)	3 (3)
Homes are built to optimize passive energy or other renewable energy sources (n=38)	2 (5.3%)	9 (23.7)	15 (39.5%)	7 (18.4%)	5 (13.2%)	0 (0%)	3.1 (1.1)	3 (2)
Life cycle cost assessment to showcase sustainable home construction options (n=52)	5 (9.6%)	12 (23.1%)	14 (26.9%)	14 (26.9%)	3 (5.8%)	4 (7.7%)	3.0 (1.1)	3 (2)
Homes are built to control ventilation and humidification efficiently (n=3)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	0 (0%)	0 (0%)	3.0 (0.00)	3 (0)
Making design and planning decisions based on regional and local sustainability goals (n=33)	5 (15.2%)	9 (27.3%)	10 (30.3%)	6 (18.2%)	2 (6.1%)	1 (3.0%)	2.7 (1.1)	3 (2)
Planning houses' footprint with ecological and natural features in mind (n=21)	3 (14.3%)	8 (38.1%)	4 (19.1%)	5 (23.8%)	1 (4.8%)	0 (0%)	2.7 (1.1)	2 (2)
Project energy modelling (n= 26)	6 (23.1%)	6 (23.1%)	5 (19.2%)	8 (30.8%)	0 (0%)	1 (3.8%)	2.6 (1.2)	3 (3)
Ethical or local material sourcing (n=24)	1	10	10	3	0	0	2.6	3

Sustainable features	Not interested at all	Slightly Interested	Moderately Interested	Very Interested	Extremely Interested	I do not know	Mean (SD)	Median (IQR)
	(4.2%)	(41.7%)	(41.7%)	(12.5%)	(0%)	(0%)	(0.75)	(1)
Design to consider end-of-use or end-of-life deconstruction with minimum waste (n=54)	13 (24.1%)	16 (29.6%)	14 (25.9%)	7 (12.9%)	1 (1.9%)	3 (5.6%)	2.4 (1.1)	2 (2)

4.2.3 Norms of the social system: Respondents' Perspective on Sustainability of the Residential Construction Sector

Norms of the social system are the established behaviours, beliefs, values, and expectations that guide the conduct of individuals within a particular social group or community (Rogers, 1983, 2003).

Most respondents strongly (50%) or somewhat disagreed (28.9%) that sustainable development is a temporary market trend (mean=1.8, median=2; Figure 4.2). Furthermore, the majority of respondents strongly (50.6%) or somewhat agree (24.7%) (mean=3.1, median=5) that the residential housing development industry harms the environment (Figure 4.3).

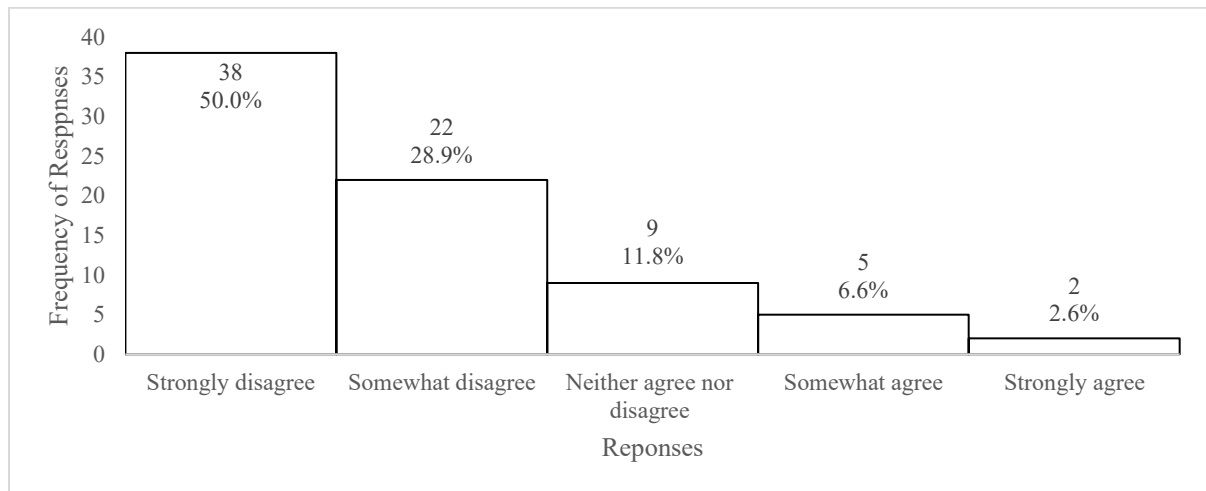


Figure 4.2: Responses to question on Sustainable development is a temporary market trend. Mean = 1.8, Median = 2

About 66% of the respondents 'Somewhat or Strongly' agreed that their company has implemented and urged building projects to be more sustainable (Mean=3.9 and median=4; Figure 4.23). Some respondents even stated that they believed that the construction industry wants to do the sustainable thing, is willing to change and are interested in sustainability:

We all want to facilitate good developments done in a way that respects the natural environment.... (R2)

I believe the construction industry is willing to change... however the barriers are government approval and market forces. We can and need to build better, energy efficient, healthy homes. (R4)

Most builders like us would love to do as much as possible (affordably) to increase the level of energy efficiency and sustainability. (R15)

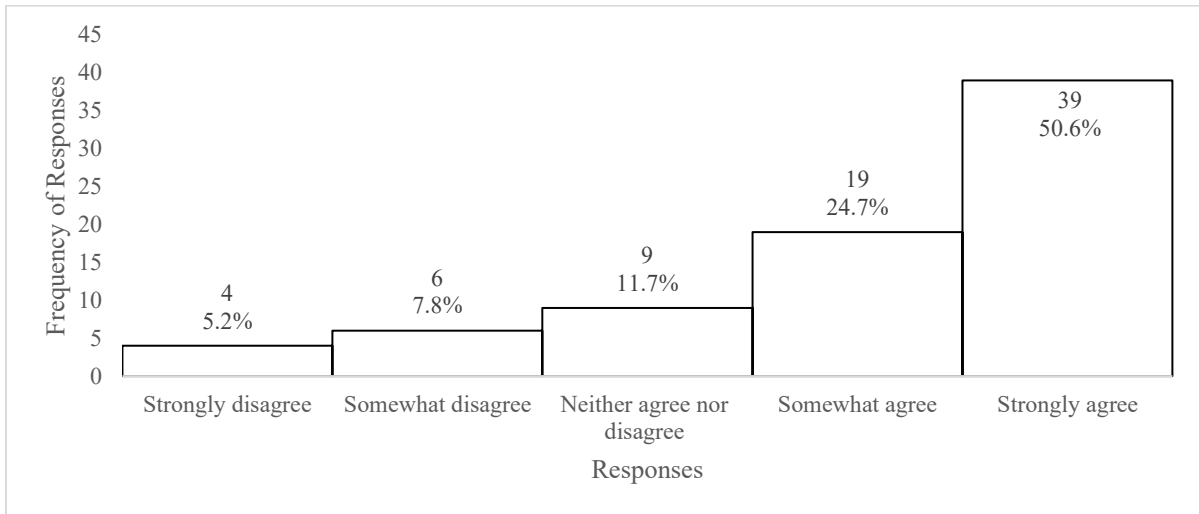


Figure 4.3: Responses to question on whether residential construction industry harms the environment.

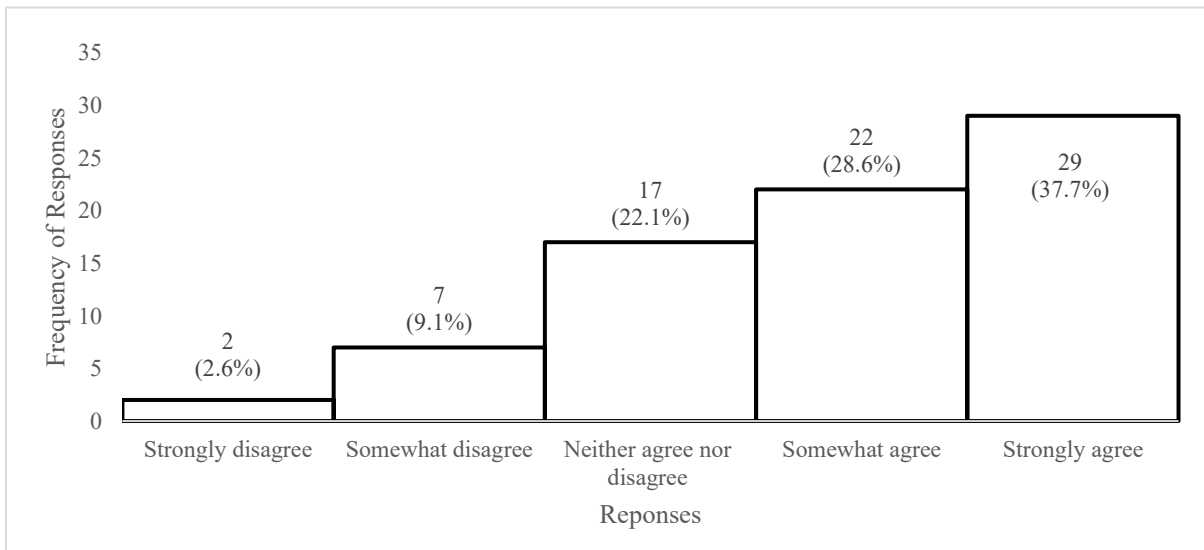


Figure 4.4: Responses to statement: “The company where I work has implemented and urges more building projects to be more sustainable.”

Some respondents also agreed that they were interested in sharing ideas about sustainable development with others in the construction industry (Figure 4.5; Mean=3.8; Median=4). One respondent found the survey information insightful for sustainability concepts:

Excellent survey. While it is information gathering, also thought provoking. Following this survey, I will pull the thread on some sustainable concepts highlighted by the survey. (R12)

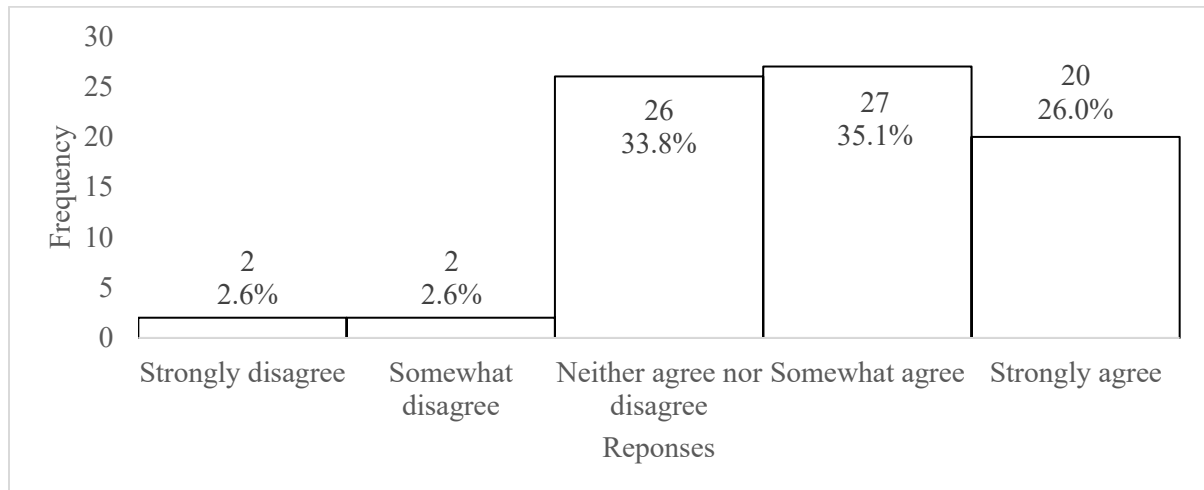


Figure 4.5: Respondents' interest in sharing ideas about sustainable development with other workers in the construction sector. Mean=3.8; SD=0.94; Median=4.

4.3 Knowledge

In this stage an individual becomes aware of an innovation and learns how it works (Rogers, 2003). The types of knowledge about an innovation are awareness knowledge (knowing an innovation exists), how-to knowledge (knowing how to use an innovation appropriately), and principles knowledge (knowing why a strategy works) (Henderson, 2005; Rogers, 1983, 2003). This study only considered awareness knowledge, measured by whether respondents were familiar with certifications.

4.3.1 Respondents' Awareness of Building Sustainability Certifications

The results in Table 4.4 are arranged based on the highest to lowest mean of the responses. The most familiar third-party certifiers were: Energy Star (Mean=4.4; median=5), LEED (Mean=3.7; median=4), and CHBA (Canadian Home Builders Association) Net Zero Home Labelling Program (Mean=3.4; median=4). Respondents were moderately familiar with The Built Green Program (mean =2.7, median=3) and Passive House (mean =2.6, median=3), but very few were familiar with the International WELL Building Institute (mean =1.5, median=1), Building as Material Banks (BAMB) (mean =1.3, median=1), and International Living Future Institute (mean =1.2, median=1).

Table 4.4: Familiarity with third-party sustainable certifications. 1=Not at all familiar and 5=Extremely familiar.

Results	Not at all familiar	Slightly familiar	Moderately familiar	Very familiar	Extremely familiar	Mean (SD)	Median (IQR)
Third-party Certifiers							
Energy Star (n=77)	0 (0%)	2 (2.6%)	9 (11.7%)	24 (31.2%)	42 (54.5%)	4.4 (0.79)	5 (1)
LEED (n=77)	2 (2.6%)	10 (13.0%)	19 (24.7%)	27 (35.1%)	19 (24.7%)	3.7 (1.06)	4 (2)
CHBA (Canadian Home Builders Association) Net Zero Home Labelling Program (n=76)	11 (14.5%)	12 (15.8%)	13 (17.1%)	14 (18.4%)	26 (34.2%)	3.4 (1.45)	4 (3)
Built Green Program (n=75)	22 (29.3%)	14 (18.7%)	15 (20.0%)	15 (20.0%)	9 (12.0%)	2.7 (1.39)	3 (3)
Passive House (n=75)	18 (24.0%)	17 (22.7%)	21 (28.0%)	14 (18.7%)	5 (6.7%)	2.6 (1.22)	3 (2)
International WELL Building Institute (n=74)	54 (73.0%)	8 (10.8%)	7 (9.5%)	3 (4.1%)	2 (2.7%)	1.5 (1.00)	1 (1)
Building as Material Banks (BAMB) (n=74)	56 (75.7%)	13 (17.6%)	5 (6.8%)	0 (0%)	0 (0%)	1.3 (0.59)	1 (0)
International Living Future Institute (n=73)	61 (83.6%)	8 (11.0%)	3 (4.1%)	0 (0%)	1 (1.4%)	1.2 (0.66)	1 (0)

4.3.2 Socioeconomic characteristics and knowledge of sustainability practices and features

One of the research's objectives includes identifying the socioeconomic characteristics influence on knowledge of sustainable development practices in the construction industry in Ontario. The following variables were tested.

- Independent variable: Age, job title, the highest level of education achieved, educational background, years of experience, and number of places of employment.
- Dependent variables: Knowledge of third-party sustainable certifiers and sustainability features.

The SPSS tests showed no relationship between construction members' socioeconomic characteristics and their knowledge of sustainability practices and features.

4.4 Communication Channels

Communication channels are a dominant part of Rogers Theory of Innovation; specifically, it is a key factor that informs all Five Stages of the Innovation-Decision Process. Thus, respondents were asked about how they maintain their knowledge of sustainability trends, education and innovations in the residential construction industry (Table 4.5). The most commonly used method was 'Personal research', with 28.6% using this method 'Most of the time' and 24.3% using this method 'Always' (median=4; mean=3.3). Another common method was using training, courses and credentials offered by third-party building certifiers, with 28 and 14.7% of the respondents using this 'Most of the time' and 'Always', respectively (Median and mean=3.0).

There was very low use of other communication channels. The following responses had a median of 2 (indicating 'Sometimes'): 'Maintaining membership in a non-profit professional association for networking' (mean=2.5), although 42.7% of the respondents indicated they never use this method; 'Attending public forums led by the municipality regarding environmental plans' (mean=2.2); and 'Attending and participating in events or workshops (webinars) led by local green non-profit initiative groups' (mean=2.2). The options with the lowest use (median=1, indicating 'Never') were: 'Following municipalities' social media pages' (mean=1.8); 'Following local green non-profit initiative groups on social media' (mean=1.7); and 'Following universities on social media' (mean=1.4); 'Volunteering in local non-profit green initiative groups' (mean=1.4); 'Attending University-led events' (mean=1.4); and 'Following University Departments on social media' (mean=1.4). Of these, more than 75% of respondents said they 'never' use the latter two methods.

Table 4.5: Respondents communication channels for obtaining information on sustainable trends, innovations, and education (19). Never=1 and Always=5.

Responses Options	Never	Sometimes	About half of the time	Most of the time	Always	Mean (SD)	Median (IQR)
Personal Research (n=70)	8 (11.4%)	16 (22.9%)	9 (12.9%)	20 (28.6%)	17 (24.3%)	3.3 (1.36)	4 (2)
Third-party building certifiers training, courses, and credentials (n=75)	12 (16.0%)	21 (28.0%)	10 (13.3%)	21 (28.0%)	11 (14.7%)	3.0 (1.34)	3 (2)
Maintaining membership in a non-profit professional association for networking (n=75)	32 (42.7%)	13 (17.3%)	5 (6.7%)	12 (16.0%)	13 (17.3%)	2.5 (1.57)	2 (3)
Attending public forums led by the municipality regarding environmental plans (n=75)	25 (33.3%)	30 (40.0%)	6 (8.0%)	11 (14.7%)	3 (4.0%)	2.2 (1.16)	2 (2)
Attending and participating in events or workshops (webinars) led by local green non-profit initiative groups (n=75)	25 (33.3%)	26 (34.7%)	12 (16.0%)	9 (12.0%)	3 (4.0%)	2.2 (1.14)	2 (2)
Following municipalities' social media pages (n=74)	38 (51.4%)	22 (29.7%)	6 (8.1%)	5 (6.8%)	3 (4.1%)	1.8 (1.09)	1 (1)
Following local green non-profit initiative groups on social media (n=74)	42 (56.8%)	17 (23.0%)	11 (14.9%)	3 (4.1%)	1 (1.4%)	1.7 (0.95)	1 (1)
Volunteering in local non- profit green initiative groups (n=75)	49 (65.3%)	12 (16.0%)	5 (6.7%)	5 (6.7%)	4 (5.3%)	1.7 (1.17)	1 (1)
Attending University-led events (n=74)	56 (75.7%)	11 (14.9%)	4 (5.4%)	2 (2.7%)	1 (1.4%)	1.4 (0.82)	1 (0)
Following University Departments on social media (n=75)	58 (77.3%)	10 (13.3%)	4 (5.3%)	2 (2.7%)	1 (1.3%)	1.4 (0.81)	1 (0)

4.5 Barriers and Drivers to Sustainable Residential Construction

This section goes over the barriers and drivers to the construction of residential homes. The survey results were categorized into cost-related factors and two main categories of barriers and drivers- internal and external. Internal factors are those that are related to the company or industry, while external factors are outside of the company and industry and may be out of the company's or industry's control. In addition to presenting the Likert-scale responses, the end-of-survey open-ended responses are incorporated throughout.

4.5.1 Cost-related Factors

Respondents were asked how often cost barriers hindered construction of sustainable homes. "Cost and economy" were seen as barriers "most of the time", if not "always," with 84.2% of responses falling into these categories (Figure 4.6).

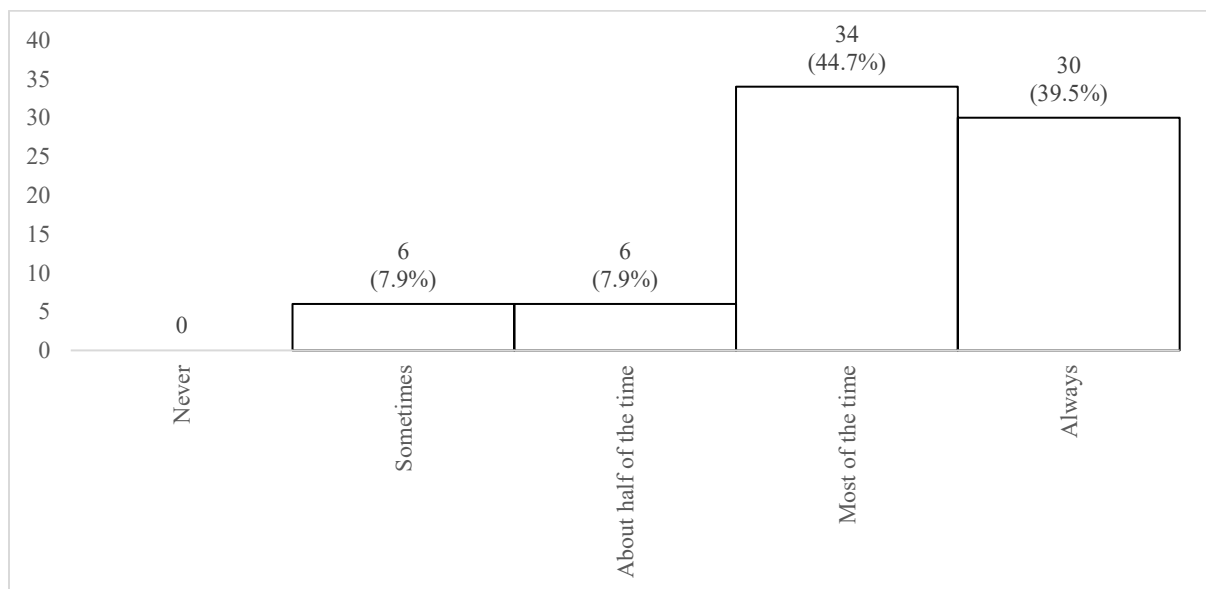


Figure 4.6: The barrier of 'cost and economy' to adopting sustainable home construction (N=76, Mean= 4.3, Median 4).

Respondents were also asked how important cost-related drivers were in encouraging the construction of sustainable homes. "Cost reduction or incentives" was a significant factor that respondents found very important in adopting sustainable construction (Mean=4.2; Median=4; Figure 4.7).

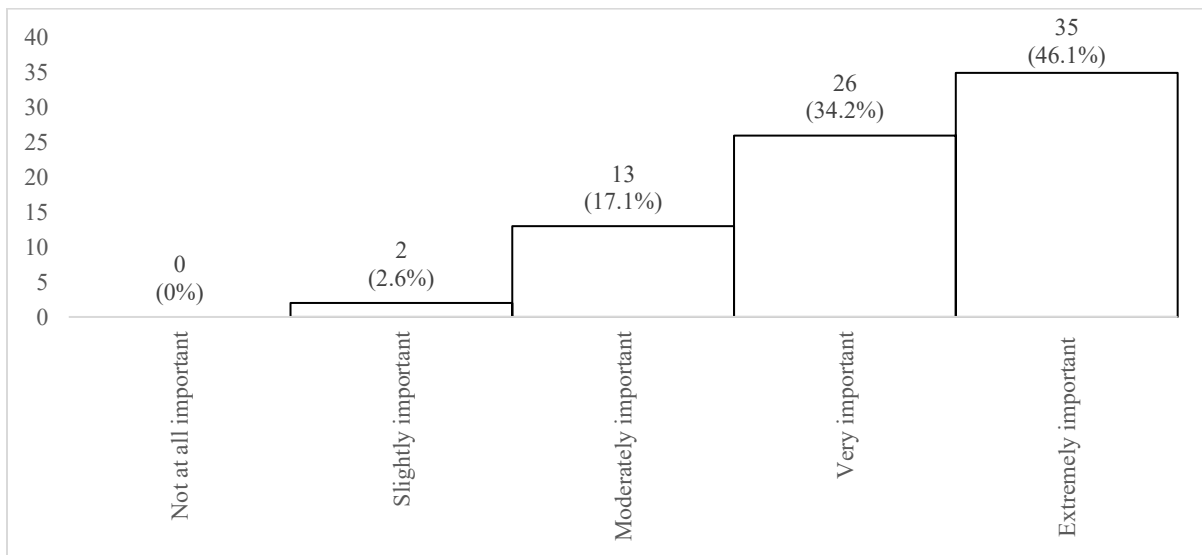


Figure 4.7: Importance of ‘cost reduction and incentives’ as a driver to sustainable construction (N=76, Mean= 4.2, Median 4).

Several respondents also mentioned costs as a major barrier in the open-ended responses, from building to much higher standards to material and personnel costs.

ALL Builders will never build to the NetZero standard if not required by law. It is expensive to do and you need to train your employees. (R3)

Major hurdles to environmentally conscience [sic] developments are centered around material and consultant cost increases (R13)

Two respondents also added that homebuyers prioritize spending money on aesthetics (e.g. gourmet kitchen) over sustainable features.

I find when building for either high end or low-end customers- money is always the motivating factor. 99.5 percent of the time people will not lower their product selection for higher energy efficiency E.g., would you rather have quartz kitchen countertops or laminate to have quartz you will have to go from R 60 attic insulation to R 40. Customers will almost always go for the luxury product upgrade than locally sourced products or energy efficiency. (R7)

The main issue we see with sustainable housing is the cost. When purchasers are given the choice between energy efficiency or upgrading the cosmetics of their home, most of the time they choose to spend on cosmetic's [sic].(R9)

In a more nuanced response, one respondent said:

Older generations do NetZero homes because they realize the value it has (cheaper electrical bill) = more money in your pocket. Younger home buyers will never invest

in solar because they would rather add upgrades to the home. At the end of the day it all comes down to money solar saves you money, not one person buying a NetZero home really cares about how it impacts the environment.. its how can my house cost me less in the future. (R3)

Another respondent said that although home buyers may care about sustainability, only those in the luxury market are willing to pay for the increased costs:

Purchasers do care but are not always willing to pay for significant costs. Yes, on the luxury market, but less so on the mid-market buildings. (R14)

Affordability for the home owners was also a major issue identified by some respondents:

People are really stretching to get into any type of housing and as an industry we have to measure affordability along with sustainability and energy efficiency. Very tough to have all three. (R15)

I believe sustainable housing is important (as an option) but affordable housing is more important, it's no good to have a great sustainable home that you cannot afford. (R6)

4.5.2 Barriers to sustainable home construction

Respondents were asked how often various barriers hindered construction of sustainable homes. These results are presented as 'Internal barriers', associated with the construction sector and its supply chain, and 'External barriers', over which the construction sector has little control.

4.5.2.1 Internal Barriers to Sustainable Home Construction

The barrier of "Required additional equipment and training" was a factor "about half of the time." (Table 4.6; Mean= 3.1; Median=3). In the open-ended responses, one respondent mentioned that employees need to be trained on newer construction methods associated with sustainable home building.

"Material availability and production" was also a barrier "about half of the time." (Mean=3.0; Median=3). One respondent mentioned that materials used to maintain and fix a sustainable home are less accessible than current standard construction materials, using the example of Passive house.

Passive housing comes with many issues and technology which needs to be refined.. people with passive houses can't just call in a regular service man to service their hot water.. its a whole new way of building. Its more expensive, creates a lot of hassle for the client and isn't reasonable to mass produce. (R3)

"Construction stakeholder knowledge and capacity" was the lowest barrier, possibly meaning respondents do not think their jobs and positions are preventing them from pursuing sustainable

construction. However, one respondent mentioned that passive homes were problematic for the industry, from the building to the maintenance of these homes:

.... passive housing comes with many issues and technology which needs to be refined. people with passive houses can't just call in a regular service man to service their hot water. it's a whole new way of building. Its more expensive, creates a lot of hassle for the client and isn't reasonable to mass produce. (R3)

Table 4.6: Barriers experienced by the construction sector.

Collected Data Barrier	Never	Sometimes	About half of the time	Most of the time	Always	Mean (SD)	Median (IQR)
Required additional equipment and training (n=75)	7 (9.3%)	27 (36.0%)	8 (10.7%)	23 (30.7%)	11 (14.7%)	3.1 (1.27)	3 (2)
Material availability and production (n=74)	8 (10.8%)	25 (33.8%)	11 (14.9%)	17 (23.0%)	13 (17.6%)	3.0 (1.30)	3 (2)
Construction stakeholder knowledge and capacity (n=75)	13 (17.3%)	30 (40.0%)	13 (17.3%)	14 (18.7%)	5 (6.7%)	2.6 (1.17)	2 (2)

Additionally, respondents were split on whether they had concerns with changes that would have to be made to current work routines (Table 4.7, mean=3.0, median=3). About 34% disagreed (somewhat to strongly) that this was an issue, while about 40% agreed (somewhat to strongly) that this was an issue. Similarly, there was a split on concerns on the time it would take to adapt if new sustainable construction practices were implemented (Mean=3.2, median=3), with about 30% disagreeing (somewhat to strongly) that this as a concern, and about 49% agreeing (somewhat to strongly) that this was a concern.

Table 4.7: Individuals' perspective on applying sustainable practices to the construction industry.

Collected Data Survey Question	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree	Mean (SD)	Median (IQR)
I am concerned about the changes that would have to be made to current work routines if new sustainable construction practices were implemented. (n=76)	12 (15.8%)	14 (18.4%)	19 (25.0%)	22 (28.9%)	9 (11.8%)	3.0 (1.26)	3 (2)
I am concerned about how long it will take to adapt to new sustainable building approaches if new sustainable construction practices are implemented. (n=76)	9 (11.8%)	15 (19.7%)	15 (19.7%)	26 (34.2%)	11 (14.5%)	3.2 (1.25)	3 (2)

4.5.2.2 External Barriers to sustainable home development

External barriers refer to those that are outside the influence or control of the construction company or industry.

Respondents were asked how often specific barriers hindered construction of sustainable homes. For the barrier of “Policy, codes, bylaws or government restrictions”, there was a split in how often this was a barrier with ~49% of respondents stating that it was a barrier ‘Sometimes’ or ‘Never’, and ~51% stating that it was a barrier ‘About half the time’, ‘Most of the time’, and ‘Always’ (Table 4.8; mean= 3.1 and median=3). These results were also further discussed in the open-ended responses. Respondents mentioned that by-laws and government in general are hindering sustainability in the construction industry:

Local zoning by-laws prevent affordability! The spider web of building code, conflicting archaic local zoning by-laws and building cost are not aligned with sustainable or affordable building efforts.(R5)

Perhaps if governments stopped playing gate keeper thus allowing us to meet market demand, we may have more opportunity to think about these other factors. (R2)

I believe the construction industry is willing to change however the barriers are government approval and market forces.(R4)

Table 4.8: External barriers to sustainable home construction.

Collected Data Barrier	Never	Sometimes	About half of the time	Most of the time	Always	Mean (SD)	Median (IQR)
Policy, codes, bylaws, or government restrictions (n=77)	7 (9.2%)	31 (40.8%)	7 (9.2%)	16 (21.1%)	16 (21.1%)	3.1 (1.35)	3 (2)
Homebuyer interest and knowledge (n=75)	8 (10.7%)	19 (25.3%)	13 (17.3%)	26 (34.7%)	9 (12.0%)	3.1 (1.22)	3 (2)

Lastly, “Homebuyer's interest and knowledge” was seen as more of a barrier to sustainable construction, with ~36% of respondents stating that it was a barrier ‘Sometimes’ or ‘Never’, and ~64% stating that it was a barrier ‘About half the time’, ‘Most of the time’, and ‘Always’ (Table 4.8; mean= 3.1 and median=3). There were specific insights from the open-ended responses as to why homebuyer’s interest and knowledge is such a barrier:

Major hurdles to environmentally conscience [sic] developments are centered around material and consultant cost increases and lack of buyer awareness or inclination to pay a premium for this product. (R13)

As already mentioned in Section 4.5.1, the lack of interest is related to how cost of sustainable features affects the ability of homeowners to get the desired aesthetic/cosmetic features in their houses.

Fast housing will always be preferred and what "builder incentives/cosmetic upgrades" a builder can offer for the cheaper price will always prevail. (R3)

One respondent highlighted both market and government (through standards) as a barrier to sustainable home construction.

The market is constantly changing and the standards are constantly changing. (R15)

Another respondent provided another example of material availability and production with building departments [BMEC- Building Materials Evaluation Commission] preventing approvals of innovative

methods and products. BMEC [Building Materials Evaluation Commission] is the agency that authorizes new and innovative building materials, systems, and designs for use in Ontario (*Building Materials Evaluation Commission | Ontario.Ca*, 2024). Additionally, plan examiners review building plans to ensure compliance with building codes and regulations (Building Code Department, 2023).

Most plans examiners are "checklist" people who are looking for someone else to take responsibility for innovative materials/methods and will often hold up approvals because they don't want to assume that responsibility for approving. The BMEC process could use an overhaul to streamline. (R8)

4.5.3 Drivers to sustainable home development

Respondents were also asked how important certain drivers were in encouraging the construction of sustainable homes.

4.5.3.1 Internal Drivers to Sustainable Home Development

“Suppliers' availability of sustainable materials and resources” was a very important driver for encouraging the construction of sustainable homes, with over 80% of respondents say it was “Very” or “Extremely” important (Table 4.9; Mean=4.2; Median=4). “Company knowledge and awareness” was also an important driver, with ~79% of respondents say it was “Very” or “Extremely” important (Mean=4.0; Median=4). A respondent stated that the company they work for currently builds homes at NetZero as a minimum “because it’s the right thing to do - not because we’re told to do so” (R1), suggesting that there is awareness in the sector and it drives the construction of sustainable homes. “Company image” was a weaker driver with ~65% of respondents say it was “Very” or “Extremely” important (Mean=3.7; Median=4).

Table 4.9: Importance of internal drivers to sustainable home development.

Driver \ Collected Data	Not at all important	Slightly important	Moderately important	Very important	Extremely important	Mean (SD)	Median (IQR)
Suppliers' availability of sustainable materials and resources (n=75)	0 (0%)	3 (4.0%)	10 (13.3%)	38 (50.7%)	24 (32.0%)	4.1 (0.78)	4 (1)
Company knowledge and awareness (n=76)	0 (0%)	5 (6.6%)	11 (14.5%)	38 (50.0%)	22 (28.9%)	4.0 (0.83)	4 (1)
Company image (n=76)	2 (2.6%)	9 (11.8%)	16 (21.1%)	32 (42.1%)	17 (22.4%)	3.7 (1.03)	4 (1)

4.5.3.2 External Drivers to Sustainable Home Development

For the respondents “Government policy” was ‘Very important’ (42.1%) to ‘Extremely important’ in encouraging the construction of sustainable homes (Table 4.10; Mean=4.0, median=4). Specific policies were cited by various respondents:

Sustainable construction methodologies are increasing as Toronto has adopted more stringent green standards than previous years. The city has provided more incentives such as credits on development charges at the end of the project once verified. I think the city needs to provide more of an upfront credit. If the builder can see real credits on the front end, I think that would be better. (R14)

In addition to need for ‘green standards’, the respondent implies that governments should also provide more upfront incentives to lower the high initial costs of sustainable construction.

One respondent suggested that government regulations was not a driver because they were already doing the ‘right thing.’

Government push or regulations have zero impact on our green initiatives. We’d be happy to take their money to offset costs but do it because it’s the right thing to do - not because we’re told to do so. We also build Net Zero Ready as a minimum, so we don’t have to change our way of doing things if code changes. (R1)

Additionally, one respondent mentioned that:

ALL Builders will never build to the NetZero standard if not required by law. (R3)

Table 4.10: External Drivers for Adopting Sustainable Construction

Collected Data Driver	Not at all important	Slightly important	Moderately important	Very important	Extremely important	Mean (SD)	Median (IQR)
Affordability for homebuyers (n=77)	0 (0%)	2 (2.6%)	3 (3.9%)	16 (20.8%)	56 (72.7%)	4.6 (0.68)	5 (1)
Interest from homebuyers (n=77)	1 (1.3%)	2 (2.6%)	5 (6.5%)	23 (29.9%)	46 (59.7%)	4.4 (0.83)	5 (1)
Government policy (n=76)	3 (3.9%)	8 (10.5%)	14 (18.4%)	26 (34.2%)	25 (32.9%)	3.8 (1.12)	4 (2)

For “Affordability for homebuyers” about 73% of the respondents rated this driver as “Extremely important” and ~21% rated this as “Very important” (Table 4.10; Mean=4.6; Median=5).

I believe sustainable housing is important (as an option) but affordable housing is more important, it’s no good to have a great sustainable home that you cannot afford. (R6)

With respect to “Interest from homebuyers” about 60% of the respondents rated this driver as “Extremely important” and ~30% rated this as “Very important” (Table 4.10; Mean= 4.4; Median=5), aligning with what respondents mentioned on cost-related factors in Section 4.5.1.

However, with respect to their perspective on homebuyers' interest in sustainable homes, 32.5% of respondents stated that they “somewhat disagree,” that homebuyers are not interested in sustainable homes, while 31.2% stated that they “somewhat agree” (Mean=3.0, Median=3; Figure 4.8).

Therefore, there is a split in opinion about homebuyers interest in sustainable homes.

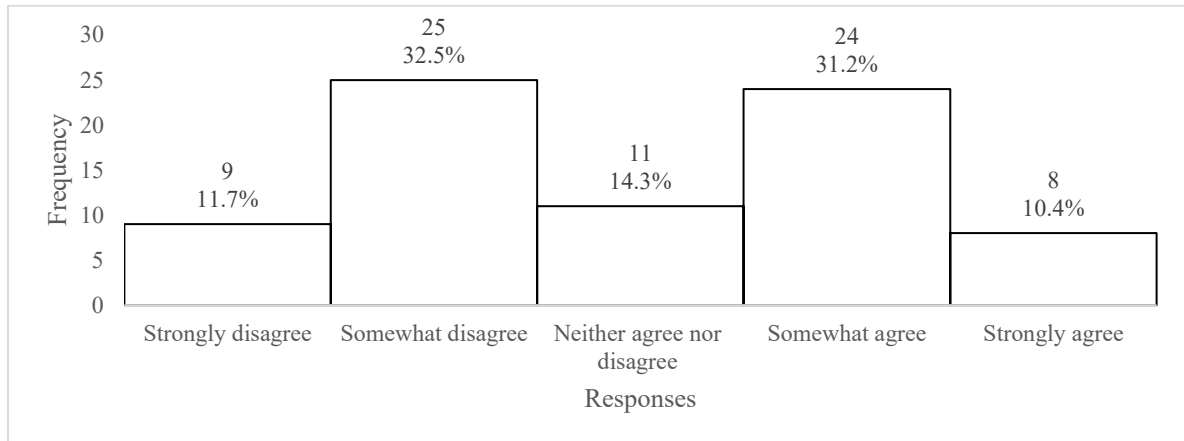


Figure 4.8: Respondents' views on homebuyer demand for sustainable homes. Mean = 3, Median = 3.

Chapter 5: Discussion

This exploratory study examines the knowledge of and perceptions towards sustainable residential construction of 83 individuals within the Ontario construction industry. The research objectives were as follows:

1. To identify the sustainability practices/methods currently implemented in the residential home construction sector (Prior Conditions);
2. To determine the level of awareness/knowledge of sustainability practices and features in the residential home construction sector (Knowledge) and relate this to socioeconomic characteristics;
3. To identify communication channels used to obtain knowledge and information of sustainability knowledge and practices in the residential home construction sector; and
4. To determine factors (barriers and drivers) affecting the implementation of sustainability in residential home construction (Persuasion: Perceived Characteristics of the Innovation)

The study used Rogers Theory of Diffusion of Innovation, specifically the Five Stages of Innovation-Decision Process as the theoretical framework for the data collection. Additionally, the Five Stages of Innovation-Diffusion Process assumes that the decision-makers are evaluating the ‘innovation’, which in this case was defined as ‘sustainable residential building construction’.

5.1 Prior Conditions

A major precursor and strong influencer on adoption is the concept of ‘prior conditions,’ which refer to the existing conditions faced by the decision-maker. In terms of ‘Previous practice’ or the existing behaviours, methods, or technologies that individuals or groups are accustomed to before introducing an innovation. Overall, the most commonly implemented sustainability features (more than 60% of the time) were related to energy and water efficiency, or efficient use of building materials. These are more easily implemented as they are widely available technologies and well-known practices. They save homeowners and the construction industry money.

An additional feature that was implemented was ‘Measures to prevent land contamination’, which does not directly benefit the construction sector but is likely a requirement of the local government. This study also found that ‘Policy, codes, bylaws, or government restrictions’ were a significant barrier to building sustainably for about half of the respondents. In particular, specific concerns

mentioned as barriers to affordable and sustainable housing were local zoning by-laws, building code, too much interference or issues with government approval. Other studies have found that government regulations and financial incentives drive sustainable construction, making it easier for builders to adopt mandated or encouraged features (Bond, 2011; Pitt et al., 2009; Ruparathna & Hewage, 2015). For example, higher landfill taxes promote better waste management, while building codes influence builders to adopt improved construction practices for a more sustainable industry (Pinkse & Dommisse, 2009; Pitt et al., 2009).

Features that are currently implemented in about half the housing included ‘Homes built to optimize passive energy or other renewable sources’. As this question mentioned both passive energy or renewable resources, it is not clear which practice is implemented. Although cost was a major barrier identified in this study, the practice of ‘Life cycle cost assessment’ was only implemented in 30% of the houses being built. The reason for the low implementation of these features may be that the respondents were not aware of them, or they might be too complex or costly to implement. Complexity leads to long-term uncertainty, a tendency to maintain current practices, a lack of knowledge and skills, and a lack of demand due to high costs (Bond, 2011; Choi, 2009; Häkkinen & Belloni, 2011; Singh et al., 2019; Zou & Yang, 2014).

In terms of ‘Felt needs or problems’ or the perceived deficiencies or challenges experienced by individuals or groups within a community or society, there were several insights from the survey responses. Out of 38 respondents, 27 were moderately interested to extremely interested in building homes to optimize passive energy or other renewable energy sources. Thirty-one were moderately interested to extremely interested in implementing life cycle cost assessment. However, there was a low number of respondents for this question and it is inconclusive in terms of whether there is a felt need or problem for the industry.

Social norms’, or the established behaviours, beliefs, values, and expectations that guide the conduct of individuals within a particular social group or community, with innovations that are more aligned with prevailing norms are more likely to be accepted (Rogers, 1983, 2003). One of the more interesting findings in this study is that there seems to be alignment of ‘Norms of the social system’ related to the respondents and ‘sustainable home construction’ as an innovation. Many respondents mentioned that the company they worked for were already implementing sustainability and even

pushing for building projects to be more sustainable, as well as being interested in sharing sustainability concepts with others in the construction industry.

5.2 Knowledge of Sustainability Certifications

In terms of knowledge of more innovative sustainability practices, measured by familiarity with certifications, respondents were very familiar with Energy Star over other certifications. Established in 1992, this certification has become the most recognized sustainability and environmental certification across various industries, primarily focusing on energy efficiency. However, it is unclear whether the respondents were familiar with the certification body or with its use on appliances. LEED certification is important for businesses as it can validate sustainability efforts, improve company image, improve indoor air quality and improve employee productivity. This is not the case for homeowners. Though there might be a perceived market value to a property with a certification (Choi, 2009), respondents in this study mentioned that homebuyers had little interest in sustainable construction, did not want additional costs, or would choose cosmetic updates over the additional costs of sustainability features.

Many of the respondents were also very familiar with the CHBA (Canadian Home Builders Association) Net Zero Home Labelling Program. It is likely that many of the respondents are members of this association. The Net Zero program started with a pilot in 2015 and has certified 2,688 homes, 1,663 of which were detached (CHBA, n.d.).

The respondents were in general highly educated (50 had a university degree, of which 11 had a Masters degree), and 49 were company owners likely responsible for key decisions. However, no relationship was found between industry members' socioeconomic characteristics and their knowledge of sustainability practices and features. Rogers's theory suggests that higher education graduates are more likely to adopt innovations and Ololade & Rametse (2018) found that older, highly educated managers support environmental initiatives, pushing for sustainable practices. Furthermore, various studies have found that a company's decision to build homes sustainably ultimately depends on its leadership (Atmoko et al., 2019; Choi, 2009; Darko & Chan, 2017; Oke et al., 2019; Zhang et al., 2019). However, the survey design did not include questions to determine whether respondents were decision-makers nor to identify likelihood of adopting specific sustainability features or technologies to evaluate whether socioeconomic characteristics were a factor in deciding to adopt sustainability features in the construction industry.

5.3 Communication Channels

Rogers' (1983) concept of diffusion relies heavily on effective communication channels at all stages of the innovation-decision process. This study found that the most common communication channel for learning about sustainability trends, education, and innovations in the residential construction industry was 'Personal Research', with 37 out of 70 respondents using this method most of the time or always. The finding that personal research is the most frequently employed method by respondents aligns with Rogers' (1983) emphasis on the importance of individual knowledge in the innovation-decision process. This method may be the simplest and quickest way to identify topics of interest and address the market's concerns about sustainability. This active approach to information gathering not only demonstrates a proactive engagement by industry professionals but also reflects trends noted by Ahn et al. (2013), who highlighted the role of project managers in driving innovation adoption through self-motivated research.

There was very low use of professional associations and municipal forums or attending events to obtain knowledge and information related to sustainability in the construction sector. This may be because many of the respondents were the heads of the company and may not have time to attend these events. Nevertheless, these channels have been found to be essential for networking and information sharing for the construction industry (Hwang & Ng, 2013).

5.4 Barriers and Drivers

Costs associated with sustainability features were found to be a major barrier to adopting sustainable construction. Respondents mentioned that homebuyers prioritize aesthetics over improving their homes with sustainability features. The exception was that older generations may invest in sustainable homes, like NetZero, because they value the cost savings (lower utilities), while younger buyers prioritize cosmetic upgrades over sustainability upgrades. This underscores the need to address diverse demographic motivations in order to promote sustainable construction effectively. Bond (2011) also notes that cost is a primary consideration. If homebuyers do not perceive the savings associated with sustainability features, or are more concerned with affordability, they will not choose the sustainable option. This can especially be seen in Ontario's Electricity Supply, where Nuclear Energy is 48.5%, Water Power is 23.4%, Natural Gas/Oil/Other 16.6%, and Wind, Solar PV and Bioenergy are a combined 11.6% (Ontario Energy Board, 2025). This energy supply presents a balanced and sustainable composition, mitigating the potential harms associated with energy

overconsumption and significant environmental damage; however, residents might think that their efforts in conserving energy, which they also benefit from financially, make a meaningful contribution to broader environmental and societal benefits. Additionally, the focus of contractors was shown to shift to design and perceived lifestyle over energy efficiency, especially if people believe these are more substantial selling points (Bond, 2011).

Respondents indicated that knowledge and capacity within the industry was not a barrier for sustainable construction. However, respondents identified that factors such as additional equipment, training, and the availability of materials often posed barriers to sustainable construction. Some recent literature has addressed procurement, a stage of home construction that bypasses the approval or knowledge of the homebuyers to provide sustainable materials to construction companies. (Ershadi et al., 2021) and (Osei-Kyei et al., 2024) study the barriers and drivers to adopting sustainable construction, which keeps the adoption of sustainable practices within the construction industry. There were also some concerns with how sustainable construction would affect current work routines and the time it would take to adapt if new sustainable construction practices were implemented. Respondents also noted that the industry would benefit from an increase in the availability of sustainable materials and resources from suppliers. Access to sustainable materials, combined with organizational knowledge and awareness, is essential for effective implementation, as noted by Ahn (2010) and Hwang et al. (2018). Additionally, education and training are imperative for maximizing the potential of sustainable practices and addressing knowledge gaps within the industry that hinder progress towards sustainability (Abdelaal & Guo, 2021; Gupta et al., 2017).

The company's image was also considered somewhat important. A company's positive image has a significant influence on the adoption of sustainable practices, mainly due to consumer demand and industry competition (Abdelaal & Guo, 2021). Companies can benefit from adopting sustainable construction that enhances their reputation and encourages engagement in sustainable practices across the industry, although various factors have hindered progress in these initiatives, according to respondents.

The findings indicate that government policies play a crucial role in promoting sustainable construction practices. Respondents noted that cities have enhanced their commitment to sustainable building through stringent green standards and development incentives, yet further government support is necessary to foster broader adoption among homebuyers. It was also found that the most

support for sustainable construction comes from local governments. This aligns with the findings from other studies in the world, that found that government support is crucial due to their flexibility in implementing policies and incentives that can positively influence attitudes and knowledge about green building (Abdelaal & Guo, 2021; Hwang et al., 2018; Hwang & Tan, 2012).

Cost reductions and incentives (government) were also cited as being very to extremely important factors by 80% of respondents. It has been found that incentives such as tax credits and grants have shown promise in encouraging developers to adopt sustainable features (Abdelaal & Guo, 2021; Darko & Chan, 2017). Even studies from various countries highlight the importance of government support in promoting sustainability initiatives across residential and public buildings (Zhang et al., 2019; Oke et al., 2019), underscoring a need for strategic policy improvements to enhance sustainable construction.

Affordability and homebuyer interest (market) were found to be critical influences on whether the residential construction sector builds more sustainable homes- this was visible literature and supported by the study findings. Notably, sustainability upgrades often involve higher costs, which present substantial challenges, particularly for mid-market homebuyers. Another study in Canada highlighted cost as a significant barrier to sustainable construction, emphasizing the additional upfront expenses associated with net-zero homes by Singh et al., (2019), even though there are potential long-term operational cost reductions for homeowners. Financial incentives, as recognized by researchers such as Hwang and Tan (2012), is crucial in mitigating these concerns.

The literature, in contrast to some responses, suggests that over time, the barriers and drivers to sustainable construction have evolved in response to technological advancements, policy developments, and shifting market preferences. Cost remains a significant barrier, especially for homebuyers, despite the availability of incentives like tax credits and grants that promote sustainable features; though this has also significantly benefited homeowners who wish to upgrade their homes to be more sustainable. Public awareness and consumer demand for environmentally friendly buildings have also grown, influencing companies to enhance their reputation through sustainable practices, but this is still not as popular in the residential sector; therefore, a shift in the procurement stage over the education of end-users (homebuyers) has been addressed more in recent literature. Overall, the balance between barriers and drivers continues to shift, playing a more pivotal role in encouraging wider adoption of sustainable construction methods.

5.5 Study Strengths and Limitations

This study's key strength is its focus on knowledge, awareness, and the barriers and drivers specific to the residential sector, in contrast to most existing literature, which predominantly addresses large-scale buildings such as skyscrapers and factories, with significantly larger footprints. This study addresses the issue of residential housing, a market-driven industry where sustainability considerations have been largely overlooked.

One of the major limitations is that there were some issues with clarity of questions and validity of constructs as well as several questions that included too many variables (e.g. Policy, codes, bylaws, or government restrictions), making it difficult to determine which of these were the most important barriers. Although there were some insights into this through the open-ended responses, it was still difficult to determine what was most important.

Another limitation was that the survey did not request the respondents' locations, which could have provided additional insights as local government legislation and regulations influence companies and organizations to adopt sustainable construction. Finally, the limited number of respondents was not sufficient to create generalizations. Nevertheless, this study provided important new insights into this sector in Canada.

5.6 Implications and Recommendations

This study showed that there were four major barriers to sustainable residential home construction: costs associated with sustainability features for residential housing; availability of sustainable materials and training; policies and by-laws; and lack of homebuyer interest or awareness. The following recommendations are made to address these barriers:

1. Develop a database on sustainable materials.

A database can identify and classify sustainable materials, providing researchers, designers, and manufacturers with essential information on material properties, availability, lifecycle assessments, and tracking advancements in sustainable technologies to foster innovation and collaboration among stakeholders.

2. Provide the residential construction industry with incentives. These could be credits on development charges (e.g. Toronto), but also upfront credits that are more visible to the builder.

Implementing incentives for sustainable construction can be crucial for encouraging builders. Removing financial barriers can enhance collaboration between the government and the construction sector.

3. Develop green standards at the local level that are required to be followed.

Updated local green standards are crucial for fostering community engagement, raising environmental awareness, and ensuring that businesses and residents meet specific environmental criteria to address community challenges/goals effectively. Aligning with third-party certifiers like the International WELL Building Institute | IWBI, which follow the United Nations Sustainable Development Goals, will help with holistically adopting sustainable construction methods for homes and communities.

4. Upgrade the Ontario Building Code to require that sustainability features are part of standard practices.

Upgrading the Ontario Building Code to include sustainability features aligns with trends in environmental stewardship. Mandating these practices ensures new residential builds meet sustainability standards, streamline processes, and reduce costly third-party certifications. These features foster innovation and commitment to sustainability, providing clarity for builders, consumers, and regulators.

5. Provide more homeowner incentives to buy sustainable homes.

Homeowner incentives promote sustainable home purchases by reducing financial burdens. Tax credits, rebates, and low-interest loans encourage homeowners to choose sustainable options that, while initially costlier, provide long-term savings through energy efficiency and reduced utility costs. These incentives increase the appeal of sustainable homes, making them competitive in the real estate market.

6. Create awareness of sustainability upgrades and lifecycle costs to homeowners. This could be accomplished by the contractors, real estate agents, and local government.

To promote sustainability upgrades and reduce costs for homeowners, engaging stakeholders like contractors, real estate agents, and local government is essential, as they can offer vital information on the benefits of sustainable homes to homebuyers during the homebuilding or purchasing process.

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Chapter 6: Conclusion and Future Research

The aim of this study is to investigate the current status of the residential construction industry in terms of implementing sustainable practices in construction, as well as the barriers and drivers associated with constructing more sustainable new-build residential homes in southern Ontario. Based on the survey responses, the residential construction sector seems interested and capable of implementing many sustainability features and practices, but faces various challenges. Within the sector, the availability of materials or technologies was important, as was training to a lesser degree. These barriers have shifted over time due to evolving technology, policies, and market trends; however, the most important barrier is the additional costs of some sustainability features, and the lack of demand or interest from home buyers. In terms of drivers, providing financial incentives was an important factor for building more sustainably, as was policy, particularly at the local level.

For the content of the study, the areas in which the theory was utilized were sufficient. However, because the study had a very broad scope, it was difficult to apply the theory wholly due to its extensive and detailed stages and elements. A more effective application of the theory would have been to look into specific sustainable construction methods and, using the theory in its entirety, understand its adoption stage. Doing this with several of the most popular and unique sustainable construction methods would help understand trends in the adoption of other sustainable construction methods in the future. This theory would also be better utilized if a single decision-maker category, such as business owners or company owners, were studied to gain a deeper understanding of the industry's decision-making characteristics and their adoption patterns.

Future research should focus on interviewing decision-makers in the construction industry to obtain more insights into decision-making processes associated with the sector, so as to better understand bottlenecks in the residential building project life cycle that hinder the implementation of sustainability features and practices. Additionally, leadership and organizational innovativeness in the sector could be studied to understand their relationship to sustainable construction adoption better. Future research could also include the replication of the study with the addition of the previously mentioned improvements to different provinces in Canada to test if additional provincial regulations or institutions influence sustainability adoption.

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Appendix A: Third-party certifier's areas of focus of sustainable construction practices

Category and Point		Third-party certifier							
		A	B	C	D	E	F	G	H
Site, Neighborhood & Community	Build around a culture that accommodates essential healthcare, diverse population needs and engaged occupant community.								•
	Help create stable, safe, and high-paying job opportunities for people in the local community, and support diverse local businesses through hiring, purchasing, and workforce development practices							•	
	The placement of homes in socially and environmentally responsible ways concerning the larger community		•		•		•	•	•
	Promote healthy lifestyles through environment, design, policies, and programs integrated into the fabric of our culture, homes, and communities.							•	•
	Utilizing the climatic, regional conditions, landscaping, and home orientation to optimize passive gains, maximize the use of the free energy generated by the local environment, and control solar access		•		•		•	•	
	Preserve and protect ecology and wildlife and encourage ecological regeneration to enhance communities and outdoor spaces.		•			•		•	•
	Support local communities and businesses while minimizing transportation impacts by the creation of walkable, pedestrian-oriented, car-sharing, public transportation, and bicycle lane communities that reduce the use of fossil fuel vehicles.							•	•
	Integrate opportunities for connecting the community to locally grown fresh food.							•	•
	Utilizing the entire property to minimize the project's impact on the site		•					•	

Category and Point		Third-party certifier							
		A	B	C	D	E	F	G	H
	Strategic positioning of plants (e.g., recycling, material traders, etc.) and supply chain management						•		
	All home features work together to minimize household environmental footprint significantly.		•			•	•	•	
Material and Resource Efficiency	Manufacturing products and materials used for a home within 800 km of the building site		•	•				•	•
	Optimizing organic and inorganic materials by balancing their relative strengths and weaknesses against environmental impact considerations.				•				
	Reduce exposure to harmful toxins, chemicals, and VOCs during the construction, remodelling, furnishing, and occupancy of a home.		•	•	•	•	•	•	•
	Efficient utilization of materials, selecting environmentally beneficial and durable materials while minimization of waste during construction		•	•			•		•
	Support and promote sustainable material and resource extraction							•	•
	Support and encourage material and resource transparency labelling		•				•	•	•
	Keep or increase the quality, value, and security of materials, products, and resources over time (residual value) and make relevant data available for assessments on various hierarchy levels.			•			•	•	•
	Promote and develop circular products design, material recovery, chain of possession partnerships and sustainable lifecycle management of materials products and buildings throughout all phases of a project (e.g., deconstruction, salvaged materials, reuse, waste reduction, managing supply and demand)		•	•			•	•	•

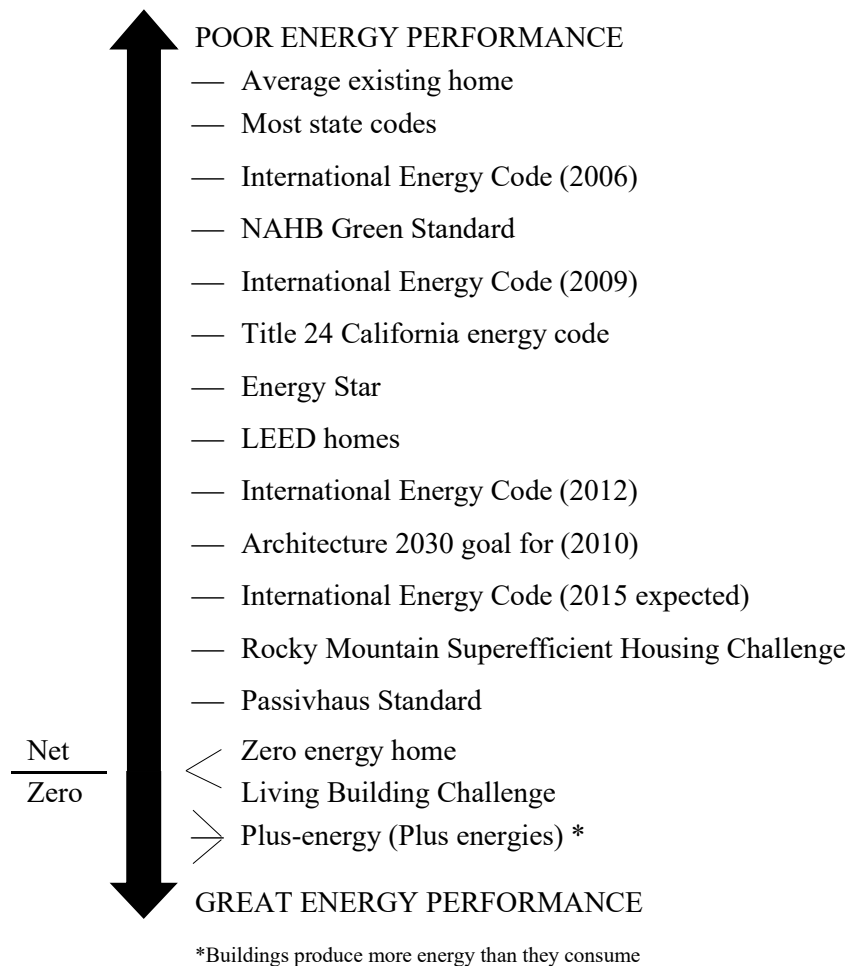
Category and Point		Third-party certifier							
		A	B	C	D	E	F	G	H
	Reduce the costs by managing virgin resources rather than managing waste.						•		
Awareness, Education & Innovation	Educating homeowners on operating and maintaining green features in their home			•			•	•	•
	Educating stakeholders and homeowners about the benefits of green spaces and incorporating biophilic design elements into properties		•					•	•
	Educating stakeholders about sustainable best practices and approaching each project with unique strategies specific to project location		•	•	•		•	•	•
	Make information, reports, and educational material on sustainability accessible to the public (e.g., home design, operations, policies, health benefits, cost-savings, comparisons)	•	•	•			•	•	•
	Promote and create opportunities to encourage durability, high-performance, sustainable design, and construction measure that have tangible and demonstrable benefits.		•	•	•		•	•	•
	Promote mental health through policy, program, and design strategies that address the diverse factors that influence cognitive and emotional well-being.							•	•
	Create incentives and tools for suppliers to produce healthy, sustainable, circular materials and building products.			•			•	•	
Energy	Minimize energy-related carbon emissions and promote carbon-free renewable energy.		•		•			•	•
	Produces additional clean and renewable energy as it consumes it (Net-positive)				•	•		•	
	The home produces as much energy as it consumes (Net-Zero)		•		•	•		•	

Category and Point		Third-party certifier							
		A	B	C	D	E	F	G	H
Lighting and Windows	Reduce solar heat gains.		•		•				
	Promote airtightness to prevent energy loss through windows.	•	•	•	•	•		•	•
	Balanced daylighting from windows		•		•			•	•
	Light-coloured paint or high albedo materials for comfortable room function		•		•				
Noise Control	Acoustic comfort parameters				•	•		•	•
	Resources and programs for stakeholders at risk of occupational hearing loss								•
Quality HVAC and Indoor Air	Encourage both mechanical and manual methods of ventilation, along with active and passive design for a comfortable indoor environment.		•	•	•	•	•	•	•
	Insulated building envelope for efficient heating and cooling	•	•		•	•			•
	Decrease air exchange with allergens, dust, pollens, and air pollution through home air filtration systems.		•	•	•	•		•	•
	Minimal home footprint to prevent air and energy leak	•	•		•	•	•		
	Interior layout to help passive strategies, such as thermal mass, lighting, temperature, and ventilation consideration		•		•	•	•	•	•
	Using the locations' known wind patterns to orient the hinged window and choose a style that catches and directs the wind as required, in methods such as either stack effect or cross ventilation				•				
Water Conservation and	Drain water heat recovery (DWHR) units on the main drain stack to recover heat from shower drain water.		•	•	•	•		•	
	Equipped with low-flow fixtures and appliances		•	•	•	•		•	
	Encourage the reduction of the amount of water used in a home.		•	•	•		•		

Third-party certifier		A	B	C	D	E	F	G	H
Category and Point									
	Water use and release with the natural water flow of the site and its surroundings			•				•	•
	Use of greywater and potable water while avoiding pollution		•	•	•			•	•
Number of sustainability practices covered by a third-party certifier		4	29	18	24	14	19	35	30

Third-party certifier legend	Established
A. ENERGY STAR*	1992
B. LEED*	1993 (LEED Canada est., 2003)
C. Built Green Program	2003
D. Passive House*	1988 (Passive-house Canada est., 2013)
E. CHBA Net Zero Home Labelling Program*	2014
F. Building as Material Banks (BAMB)	2015
G. International Living Future Institute	2009
H. International WELL Building Institute	2014
*Government of Canada promotes this third-party certifier	

Appendix B: Energy Performance of Certifiers (Lechner, 2015)



**Appendix C: Number of Construction Companies within each
Region, Township or County where Surveys were sent to.**

Region/ Township/ County	Number of Construction Companies
Binbrook Township	1
Brant County	13
Bruce County	2
Chatham-Kent Region	6
Cochrane District	1
Cornwall	6
Durham Region	29
Elgin County	8
Essex County	18
Guelph	20
Haldimand Region	2
Haliburton County	8
Halimond County	3
Halton Region	28
Hamilton	23
Hastings County	16
Kawartha Lakes	1
Kingston	10
Lambton County	7
Lanark County	2
Lanaudière	1
Leeds and Grenville United Counties	1
Lennox and Addington County	3

Region/ Township/ County	Number of Construction Companies
London	56
Middlesex County	4
Niagara Region	32
Nipissing District	2
Northumberland County	3
Ottawa	55
Outaouais	1
Oxford County	3
Peel Region	20
Perth County	9
Peterborough County	13
Port Dover	1
Prescott and Russell County	3
Prince Edward County	1
Simcoe County	20
Sudbury	4
Toronto	126
Township of East Ferris	1
Waterloo Region	39
Wellington County	7
York Region	84
Total	693

Appendix D: Survey Recruitment Email Letter

Hello,

My name is Natalie Garstka. I am a Master of Sustainability Management student. I am working on a research study under Professor Goretty Dias's supervision in the School of Environment, Enterprise, and Development (SEED) Department at the University of Waterloo. I am contacting you because you are a Residential Community Home Developer or work for one in Ontario.

I am conducting a research study investigating Residential Homes Community Developers' perceptions and understanding of sustainable building concepts and practices. I am seeing whether there have been discussions about this topic in your construction industry experience. I also want to analyze barriers that prevent further sustainable development and drivers that promote sustainable development. I wish to reach out to the type of people: project managers, project coordinators, designers, architects, and engineers that are the main participants in designing and developing new communities in Ontario. I hope to gain insight from their perception or stance on these developments.

This study aims to help identify the core themes that prevent and drive sustainable residential homes. This survey is key to gathering input from local leaders of residential home development on how environmental sustainability is implemented into the new-build construction of neighbourhood developments in Ontario cities and addresses the issues specific to these stakeholders.

Participation in this study involves completing the survey using the link provided in this email. I would greatly appreciate further distributing this email with the information outlining the research and the survey link. Further distribution can be made to project managers, project coordinators, designers, architects, engineers, or company members who provide leadership in constructing residential home developments. Other titles may include but are not limited to technical experts, client service advisors, accommodation managers, acquisition/ supply officers, specialists, or a decision-maker in your company. The survey should only take up to 15 minutes of your time. I want to assure you that study has been reviewed and received ethics clearance through the University of Waterloo Research Ethics Committee.

The final decision about participation is yours.

If you are interested in participating, please do so. Additionally, please contact me at nkgarstka@uwaterloo.ca if you have any questions regarding the survey or my research.

Link to Survey (https://uwaterloo.ca/1.qualtrics.com/jfe/form/SV_dbgfj7HU6quzEON)

I appreciate any help you can provide.

Natalie Garstka, BATech

Student Number: 20567129 | nkgarstk@uwaterloo.ca

Appendix E: Follow-up Recruitment Email

Hello,

You may have received my email explaining my research and have completed the survey. Due to the survey's anonymity, I do not know if you have completed the survey or not. Nevertheless, I would like to thank you for reading my email and completing the survey if you have done so. If you have not completed the survey, I would really appreciate it if you took some time to complete it. It would benefit my research. If you have not completed the survey because the study does not apply to you, please ignore this email. However, if you know someone whose knowledge can be used in this research, I ask that you forward this email to them.

Please contact me at nkgarstka@uwaterloo.ca if you have any questions regarding the survey or my research.

Link to Survey (https://uwaterloo.ca/1.qualtrics.com/jfe/form/SV_dbgfj7HU6quzEON)

I appreciate any help you can provide.

Natalie Garstka, BATech

Student Number: 20567129 | nkgarstka@uwaterloo.ca

Appendix F: Consent Information

Barriers and Drivers to Developing Sustainable Residential Homes in the Ontario Construction Industry

You are invited to participate in a study conducted by Natalie Garstka, a master's student under the supervision of Dr. Goretty Dias from the Faculty of Environment at the University of Waterloo, Canada. This study aims to understand the residential construction industry's knowledge and awareness of sustainable building concepts.

If you choose to participate, you will be asked to complete a confidential online survey for up to 15 minutes. The survey questions mostly consist of Likert scales and multiple-choice, focusing on personal knowledge and perceptions of sustainable construction concepts in the residential (OBC Part 9) development industry. There are no known or anticipated risks from participating in this study.

Eligible participants for this study must be:

- a) 18 years or older,
- b) A Canadian citizen or permanent resident and
- c) Member of the construction industry

Participation in this study is voluntary. You may skip any questions that you do not wish to answer by leaving a blank response or not selecting any of the provided response options, then continuing to the next question. You can withdraw your participation from the survey anytime by closing the browser window before submitting all your results. However, once you have submitted your results, you cannot withdraw from the study, as this is an anonymous survey, and we don't have any way of identifying which are your responses. In that case, your incomplete collected data will be deleted.

You will be completing the study using an online survey operated by Qualtrics. Qualtrics has implemented technical, administrative, and physical safeguards to protect the information provided via the Services from loss, misuse, and unauthorized access, disclosure, alteration, or destruction. However, no Internet transmission is ever fully secure or error-free. Qualtrics™ temporarily collects your computer IP address to avoid duplicate responses in the dataset but will not collect information that could identify you personally. If you would not like to submit your survey responses through this host, please contact Natalie Garstka so that another method of participation may be arranged, whether

through email, phone call or a paper-based questionnaire. The alternate method may decrease anonymity, but confidentiality will be maintained.

The data will be kept for at least two years on password-protected computer. Because no personal identifiers are collected in this study, your identity will be confidential.

This study has been reviewed and received ethics clearance through the University of Waterloo Research Ethics Committee (ORE # 41825). If you have questions for the Committee, contact the Office of Research Ethics at 1-519-888-4567 or ore-ceo@uwaterloo.ca. For all other questions about the study, please contact Natalie Garstka at nkgarstka@uwaterloo.ca or Dr. Goretty Dias at gdias@uwaterloo.ca. If you wish to participate, please provide your consent below to continue the survey. By agreeing to participate in the study, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

Thank you for taking the time to read this and considering participating in this study.

With full knowledge of all the foregoing, I agree, of my own free will, to participate in this study.

☐ I agree to participate

☐ I do not agree to participate

Appendix G: Survey Development Breakdown

Survey Question	Theory Application Foundation	Source
3. Job Title	Generalization 7-5: Earlier adopters have higher social status than later adopters. Generalization 7-31: Earlier adopters have a higher degree of opinion leadership than later adopters. Generalization 7-32: Earlier adopters are more likely to belong to highly interconnected systems than are later adopters.	(Ahn et al., 2013; Mahpour, 2018; Rogers, 1983, pp. 251, 259)
4. Highest level of education relating to the current employment position	Generalization 7-3: Earlier adopters have more years of education than later adopters have.	(Ahn et al., 2013; Mahpour, 2018; Rogers, 1983, p. 251)
5. Educational background in construction (follow-up to the previous question)	Generalization 7-10: Earlier adopters have a more specialized operations than later adopters	(Mahpour, 2018; Rogers, 1983, p. 252)
6. Years of experience in the industry	Generalization 7-2: Earlier adopters are not different from later adopters in age. Generalization 7-3: Earlier adopters have more years of education than later adopters have.	(Ahn et al., 2013; Mahpour, 2018; Rogers, 1983, p. 251)
7. List of sustainable standards, practices, and features 1. Individual's awareness of the industry's current sustainable standards, practices,	Generalization 6-3: As perceived by members of a social system, innovation complexity is negatively related to its adoption rate.	(Ahn et al., 2013; Hwang & Ng, 2013; Rogers, 1983, pp. 231, 258; Serpell et al., 2013)

Survey Question	Theory Application Foundation	Source
and features in recent and current projects	Generalization 7-23: Earlier adopters have more social participation than later adopters	
7. List of sustainable standards, practices, and features 2. Individual's level of interest in the industry's potential and desire to apply sustainable standards, practices, and features to future projects	Generalization 6-3: As perceived by members of a social system, innovation complexity is negatively related to its adoption rate. Generalization 7-23: Earlier adopters have more social participation than later adopters	(Ahn et al., 2013; Rogers, 1983, pp. 231, 258)
8. Significance of barriers to sustainable home development	List generated from literature review	(Ahn et al., 2013; GhaffarianHoseini et al., 2013; Hwang & Ng, 2013; Mahpour, 2018; Singh et al., 2019)
9. Importance of drivers to sustainable home development	List generated from literature review	(Ahn et al., 2013; GhaffarianHoseini et al., 2013; Hwang & Ng, 2013; Mahpour, 2018; Serpell et al., 2013; Singh et al., 2019)
10. Familiarity with third-party sustainable certifications	Generalization 7-23: Earlier adopters have more social participation than later adopters	(Rogers, 1983, p. 258)
11. Frequency of the use of sustainable third-party certification within the industry	Matching	(Ahn et al., 2013; Rogers, 1983, p. 364)

Survey Question	Theory Application Foundation	Source
12. Individual knowledge of the company's sustainability application efforts	Generalization 7-28: Earlier adopters have greater exposure to interpersonal communication channels than later adopters. Generalization 7-29: Earlier adopters seek information about innovations more actively than later adopters.	(Rogers, 1983, p. 259; Serpell et al., 2013)
13. Individuals concerned about changes in current work routines	Generalization 7-17: Earlier adopters can cope with uncertainty and risk more than later adopters.	(GhaffarianHoseini et al., 2013; Hwang & Ng, 2013; Rogers, 1983, p. 258)
14. The individual is concerned about the time it will take to adapt to the change	Generalization 7-17: Earlier adopters are more able to cope with uncertainty and risk than later adopters.	(Ahn et al., 2013; GhaffarianHoseini et al., 2013; Hwang & Ng, 2013; Rogers, 1983, p. 258)
15. Individual's enthusiasm to share and deliver sustainability efforts	Generalization 7-19: Earlier adopters have a more favorable attitude toward science than later adopters.	(Caldeira et al., n.d.; GhaffarianHoseini et al., 2013; Rogers, 1983, p. 258; Serpell et al., 2013)
16. Individual's views on the residential industry not harming the environment	Generalization 6-5: The observability of innovation, as perceived by social system members, is positively related to its adoption rate.	(GhaffarianHoseini et al., 2013; Rogers, 1983, p. 232)
17. Individuals view that homebuyers are not interested in sustainable homes	Generalization 6-5: The observability of innovation, as	(Ahn et al., 2013; GhaffarianHoseini et al.,

Survey Question	Theory Application Foundation	Source
	perceived by social system members, is positively related to its adoption rate.	2013; Hwang & Ng, 2013; Rogers, 1983, p. 232; Serpell et al., 2013; Singh et al., 2019, 2019)
18. Individuals view that sustainable development is a temporary market	Generalization 6-5: The observability of innovation, as perceived by social system members, is positively related to its adoption rate.	(Rogers, 1983, p. 232)
19. Methods of knowledge retention of sustainable trends, innovations, and education.	Generalization 7-18: Earlier adopters have a more favorable toward education than later adopters Generalization 7-22: Earlier adopters have a higher aspiration (for education, occupation, and so on) than later adopters Generalization 7-29: Earlier adopters seek information about innovations more actively than later adopters	(Hwang & Ng, 2013; Rogers, 1983, pp. 258, 259)
20. The individual has worked for several companies related to the construction industry.	Generalization 7-2: Earlier adopters are not different from later adopters in age	(Mahpour, 2018; Rogers, 1983, p. 251)

Appendix H: Copy of Survey

1. What is your age group?

- a. Under 18 years (Skip logic to end of the survey)
- b. 18-24 years
- c. 25-34 years
- d. 35-44 years
- e. 45- 55 years
- f. 56- 70 years
- g. 70 and above

2. The company I work for has completed projects that consist of residential home community development:

- a. Yes
- b. No (Skip Logic to the end of the survey).
- c. Other: _____

3. What is your current job title?

(Write-in answer)

4. What is the highest level of education related to your current job position?

- a. High school graduate, diploma, or the equivalent
- b. College credit, no degree
- c. Trade/technical/vocational training
- d. Associate degree
- e. Bachelor's degree
- f. Master's degree
- g. Doctorate
- h. Professional Degree
- i. Other: _____

5. Was this education related to the construction industry?

- a. Yes
- b. No

6. How long have you worked in the industry?

- a. < 6 months
- b. 6-12 months
- c. 1-3 years
- d. 3-5 years
- e. 5+ years

7.

Part 1: Have the following features been implemented in your most recent and current projects?

If using a computer, you can hover over each option to get an example of the feature.

If using a computer, you can hover over each option to get an example of the feature.

Part 2: How interested would you be in implementing the following features into future projects?

		<u>Part 1:</u> Yes/No/I do not know	<u>Part 2:</u> Extremely interested/ Very interested/ Moderately interested/ Slightly interested/ Not
Economic and Social Planning and Design			
SF1	Project energy modelling (i.e., residential project simulation programs to help with maximizing home energy efficiency)		
SF2	Life cycle cost assessment to showcase sustainable home construction options (i.e., the use of lifecycle cost assessment for different design options)		
Economic, Social and Environmental Material Planning and Design // Economic Home Planning			
SF3	Efficient use of building material during construction (i.e., reduce waste at project end or allocate material to other projects)		
SF4	Ethical or local material sourcing (i.e., maximizing opportunities for local or ethically sourced material manufacturers, suppliers, businesses, labourers, trainers, or partnerships)		
SF5	Making design and planning decisions based on regional and local sustainability goals (i.e., Encouraging energy conservation and sustainable use of energy or materials from naturally regenerating sources, such as wind, solar and earth energy.)		

		<u>Part 1:</u> Yes/No/I do not know	<u>Part 2:</u> Extremely interested/ Very interested/ Moderately interested/ Slightly interested/ Not
SF6	Proper measures to prevents future contamination of land and the surrounding environment (i.e., this may be during the construction phase or the lifespan of the residential neighbourhood)		
Economic and Environmental Design and Construction			
SF7	Homes are built to optimize passive energy or other renewable energy sources.		
SF8	Homes are built with ‘user-friendly’ Smart home systems/appliances		
SF9	Homes are built to use water efficiently (i.e., use of low flow fixtures, maximize the use of greywater and rainwater where applicable)		
SF10	Homes are built to control ventilation and humidification efficiently (i.e., Personal control and space for well-being and comfort)		
Economic, Social and Environmental planning and Finished Process			

		<u>Part 1:</u> Yes/No/I do not know	<u>Part 2:</u> Extremely interested/ Very interested/ Moderately interested/ Slightly interested/ Not
SF11	Planning home and community footprint with ecological and natural features in mind (i.e., Protect and enhance biodiversity and ensure that they can be easily managed and maintained, such as pre-existing ponds and forested areas)		
SF12	Design to consider end-of-use or end-of-life deconstruction with minimum waste. (i.e., what will happen to the material x years from construction, proper disposal of home components once they reached their life expectancy, such as windows being replaced)		
SF13	Post-occupancy evaluation to better future projects		

8. Based on your experiences, how have the following barriers hindered your construction of sustainable homes?

	Never	Sometimes	About half the time	Most of the time	Always	N/A
a. Homebuyer interest and knowledge						
b. Construction stakeholder knowledge and capacity						

c. Costs and economy						
d. Material availability and production						
e. Required additional equipment and training						
f. Policy, codes, bylaws, or government restrictions						
g. Purpose of building and building use						
h. Other, please specify:						

9. How important are the following drivers in encouraging the construction of sustainable homes?

	Not important at all	Slightly important	Moderately important	Very important	Extremely important	N/A
a. Government policy						
b. Company knowledge and awareness						
c. Company image						
d. Cost reduction or incentives						
e. Suppliers' availability of sustainable materials and resources						
f. Affordability for homebuyers						
g. Interest from homebuyers						
h. Other, please specify:						

10. How familiar are you with the following third-party sustainability certification organizations?

	Not at all Familiar	Slightly Familiar	Moderately Familiar	Very Familiar	Extremely Familiar
a. Energy Star 					
b. LEED 					
c. Built Green Program 					
d. Passive House 					
e. CHBA Net Zero Home Labelling Program 					
f. Building as Material Banks (BAMB) 					
g.					
h. International Living Future Institute 					
i. International WELL Building Institute					

					
j. Other, please specify:					

11. How frequently are the following third-party sustainable certification organizations used in the residential industry based on your industry experience?

	Never	Rarely	Sometimes	Often	Always
a. Energy Star 					
b. LEED 					
c. Built Green Program 					
d. Passive House 					
e. CHBA Net Zero Home Labelling Program 					
f. Building as Material Banks (BAMB) 					

g. International Living Future Institute  LIVING BUILDING CHALLENGE					
h. International WELL Building Institute  INTERNATIONAL WELL BUILDING INSTITUTE					
i. Other, please specify:					

Please describe your level of agreement with the following statements:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
12. The company where I work has implemented and urges more building projects to be more sustainable.					
13. I am concerned about the changes that would have to be made to current work routines if new sustainable construction practices were implemented.					
14. I am concerned about how much time it will take to adapt to new sustainable building approaches if new sustainable construction practices were implemented.					
15. I am looking forward to sharing some ideas about sustainable development with other workers in the construction industry					
16. The current residential housing development industry (single, semi-detached and townhouses) does not impact the environment					
17. Homebuyers are not interested in sustainable homes					

18. Sustainable development is a temporary market trend					
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19. How often do you use the following sources to maintain knowledge on sustainability trends, education, and innovations in the residential construction industry?

- ☐ Third-party building certifiers training, courses, and credentials (e.g., LEED Green Associate Course, ENERGY STAR Partnership, Passive House Building Certification)
- ☐ Maintaining membership in a non-profit professional association for networking (Passive House Canada, Urban Land Institute)
- ☐ Volunteering in local non-profit green initiative groups (e.g., reep Green Solutions, Sustainable Region of Waterloo)
- ☐ Following local green non-profit initiative groups on social media
- ☐ Attending and participating in events or workshop (webinars) lead by local green non-profit initiative groups
- ☐ Following municipalities' social media pages (e.g., City of Kitchener, Region of Waterloo)
- ☐ Attending public forums led by the municipality regarding environmental plans
- ☐ Following University Departments on social media
- ☐ Attending University-led events
- ☐ Personal research
- ☐ Other:

20. Throughout your time in the construction industry, how many companies have you worked for, including your current place of employment?

- a. 1
- b. 2-4
- c. 5-10
- d. Over 10

21. Please feel free to add additional thoughts or comments you may have:

Thank you!

If you would like a copy of the results, they would be sent to you by email in July 2020.

Please provide your email if you wish to see the results: _____

This study has been reviewed and received ethics clearance through the University of Waterloo Research Ethics Committee (ORE#41825ss). If you have questions for the Committee, contact the Office of Research Ethics at 1-519-888-4567 ext. 36005 or ore-ceo@uwaterloo.ca.

For all other questions or if you have general comments or questions related to this study, please contact Natalie Garstka at nkgarstka@uwaterloo.ca.