

Do homebuyers prioritize sustainability? Examining the GHG emission impact of housing choices

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ABSTRACT

Housing is a major source of global greenhouse gas (GHG) emissions, yet environmental performance is often assumed to play a limited role in homebuying decisions. This study investigates this claim using empirical data and explores how sustainability factors into real-world housing preferences using a choice experiment conducted in Ottawa, Canada. Participants selected from real housing listings without explicit environmental cues, while total annual GHG emissions – from both building energy use and commuting combined – were calculated for each option. Despite having low-emission listings in their choice set, respondents across all income groups overwhelmingly selected higher-emission homes. On average, the chosen homes emitted 6.93 tonnes CO₂e annually, which is over four times the emissions of the most sustainable available alternatives. Regression analyses revealed systematic deviations from optimal choices, especially among higher-income households. Open-ended responses confirmed that location, price, and size were prioritized over energy efficiency. These findings highlight a persistent disconnect between sustainability potential and actual homebuyer behaviour, underscoring the need for investigating income-sensitive policy tools, emissions labeling, and better decision-support mechanisms to reduce residential carbon footprints. They also point to the opportunity for targeting energy efficiency measures at homes with the highest GHG emissions that are nonetheless most likely to be purchased due to other attractive characteristics.

1. Introduction

Housing is a fundamental human necessity and a major contributor to global environmental impacts, particularly through energy use and greenhouse gas (GHG) emissions. Residential buildings are responsible for approximately 70 % of the secondary energy demand in the building sector, accounting for roughly 21.7 % of global final energy demand [1]. In Canada, the residential sector alone contributes to 47 % of emissions from the buildings sector (excluding electricity generation) [2]. While energy efficiency improvements since 2000 have slowed the growth of residential energy use, limiting the increase to 11.0 % by 2019, compared to an estimated 42.7 % without such interventions [3], residential energy consumption and associated emissions remain a pressing concern.

Ultimately, individual households play a decisive role in energy use, both through their daily consumption patterns and their adoption (or

rejection) of energy-efficient technologies [4]. Household consumption is estimated to contribute to 72 % of global GHG emissions [5], emphasizing the critical role that residential decision-making plays in achieving climate targets. Reducing emissions at the household level requires attention not only to available technologies, but also to the behavioural, psychological, and contextual factors that influence adoption and use [6]. Among the most consequential decisions a household can make is the purchase of a home, a choice shaped by a complex mix of different factors. While many homebuyers express a preference for energy efficiency in principle [7,8], an enduring “energy efficiency paradox” continues to limit the adoption of low-carbon technologies. That is, despite their cost-effectiveness and performance benefits, energy-efficient technologies and homes are not widely chosen in practice [9,10].

This study explores how these dynamics unfold in a real-world decision-making context through a decision experiment by analyzing how

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prospective homebuyers interact with real housing listings when they are not explicitly prompted to consider environmental concerns. By designing a survey that mimics a typical housing search scenario, absent overt cues about sustainability, we aim to characterize the true behavioural priorities that guide housing selection, and to assess the gap between available low-emission options and actual household choices. Recognizing that location is often the most influential factor in homebuying decisions, and that it inherently shapes commuting patterns, we extend our analysis to include GHG emissions associated with daily travel between home and workplace. By estimating both housing emissions and personal vehicle-related commuting emissions, this approach provides deeper insight into how latent preferences, information gaps, and structural limitations contribute to the overall carbon footprint of residential decisions.

2. Literature review

A growing body of literature across various disciplines aimed to characterize consumer preferences when choosing environmentally friendly or sustainable products. However, despite housing being a major source of household GHG emissions, the residential sector, particularly homebuyer behaviour, has not received proportionate attention. Understanding the decision-making processes behind home purchases, especially regarding the willingness to invest in green homes or energy-efficient upgrades, remains an area of considerable importance.

Existing studies in this space have primarily relied on interviews, surveys, or discrete choice experiments, often asking participants direct questions about green home attributes or sustainability-related decisions. For instance, a study conducted in Hong Kong used discrete choice experiments and found that participants strongly preferred improved environmental performance in green residential developments [11]. When made aware of the implications of their choices, such as projected annual energy use and indoor air quality, respondents expressed a willingness to pay a premium for these enhancements. Similarly, another study employed a choice experiment via interviews to explore trade-offs between price and various energy-efficient attributes, offering participants alternatives to the status quo and revealing preferences for sustainable upgrades under certain conditions [12].

In this context, the framing effect that creates cognitive bias plays a significant role. When a green apartment is presented as appealing from a personal economic perspective, participants are more likely to choose green housing [13]. Foti and Devine conducted interviews with real estate agents and homebuyers in Canada, concluding that investment return uncertainty remains a key behavioural barrier, as buyers are often concerned that the upfront costs of sustainable features may not be justified. This finding is compounded by a lack of cost-saving information for buyers, when even real estate agents are often unfamiliar with energy-efficient features [14]. Chinese consumers are reportedly less inclined to purchase green homes due to limited knowledge and financial resources [15]. This observation aligns with findings from studies in New Zealand, Norway and Australia, where location and price remained the most influential factors in home purchase decisions [7,10,16], especially in markets where such properties are rare and may not meet the more commonly desired criteria. Even among those who had purchased passive houses, sustainability was not a decisive factor, but rather a positive attribute, primarily valued for its long-term economic benefits. Interestingly, when Australian residents living in dwellings with a sustainability certification were asked about their awareness, approximately 80 % were either unaware or unsure that their home had been certified [17].

Nevertheless, a study found that green homeowners in Brazil overall exhibited more positive attitudes toward sustainability, mainly because many had attended green building training programs offered by the Green Building Council Brazil and were informed about the short- and long-term benefits of living in a green home [18]. Similarly, Tan and

Goh found that Malaysian participants with a more positive attitude toward green homes are more likely to purchase them [19]. This trend also applies to tourists, as their intention to stay in green hotels is influenced by their awareness and perceptions of the attributes associated with green building design [20]. Empirical analysis of the Australian housing market supports the positive impact of energy efficiency on house prices and rents, with energy-efficient features recognized as desirable attributes. Conversely, properties with less efficient heating systems were found to be significantly discounted in both sales and rental markets, reflecting anticipated higher operational costs and lower environmental performance [7]. A study of German homeowners found a relatively high willingness to pay for CO₂ savings from heating system choices, but not for insulation, despite both being assessed using the same elicitation method [21]. Similarly, households in the United States showed limited motivation to reduce on-site fossil fuel use, despite expressing strong concern for climate impacts and resilience. This disconnect may stem from a messaging or knowledge gap about the environmental benefits of emerging technologies, particularly heat pumps for space and water heating, as tools for reducing emissions [22].

However, it is worth noting that homebuyers are often primarily influenced by the location and surrounding neighbourhood, factors not directly tied to the sustainability of the home itself, such as proximity to amenities, transportation access, and the area's social and environmental ambience [23]. To account for these influential factors, this study incorporates transportation behaviours alongside housing preferences by presenting actual location-based choices, allowing participants to naturally consider these parameters in their decision-making process.

3. Methods and data

3.1. Survey design

The survey¹ was administered anonymously through an online voluntary questionnaire. Data collection took place in the fall of 2024; an external market research firm was contracted to assist the authors with recruiting respondents. While this approach allowed efficient sampling and yielded strong comparability with local census data, it may introduce some selection bias, particularly underrepresentation of individuals with limited internet access or lower digital engagement. This limitation should be considered when interpreting the generalizability of the findings.

We conducted a naturalistic, unlabeled choice experiment using actual real estate advertisements in the city of Ottawa, Canada. While listings have a diverse range of GHG emissions, one of the ten options included a green feature, though this was not labeled or explicitly highlighted. This design aimed to assess implicit preferences for sustainable housing without introducing social desirability or framing bias through a survey. As shown in Fig. 1, the survey was structured to collect comprehensive data on respondents' demographics, housing preferences, transportation behaviours, and energy efficiency considerations. The questions were designed to assess the relationships between income, housing selection, environmental impact, and commuting patterns. The survey followed a structured flow to ensure that participants met eligibility criteria and provided relevant data in a logical sequence.

The survey began with a screening phase, where respondents were required to verify their eligibility based on three key factors: age, residency status (whether they resided in the City of Ottawa), and prior or intended homeownership experience. The second criterion underscores the necessity for participants to possess a certain level of familiarity with the city and its surrounding neighbourhoods, as well as an

¹ This research was approved by the research ethics board of the corresponding author's university. Moreover, respondents were asked to give informed consent before completing the survey.

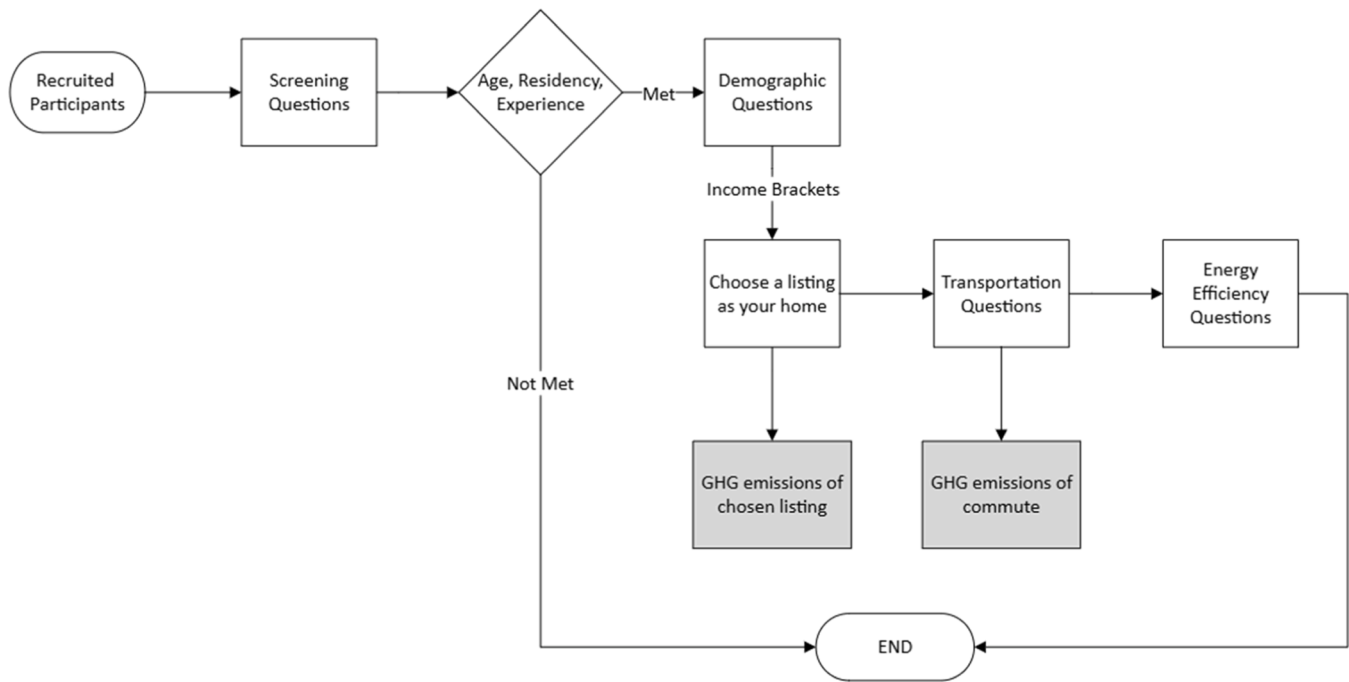


Fig. 1. Different stages of the survey.

understanding of the potential implications associated with local housing choices. The final criterion was designed to filter for individuals likely to have some awareness of the home buying process and its associated costs and requirements, particularly given their stated intention/experience to buy. While this does not guarantee complete or expert knowledge, it helps ensure that participants' perspectives broadly reflect those of prospective homebuyers. Participants who met these criteria proceeded to the main questionnaire.

Eligible participants answered a series of demographic questions, including gender, household composition, and employment status. To assess socioeconomic factors in housing and commuting choices, respondents provided their household's yearly pre-tax income, classified into predefined income brackets. They also reported the number of household members and their age distributions, which provided insights into household composition and potential space requirements. Based on their respective household income brackets in Canadian dollars as of 2024: (a) less than \$100,000, (b) between \$100,000 and \$250,000, and (c) over \$250,000, participants were presented with ten real estate listings for single-family homes within the Ottawa area. These listings were tailored to reflect both market conditions and financial feasibility for each income group. For group (a), homes were selected from the \$500,000 to \$699,000 price range; group (b) received listings priced from \$700,000 to \$999,000; and group (c) was shown homes priced at \$1 million and above (all in Canadian dollars, as of 2024). These price bands were informed by general affordability heuristics, such as the 30 % rule for housing costs and typical house price-to-income ratios ranging from 3 to 5 times annual income. However, due to the inflated housing market in Ottawa at the time of the survey, these thresholds were stretched, particularly for the lowest income group, to ensure a sufficient selection of listings. In some cases, home prices reached up to seven times annual income, reflecting the prevailing realities of housing affordability in the region.

They were asked to select the home they would most likely move into based on their personal preferences. At this stage, participants were not informed of the survey's purpose to ensure that their selection process remained natural and uninfluenced. The survey was intentionally designed to mirror real-world housing decisions, preventing any priming related to environmental impact. The listings shown to participants

were actual residential properties drawn from the local housing market, featuring standard information such as location, price, square footage, number of bedrooms, home age, and estimated utility costs. Consistent with current Canadian real estate practices, no details about energy efficiency or carbon footprint were included, as such information is not typically provided in listings. This ensured that participants' choices reflected genuine decision-making based on the type of information homebuyers normally encounter and without influence from sustainability-related cues. This approach allowed us to assess home selection behaviour in an unbiased manner and later analyze the alignment (or misalignment) between market preferences and sustainability considerations. At this stage of the survey, participants' responses were locked, and they were no longer able to return to previous questions or modify their selections. This design choice ensured that respondents could not retrospectively adjust their choices after being exposed to subsequent questions that might reveal the survey's focus on environmental sustainability or allow them to identify which listings were more sustainable. The specific details of the property listings, along with the methodology used to quantify GHG emissions, are discussed in the subsequent subsection.

Once participants chose a home, they provided the first three characters of their home and work postal codes, along with information about their employment status. These partial postal codes were geocoded to estimate the distance between each respondent's current residence, workplace, and the ten housing listings, enabling the calculation of commute-related GHG emissions where applicable. Although three-digit postal codes are less precise than full six-digit codes, a normally distributed sample of addresses in Ottawa was used to compare distance estimates from both. A paired sample *t*-test showed no statistically significant difference between the two methods ($p = 0.108$), indicating that the three-digit estimates provided sufficiently accurate distance approximations for the purposes of this study.

Participants were also asked to specify a) the number of days per week they commuted to work or school, b) their primary mode of transportation during warmer and colder months (e.g., personal vehicle, public transportation, bicycle, walking), c) vehicle details, including type, model year, and engine type (gasoline, hybrid, electric, etc.), if applicable, and d) whether they would consider changing their

workplace or commuting method if they moved to the selected home. Participants with a partner in their household were asked the same series of transportation-related questions to provide details about their partner. These data, combined with calculated distances, allowed us to quantify the GHG emissions associated with participants' commuting behaviour. A detailed explanation of the methodology used for these calculations is provided in [Section 3.5](#). This approach enabled an assessment of the environmental impact of commuting choices concerning housing location.

The final section of the survey focused on energy efficiency awareness and decision-making. Participants were asked whether they considered energy efficiency while selecting a home and to what extent energy efficiency influenced their choice, and finally to name one energy-efficient feature that factored into their decision. This section provided insights into consumer awareness of energy efficiency in housing choices and its potential role in driving sustainable housing decisions.

3.2. Sample characteristics

The survey sample comprised a diverse range of respondents ($N = 317$) in terms of age, household size, and income. Given the focus on Ottawa, the dataset captured a mix of individuals at different life stages, from young professionals to families and retirees. During the data collection phase, we aimed to ensure that the sample closely reflected the demographic characteristics of Ottawa residents across key variables.

To maintain conciseness, we provide select examples based on commonly referenced benchmarks, acknowledging that other comparable sources and key information may also exist. In terms of gender, our sample included 46.4 % males and 53.6 % females, which aligns closely with the city's population distribution in 2021 (49 % male and 51 % female). Regarding age, 17.4 % of our respondents were over the age of 65, comparable to the 16.9 % reported in the city's 2021 census. For household income, 26.2 % of participants reported annual earnings between \$50,000 and \$99,999, compared to 29.7 % nationally in 2023. Employment status was also similar: 64.7 % of respondents were employed (versus 59.1 % in Ottawa), 21.1 % were retired (compared to 17.1 % in Ottawa), and 3.5 % were unemployed, lower than Ottawa's 7.2 % unemployment rate in 2017. This lower unemployment rate is expected, given that our sample focused on potential homebuyers, who are more likely to be employed. Finally, participants were asked about their work setting (remote, hybrid, or in-person). In our sample, 23 % of respondents reported working from home two days a week or less, which aligns reasonably with 2024 estimates for the Ottawa-Gatineau region, where 34.2 % of workers primarily work from home. The difference may be partly explained by recent federal mandates requiring some government employees to reduce their remote work frequency.

The income distribution allowed for the assessment of housing preferences across different socioeconomic groups. Additionally, the inclusion of varied transportation habits and vehicle ownership enabled a detailed examination of commuting behaviours and their environmental impact. By incorporating these elements, the survey provided a holistic view of the interactions between income, housing choices, transportation behaviours, and energy efficiency considerations. The collected data facilitated an in-depth analysis of the factors influencing housing-related sustainability decisions.

3.3. Listings

The real estate listings presented to respondents were carefully selected to reflect a range of housing options available in the Ottawa market, varying by location, price, property size, number of bedrooms and bathrooms, age, and energy-related features. All listings were based on actual homes that had been listed and sold within the past two years, ensuring the relevance and realism of the options. Participants evaluated

aspects such as size based on how listings were originally presented online, including photos, room counts, and descriptive text. Although this approach may introduce some variability in perception due to the absence of standardized data (e.g., floor area), it mirrors the typical information environment encountered in real-world housing searches.

To ensure that options were financially appropriate and reflective of participants' economic situations, listings were grouped into three income categories, labeled A, B, and C, representing lower-, middle-, and higher-income brackets, respectively. The categorization was based on typical affordability ranges and market availability, ensuring that each respondent encountered listings that were consistent with their indicated income level. A detailed overview of all 30 homes is provided in [Table 1](#), with each listing identified by a prefix (A, B, or C) corresponding to its assigned income group. [Table 1](#) includes details such as home type, square footage, price, number of bedrooms and bathrooms, distance from central business district, construction year, above-grade storeys, basement presence, heating fuel, air conditioning type, and parking configuration. The homes were presented in a format similar to real-world real estate advertisements to encourage authentic selection behavior.

Each income group was presented with ten listings that varied in housing characteristics such as floor area, age, number of storeys, presence of basements, heating fuel types, cooling systems, and parking types. The distribution of housing types across groups reflected market conditions at the time of selection, based on the authors' observations. All listings were drawn from the low-rise residential segment, excluding high-rise buildings and condominiums. For instance, the lower-income group (Group A) included a mix of detached, semi-detached, and row houses, reflecting market availability at the time, while the higher-income group (Group C) consisted entirely of detached homes, which were more common in that price range.

Group A primarily consisted of older, smaller, and more affordable homes with modest features. Group B offered mid-sized homes with a balance of older and newer builds, generally with more interior space and upgraded amenities. Group C featured larger, higher-value homes, often with greater square footage, more bathrooms and bedrooms, newer construction, and upgraded physical and mechanical systems. To explore whether participants prioritize environmental considerations during housing selection, one sustainable option was intentionally embedded within each group: listings A9, B5, and C7. These homes differed from the others in their respective groups by featuring upgrades like cold-climate heat pumps, attic insulation, and energy-efficient windows, which significantly reduced their estimated GHG emissions. The inclusion of these more sustainable listings allowed us to examine whether respondents would naturally gravitate toward lower-emission options without being explicitly informed of their environmental advantages.

3.4. GHG emissions from housing

3.4.1. Data source for estimation

To estimate the annual energy consumption and greenhouse gas emissions of housing listings, a structured hierarchical matching approach was implemented using the EnerGuide for Houses (EGH) database. Since 1998, the EnerGuide for Houses (EGH) program has been a key initiative in Canada, providing comprehensive residential energy assessments. The program is a voluntary labeling initiative sponsored by the Government of Canada. Trained energy advisors conduct comprehensive on-site audits that go beyond basic visual inspections. These assessments involve collecting detailed information on building characteristics, occupancy, mechanical systems, and historical fuel consumption. These advisors typically perform diagnostic tests such as blower door tests to measure the home's airtightness. The goal is to identify energy-saving opportunities, assess retrofit feasibility, and flag any safety concerns. The collected data are processed using government-approved software, generating energy performance reports submitted to

Table 1

The list of homes presented to respondents; the prefix A, B, C represent the listings for income groups in an increasing order.

Home	Home Type ¹	Floor Area ²	Price ³	Bedrooms	Bathrooms	Built Year	Distance ⁴	Storey ⁵	Basement ⁶	Heating Fuel ⁷	A/C ⁸	Parking ⁹
A1	D	1500	628K	3	1.5	1897	2.0	2	Y	NG	N/A	Out
A2	RE	1200	695K	2	1.5	1887	3.0	2	N	NG	C	Out
A3	D	1600	510K	3	2.5	1948	3.5	2	Y	NG	C	Out
A4	D	1000	600K	2	1.5	1947	5.9	1	Y	NG	C	Out
A5	SD	1300	650K	3	1	1954	6.6	2	Y	NG	C	Out
A6	D	1400	645K	3	1.5	1979	10.6	2	Y	NG	C	A1
A7	D	1000	559K	2	1	1951	6.1	1.5	Y	NG	C	A1
A8	RE	1600	630K	2	3	2020	16.1	3	N	NG	C	A1
A9	D	1900	659K	3	1.5	1975	22.0	2	Y	E	HP	A1
A10	R	1880	600K	2	3	2022	25.0	3	N	NG	C	A1
B1	D	1600	885K	3	1.5	1887	1.3	2	Y	NG	C	Out
B2	SD	1600	910K	3	3.5	2015	4.5	2	Y	NG	C	Out
B3	D	1500	849K	2	1	1940	4.1	2	Y	NG	C	Out
B4	SD	1800	763K	2	2.5	2007	2.1	3	N	NG	C	A1
B5	D	1600	730K	3	1.5	1910	4.4	2	Y	E	HP	D1
B6	D	1600	763K	2	1	1917	6.9	2	Y	NG	C	Out
B7	D	2000	730K	4	2.5	1981	9.5	2	Y	NG	C	A1
B8	D	1700	760K	4	2	1961	13.6	1.5	Y	NG	C	A1
B9	D	2100	730K	3	2.5	2014	22.0	2	Y	NG	C	A1
B10	D	2100	825K	3	2.5	2022	25.9	2	Y	NG	C	A1
C1	D	2000	1.38M	4	3.5	1943	5.4	2	Y	NG	C	D1
C2	D	2500	1.24M	4	2.5	1890	2.5	3	Y	NG	C	Out
C3	D	1600	1.27M	3	2.5	2018	4.2	2	Y	NG	C	A1
C4	D	3300	1.17M	3	3.5	1927	2.3	3	Y	NG	WU	A2
C5	D	2800	1.13M	5	3.5	1965	7.1	2	Y	NG	C	A1
C6	D	2000	1.02M	3	2	1947	4.7	2	Y	NG	C	A1
C7	D	2500	1.61M	4	3.5	1938	7.1	2	Y	E	HP	D1
C8	D	2500	1.21M	4	3.5	1999	18.4	2	Y	NG	C	A2
C9	D	3000	1.19M	5	3.5	2014	26.6	2	Y	NG	C	A2
C10	D	3000	1.39M	4	4	2021	27.4	2	Y	NG	C	A2

1)Home types: D=detached, R=row, RE=row-end, SD=semi-detached.

2)Square footage: Some of the floor area values were estimated by the authors for the purpose of this paper, as not consistently included in the original listings, consequently, not shown to survey participants.

3)Price in Canadian dollars.

4)Distance (in kilometers) between house and central business district in Ottawa.

5)Above-grade storeys.

6)Basement: Y=it exists, N=it does not exist.

7)Heating fuels: NG=natural gas, E=Electricity.

8)Air conditioning types: N/A=no A/C, C=central, HP=heat pump, WU=wall unit.

9)Parking types: Out =outdoor, A1=attached single, A2=attached double, D1=detached single.

the EGH database. This national repository tracks residential energy efficiency trends, supporting policy development and retrofit planning. This study uses a subset of this database that contains energy performance data from approximately 1000 low-rise single-family dwellings (e.g., single-detached and semi/row homes) in Ottawa, along with their thermophysical properties required for energy simulation. This database serves as a baseline for matching the 30 listings presented in the survey regarding energy usage, even though these listings are not included in the EGH database.

3.4.2. Matching process

The matching process involved identifying listings in the survey that closely resembled homes in the EGH database based on key physical and energy-related attributes. By following this systematic approach, the annual energy consumption and corresponding GHG emissions for each listing were estimated using standardized simulation-generated data. This approach demonstrated an effective implementation in prior applications, wherein permit entries were associated with a building archetype through a matching process [24].

As illustrated in Fig. 2, the association process followed a stepwise hierarchical structure, where homes were first matched based on their heating fuel type and heating system. This was the most critical factor, as heating systems are the primary drivers of residential GHG emissions. Homes were categorized based on whether they used natural gas, electricity, or other heating fuels, and further classified based on the type of heating system (e.g., furnace, boiler, heat pump). Once a match was established based on heating system characteristics, additional building

attributes were sequentially assessed to refine the match. Building height and volume, expressed in terms of the number of above-ground storeys, was also matched to maintain comparability in heating and cooling loads. Building age was another critical parameter, as it reflects changes in construction quality, insulation standards, and material efficiency over time. Listings were matched with homes built within ± 10 -year range, with an expanded ± 20 -year tolerance when necessary. Given that building codes evolve, this step ensured a fair comparison of energy performance between homes from different construction eras.

To account for differences in building size, listings were matched based on footprint area, allowing for ± 10 % deviation. In cases where footprint data were unavailable, the project flat ceiling area (FCA) was used as an alternative size metric. This constraint ensured that homes with comparable energy demands were assessed together. Foundation type was a key factor, as it influences the building's thermal properties and overall energy efficiency. Homes were categorized as having full basements, slab-on-grade foundations, or crawl spaces. Next, attachment type was used to ensure that detached, semi-detached, and row houses were compared with homes of similar structural characteristics. Since the exposed surface area of a home affects heat loss and energy consumption, this step ensured meaningful comparisons.

Throughout the entire process, if an exact match was unavailable, the range for numerical criteria was widened or, for categorical criteria, the closest available match was selected provided the adjustment was deemed reasonable. While we propose that in cases where no reasonable match exists a criterion could be skipped in favor of the next, this fallback was not required in our study due to the large number of

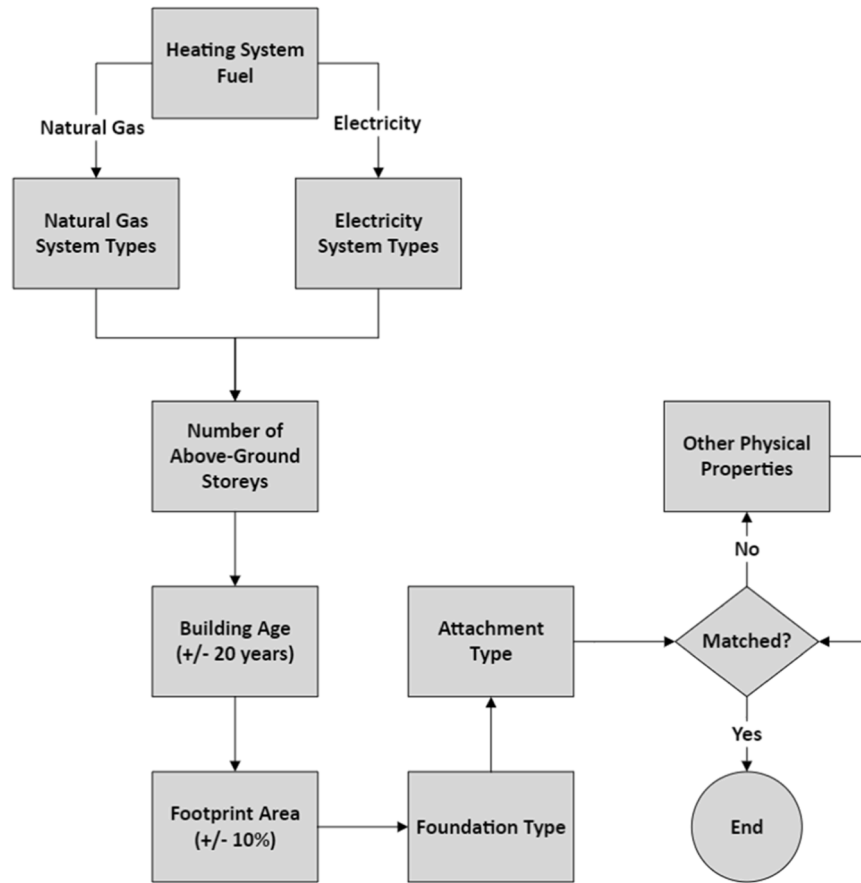


Fig. 2. A stepwise hierarchical structure for matching process.

comparable entries in the EGH database. Finally, other secondary attributes such as roof type, structure type, and building orientation were considered to further refine the matching process if multiple instances from the EGH database matched a listing. While less influential than heating system type or building size, these factors contributed to fine-tuning energy performance estimates. The matching process was repeated iteratively until a suitable match was found or flagged for manual review, at which point adjustments were made as described earlier. A summary of the matching criteria is presented in Table 2, detailing the rationale behind each step.

Once a suitable match was identified, annual energy consumption estimates from the EGH database were assigned to the listing. If multiple instances were still matched, the average of energy consumptions was computed to estimate the corresponding annual energy consumption of the listing. These values were then converted into GHG emissions using standardized emission factors: 30 gCO₂e/kWh and 1921 gCO₂/m³ for electricity and natural gas, respectively [2]. These conversion factors facilitated the estimation of total annual GHG emissions for each listing. The calculated emissions were then compared against values from a simulation database to ensure accuracy and consistency. The remaining listings will be processed using the same methodology to finalize the GHG estimations.

It is important to note that the assigned annual energy consumption and emissions values reflect standardized simulation outputs from the EGH database, which assume consistent occupancy schedules and typical heating and cooling behavior across the year. While these values provide robust estimates for comparative purposes, they do not account for individual variation in household occupancy, thermostat settings, or seasonal behavioral differences. Such assumptions are common in archetype-based modeling approaches and allow for consistent emissions estimation across diverse listings.

Table 2
Matching criteria for housing listings and EGH database.

Matching Criterion	Description	Rationale
Heating fuel & system	Homes were matched based on primary heating fuel (natural gas, electricity) and system type (furnace, boiler, heat pump).	Heating is the largest contributor to GHG emissions, making this the most crucial matching factor.
Foundation type	Homes were categorized by foundation type (full basement, slab-on-grade, crawl space).	Foundation type affects insulation and heating/cooling energy needs.
Attachment type	Detached, semi-detached, and row houses were matched accordingly.	Attachment type determines heat loss through external walls, impacting energy efficiency.
Number of storeys	The number of above-ground storeys was matched.	Multi-storey homes distribute heat differently than single-storey homes.
Footprint area (±10 %)	Homes were matched within a ± 10 % range in footprint area; FCA was used if footprint data was unavailable.	Ensures comparability in heating and cooling demand.
Building age (±10 to ±20 years)	Homes were matched within a ± 10-year range, with a fallback to ±20 years.	Older buildings often have less strict thermal requirements and efficiency standards.
Other physical properties	Factors such as roof type, structure type, and orientation were considered.	Helps refine comparisons where major factors already match.

3.5. GHG emissions from work-related commuting

To estimate the annual GHG emissions associated with work-related commuting by personal vehicles (including travel between home and workplace or post-secondary school), we combined respondents' self-reported transportation data with geospatial distance calculations and standardized emission factors by vehicle category. This methodology accounted for both the respondent's and, where applicable, their partner's commuting patterns across two seasonal profiles: warmer and colder months. Commutes related to other household members (e.g., children's schooling) and non-work-related trips (e.g., shopping or leisure) were excluded from the GHG estimation. These trips were assumed to remain relatively constant across housing scenarios, as they are generally shorter and more locally concentrated. However, we acknowledge that residential location can influence broader mobility patterns such as access to walkable amenities or transit, which in turn may affect the frequency and mode of travel. While these factors are important, incorporating them would have required a level of behavioral detail beyond the scope of the current analysis.

3.5.1. Transportation profiles and emission factors

Each respondent reported their primary mode of transportation, along with details about their vehicle type (e.g., sedan, SUV), engine type (e.g., gasoline, hybrid, electric), and year of manufacture. These attributes were used to classify vehicles into GHG emission categories, as shown in Table 3, using median CO₂ emission values (g/km) derived from the Canadian government's official fuel consumption ratings database [25]. To define emission bands for gasoline-powered vehicles, the 33rd and 66th percentiles of the entire database were used as cut-off thresholds to create three categories: *Low*, *Moderate*, and *High Emission*. Each vehicle is assigned to a category based on its CO₂ emissions relative to the calculated thresholds. This classification created an approximately even distribution of vehicle models across three categories: low, moderate, and high emission gasoline vehicles.

For non-personal vehicle modes such as walking, cycling, or public transit, GHG emissions were set to zero for the purpose of this household-level analysis. While public transit systems do produce emissions, we assume that the marginal impact of a single household's use of an existing transit route is negligible. This assumption is particularly applicable in Ottawa, where most bus and rail services operate on fixed schedules and have continued to run below capacity since the COVID-19 pandemic. Despite ongoing recovery, ridership remains at about 75 % of pre-pandemic levels as of December 2023 [26]. Given these patterns, the incremental emissions associated with an additional rider are likely minimal unless service frequency or capacity is increased. Moreover, the City of Ottawa has committed to fully electrifying its bus fleet by 2036, reinforcing the expectation of declining transit-related emissions in the coming years. Excluding these modes from household GHG calculations allows the analysis to focus on private vehicle choices, which are more directly modifiable by households. Moreover, public transit emissions are generally captured in broader municipal inventories, so excluding them here helps prevent double-counting in household-level footprints. The emission factors

Table 3
The emission factors for different vehicle types.

Category	Fuel Type	CO ₂ Emissions Range (g/km)	Median CO ₂ (g/km)
Battery Electric	Electricity	4.40 - 13.8	6.50
Plug-in Electric	Hybrid	14.0 - 472	94.0
Low Emission	Regular gasoline	104 - 225	195
Moderate Emission	Regular gasoline	226 - 284	260
High Emission	Regular gasoline	285 - 608	326

presented in Table 3 were used in subsequent calculations to estimate work-to-home commute-related emissions for both respondents and their partners, if applicable.

3.5.2. Distance estimation

The geographic commuting distance between each housing listing and the workplace of each respondent (and their partner, where applicable) were calculated using the Google Maps Directions API. Respondents provided the first three characters of their home and work postal codes, which were geocoded into latitude and longitude coordinates. The API returned both distance (in kilometers) and duration (in minutes) under typical traffic conditions. In cases where the home and work postal codes were identical, we assumed a short local commute and applied default values of 3 km for distance and 5 min for duration. This approximation reflects a conservative average for intra-neighborhood travel within Ottawa, where *forward sortation areas* (FSA, which is the first three characters of postal codes) are generally compact and often represent neighborhoods or small urban zones. While postal code size can vary across Canada, especially between rural and urban areas, Ottawa's urban FSAs typically do not span large distances. Actual travel distances could vary depending on street layouts and trip routing, using 3 km serves as a reasonable proxy for short-distance vehicular commutes, particularly when respondents reported a personal vehicle as their primary mode. This assumption minimizes the risk of overestimating emissions for such cases, and the relative contribution of these short commutes to the overall GHG estimates remains small compared to longer-distance travel across the city. For modes like walking and cycling, which were assigned zero emissions in this analysis, the assumed distance does not factor into GHG calculations.

Travel time was also retrieved to support internal validation of direction queries and ensure that estimates aligned with feasible commuting patterns. These calculations were extended to determine commuting distances from each respondent's current workplace to all ten real estate listings within their assigned income group. This allowed for the evaluation of alternative housing scenarios, enabling a comparison of potential GHG emissions based on residential location choice.

Given Ottawa's distinct seasonal variation, especially the impact of harsh winter conditions, the analysis incorporated season-specific commuting patterns. Respondents provided information on their transportation modes separately for warmer and colder months, allowing the model to capture realistic behavioral shifts between seasons. When available, commuting data for partners were processed using the same methodology. Emission factors were assigned for each individual and season based on their reported travel mode, vehicle type, engine type, and year of manufacture, ensuring that GHG emission estimates reflected both transportation behavior and vehicle characteristics throughout the year.

3.5.3. GHG estimation logic

The weekly GHG emissions associated with routine commuting were estimated using the following equation:

$$GHG_{\text{weekly}} = 2 \times \Delta L \times EF_s \times D \quad (1)$$

where:

- ΔL is the commuting distance (in kilometers) between the workplace and either the current home or one of the ten housing listings.
- EF_s is the season-specific emission factor (in g/km), derived from the respondent's or partner's vehicle category, as detailed in Table 3.
- D is the number of commuting days per week according to participants' responses.
- The factor of 2 accounts for round-trip travel (i.e., both legs of the commute).

To calculate total annual commuting emissions, Eq. (1) was extended

to capture both warm and cold seasons, assuming 24 commuting weeks per season (i.e., 48 working weeks per year). While this assumption reflects a typical full-time work schedule, actual commuting weeks may be lower for some individuals due to statutory leave, holidays, or illness-related absences. It is important to note that while Canadian labour surveys report average weekly working hours, they do not provide a standardized value for the number of working weeks per year. As such, no authoritative source exists for this specific parameter. Nonetheless, the assumption of 48 weeks per year aligns with general Canadian work norms. Furthermore, given the diverse nature of the sample, over- and underestimation at the individual level is expected to balance out at the aggregate level. The resulting annual emissions were calculated as follows:

$$GHG_{annual} = \frac{24 \times 2 \times (GHG_w + GHG_c)}{1,000,000} \quad (2)$$

where Ghe_{gs} and GHG_c represent the weekly commuting emissions during warmer and colder months, respectively. The division by 1000,000 converts emissions from grams to tonnes of CO₂ (tCO₂e/annum). This calculation was applied to both the respondent and their partner (if applicable) for all ten real estate listings within the respondent's assigned income group. The result was a distribution of commuting-related GHG emissions for each participant's means of transportation across all possible housing options. These commuting emissions were then combined with the annual housing GHG emissions (calculated as described in Section 3.4) to generate a total emissions profile for each home. Therefore, when we refer to total GHG emissions

in this paper, we specifically mean the combined housing and commuting GHG emissions, as other sources contributing to a household's total GHG emissions are not included within the scope of this study.

3.6. Retrospective power analysis

To evaluate the adequacy of the sample size used in this study, a retrospective power analysis was conducted. *GHG Difference*, defined as the annual emissions gap between the chosen and the lowest-emission listing per participant, was used as the primary outcome variable for power analysis given its direct relevance to behavioral decision patterns and environmental impact. The objective was to determine whether the sample size was sufficient to detect a meaningful deviation in GHG emissions from a conservative reference value, set at one metric ton. This threshold was selected as it reflects a relevant benchmark for household-level emissions mitigation in urban housing contexts. Assuming a one-sample, two-tailed *t*-test design, power was computed based on the effect size defined as the ratio of the one-ton threshold to the observed standard deviation within the sample. The analysis was repeated for the full sample and for each income subgroup, allowing us to determine whether subgroup sizes were adequate to support meaningful statistical interpretation. In addition to computing power for the 1-ton threshold, we calculated the observed effect size for each group by dividing the actual mean GHG difference by the corresponding standard deviation. This provides insight into the actual strength of the effect present in the data, independent of any predefined threshold.

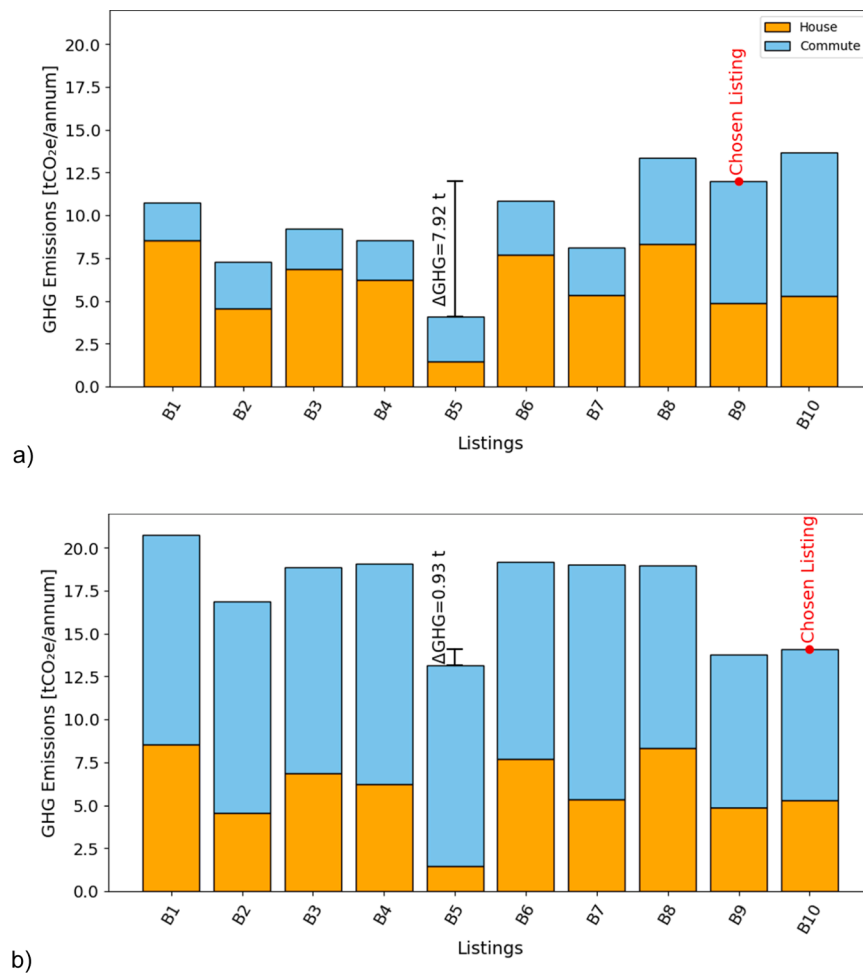


Fig. 3. Total household GHG emissions (housing plus commuting) for ten listings were presented to two respondents, along with total GHG emissions for their chosen listing.

4. Results and discussion

To illustrate how total household GHG emissions are calculated and how different decision pathways can lead to varying environmental outcomes, Fig. 3 presents stacked bar charts for two individual respondents. Each bar represents the sum of housing and commute emissions for one of the ten listings. The figures highlighted the selected listing and its difference from the lowest-emission option. The two respondents shown represent contrasting household profiles and emission dynamics. Both respondents reported that they did not consider the energy efficiency of the homes presented when making their decision in the survey.

Respondent 1 (Fig. 3a) is a middle-income (i.e., with pre-tax income for all contributing members of the household between \$100K-\$200 K in Canadian dollars), full-time employed male in his mid-30 s, living with a partner and a school-aged child. Both adults commute regularly using gas-powered personal vehicles, contributing significantly to overall transportation emissions. Their chosen listing resulted in 11.99 tCO₂e/annum while the minimum-emission alternative could have reduced their footprint to 4.07 tCO₂e/annum, yielding a ΔGHG of 7.92 tCO₂e/annum, due to differences in housing and commuting emissions. While B5 offered lowest housing emissions (1.48 tCO₂e/annum), it also came with relatively shorter commute distances (2.9 km for Respondent 1 and 16.3 km for their partner) as shown in Fig. 4. In contrast, B9 involved significantly longer travel distances (20.7 km and 29.3 km, respectively) and higher housing emissions (4.90 tCO₂e/annum). Fig. 4 presents a spatial layout of these listings relative to the workplaces of Respondent 1 and their partner, illustrating how the chosen listing was both less efficient and more distant. The combination of suboptimal energy performance and extended travel distances led to one of the highest total GHG footprints in this household's choice set.

Beyond emissions, the properties differ in other meaningful ways. B5 is a 1600 ft² detached home built in 1910, with three bedrooms, 1.5 bathrooms, and electric heating via a cold-climate heat pump. B9, by comparison, is a larger, newer (2100 ft², built in 2014) detached home with three bedrooms and 2.5 bathrooms, using a natural gas heating

system. These features may have made B9 more attractive in terms of modern amenities, space, and perceived comfort, despite its environmental drawbacks. Regardless, this respondent explicitly stated that the most attractive feature of the selected listing was that it is “away from the inner city,” suggesting a deliberate preference for suburban or less urbanized environments. This case highlights how personal lifestyle preferences and perceived housing value can outweigh environmental considerations, even when the greener choice is both available and logistically feasible.

Respondent 2 (Fig. 3b) is a higher-income (with a pre-tax household income between \$200K-\$250 K in Canadian dollars), full-time employed woman in her early 50 s, living with three other household members: two adults and a senior. Although she no longer commutes due to changes following the pandemic, her partner travels a long distance five days a week using a gas-powered SUV, leading to a GHG profile heavily dominated by transportation emissions driven by extended commuting. Her chosen listing (B10) resulted in 14.10 tCO₂e/annum, while the minimum-emission alternative (B5) was 13.17 tCO₂e/annum, yielding a ΔGHG of just 0.93 tCO₂e/annum. In this case, emissions are dominated by commuting, leaving limited potential for mitigation through housing choice alone. Notably, Respondent 2 identified “space outside” as the most attractive feature of their selected listing, indicating that outdoor amenities may have outweighed environmental considerations.

Together, these examples underscore the importance of contextual factors such as commute distance, vehicle fuel type, housing efficiency, and lifestyle preferences in shaping a household's carbon footprint. They also demonstrate the variation in “opportunity space” across households: while some could drastically reduce their emissions with a different choice, others may be more constrained due to structural factors like job location or the geographic distribution of low-emission housing options, or personal priorities related to space, neighborhood type, or amenities.

Fig. 5 presents the normalized frequency of selected housing listings across income groups, ordered by their total annual GHG emissions. Listings are colour-coded from green to red to reflect their environmental performance, with cooler tones indicating lower-emitting homes

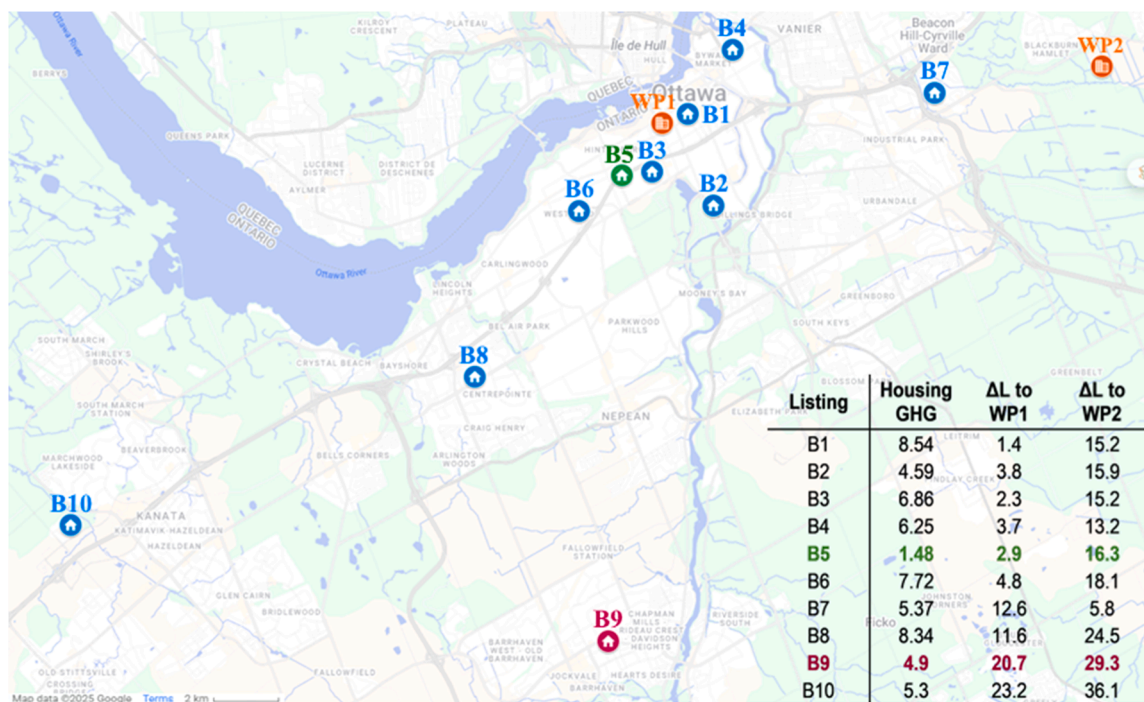


Fig. 4. Map of Ottawa showing the ten listings (B1–B10) presented to Respondent 1. Each listing is annotated with paired commute distances (ΔL) in kilometers to WP1 (Respondent 1's workplace) and WP2 (their partner's workplace), along with estimated housing-related GHG emissions in tCO₂e per year. Listings B5 and B9 are highlighted in green and red, respectively, representing the lowest-emission and the chosen options based on total GHG emissions.

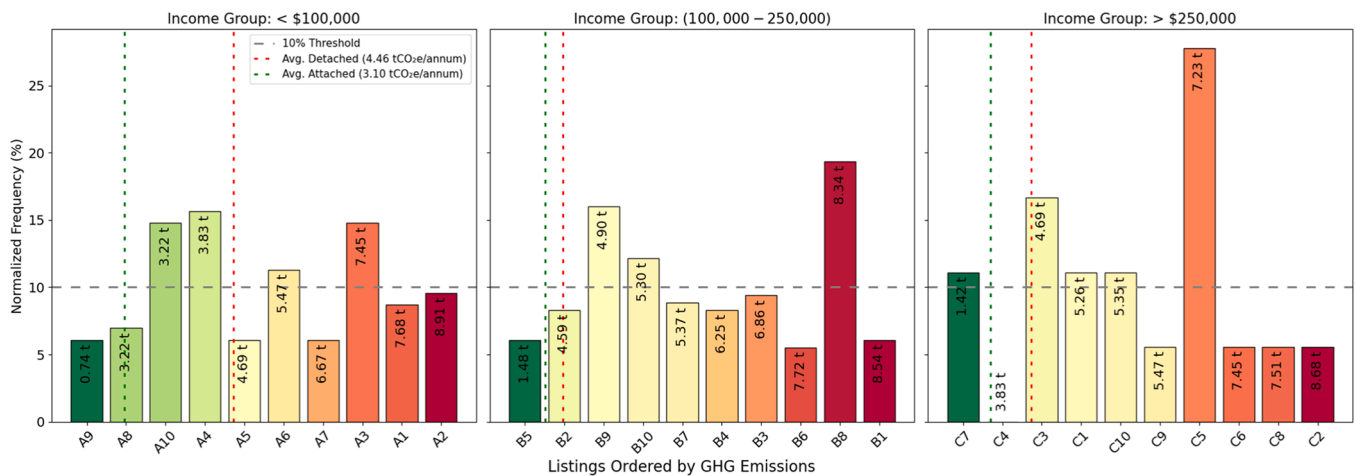


Fig. 5. The normalized frequency of chosen listings ordered by GHG emissions (in tCO₂e/annum) across income groups. The horizontal dashed line at 10 % represents the expected frequency under random choice. Vertical dashed lines indicate the national average GHG emissions for detached homes (4.46 tCO₂e/annum, red) and attached homes (3.10 tCO₂e/annum, green) to serve as benchmarks [27].

and warmer tones representing higher-emission options. Several important patterns emerge from the distribution of preferences. First, low-emission listings such as A9, B5, and C7, each equipped with low-emission features such as electricity-based HVAC systems, were not selected at disproportionately high rates. For instance, only about 6 % of respondents in the low-income group selected A9, despite its extremely low emissions of 0.74 tCO₂e/annum. Similarly, less than 10 % of middle-income respondents selected B5, another low-emission option. If we consider 10 % as a benchmark for random choice, given that each participant had ten listings to choose from, this result suggests that low-emission options were generally not prioritized. While the high-income group slightly exceeded this threshold with an 11 % selection rate for the low-emission listing C7 (1.42 tCO₂e/annum), this marginal increase should be interpreted cautiously, as it represents only a 1 % difference and comes from a smaller sample that may be more prone to selection variability.

Across all income groups, the majority of selections clustered around or exceeded national average GHG benchmarks, notably the 4.46-tCO₂e threshold for single detached homes, marked by the red vertical line. In the low- and middle-income groups, several high-emission homes including A2 (8.91 tCO₂e/annum), B1 (8.54 tCO₂e/annum), and B8 (8.34 tCO₂e/annum) were selected at relatively high frequencies, underscoring the persistent appeal of larger or less-efficient homes despite the availability of lower-impact alternatives. In contrast, many listings within the high-income group fell just above or near the national average, reflecting common trends in the current housing market likely driven by preferences for greater comfort, larger living spaces, and perceived value [28]. Yet the lowest-emitting option received only limited attention while several higher-emitting homes also remained popular among this income group. These results suggest that prioritizing energy-saving efforts for high-emission homes that are more likely to be purchased, due to their other appealing features, could serve as an effective complementary strategy.

A deeper analysis of frequently selected listings (A3, A4, A10, B8, B9, B10, C5, and C3) helps explain the patterns behind these choices. Among lower-income participants, affordability emerged as a central priority: all top-chosen homes were either low- or mid-priced within the set of listings tailored to their group. This aligns with the survey design, where the upper threshold for this income bracket was deliberately stretched to reflect the limited availability of lower-cost homes in the Ottawa market at the time. Interestingly, two subgroups emerged within this income bracket based on location preferences. Most respondents favored listings closer to the downtown core, possibly due to better access to public transit, particularly relevant given that a larger share of lower-income

participants reported not using personal vehicles (30.4 %, compared to 16.6 % in the two higher-income groups). However, some respondents prioritized larger homes over proximity, as evidenced by the selection of listing A10, which is situated farther from the city center. This suggests that floor area and comfort were weighed against commute convenience for this subgroup. Notably, the minimum-emission listing (A9) offered the largest floor area yet was not commonly chosen, likely because it was located farthest from the city center and was among the pricier options in the set, failing to meet either of the key affordability or location criteria for these two subgroups.

Middle-income respondents showed a strong preference for modern or spacious homes, often accepting increased distances from the urban core to secure these attributes. Listings like B8 and B9 reflect this trade-off, offering ample space and amenities at the cost of higher emissions. This behavior is particularly striking considering that low-emission alternatives, such as B5, were both affordable and centrally located, yet remained under-selected, indicating that larger home size or newer finishes may have outweighed sustainability in the decision-making process. High-income respondents, meanwhile, demonstrated a clear preference for high-amenity and moderately priced options like C5 and C3, suggesting that perceived value, defined by a combination of space, finish quality, and cost, played a stronger role than environmental performance. Even though some low-emission homes like C7 offered similar or larger floor areas, they were typically overlooked due to less favorable locations, older building age, or significantly higher prices.

Overall, the findings illustrate a persistent disconnect between environmental performance and actual housing preferences. GHG emissions were not a dominant factor in decision-making, particularly among low- and middle-income groups, even when low-emission homes were present in the choice set. It is important to note that homebuying is rarely a purely rational process; rather, it is often shaped by emotional responses, time constraints, and cognitive limitations. This aligns with the concept of *bounded rationality*, where individuals rely on simplified decision rules or heuristics instead of evaluating all available information [29–31]. These insights point to the importance of increasing the visibility of energy efficiency and carbon impacts in residential housing, possibly through clearer labeling or incentives tailored to diverse income and lifestyle preferences. Moreover, the availability of low-emission houses close to downtown could significantly decrease low-income population's total emissions.

To further investigate the environmental implications of participants' housing choices, Fig. 6 compares the total GHG emissions associated with each respondent's chosen listing and the minimum-emission listing available within their income group. The histogram displays the

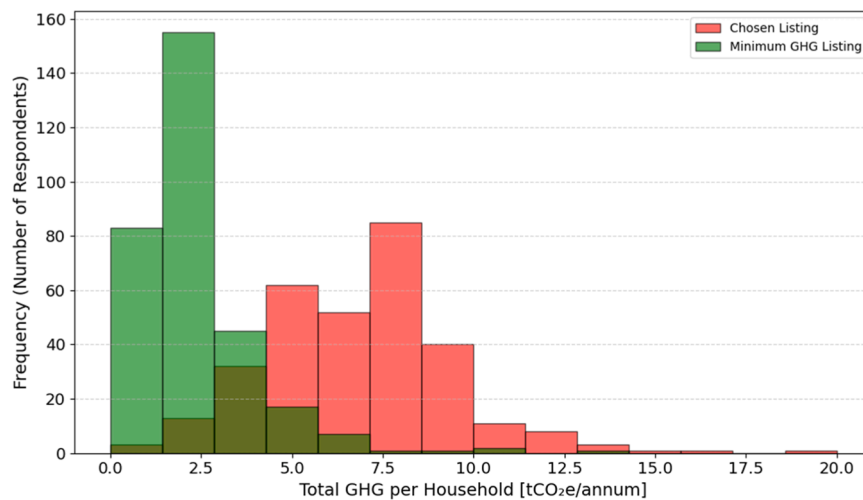


Fig. 6. Histogram of total annual GHG emissions per household for chosen listings (red) versus the minimum-emission listings available (green).

distribution of total household-level emissions, combining both housing and commuting sources, across all participants. The red bars represent the GHG emissions of the chosen homes, while the green bars show what emissions could have been if respondents had selected the lowest-emission option available to them. This comparison reveals a substantial discrepancy between actual choices and environmentally optimal alternatives. The median total GHG emissions for chosen listings is 6.93 tCO₂e per year per household, more than four times higher than the median of 1.60 tCO₂e/annum for the minimum-GHG listings. The distributions are visually distinct, with the chosen listings skewed toward higher emission values, and the minimum listings heavily concentrated in the lower emission range. The standard deviations from the medians of the chosen listing and minimum-GHG listing groups are 2.64 and 1.70 tCO₂e/annum, respectively. This further illustrates the consistent gap in emissions between the two decision paths.

These findings reinforce earlier results presented in Fig. 3, which showed limited uptake of low-emission homes even when available within the choice set. When considering both housing- and commute-related emissions, the data strongly suggest that environmental impact was not a dominant factor in respondents' selection behavior. This is further supported by the fact that 54.1 % of respondents explicitly stated that the energy efficiency of the homes did not influence their decision at all. This represents a missed opportunity for significant GHG reductions through more sustainability-oriented housing choices. The results underscore the potential for targeted interventions such as policy mandates, financial incentives, or awareness campaigns to promote low-emission living. Prior research suggested that how environmental benefits are communicated can influence consumer behavior; for example, Rosner et al. found that green framing significantly affected willingness to purchase green apartments [13]. Similarly, the way emissions are presented, whether as absolute values or relative savings, can shape perceptions and decisions [21].

In this context, standardized energy and emissions labels included in residential property listings could serve as beneficial decision-support tools for homebuyers. The absence of such labels may have reduced the salience of environmental information in this study, limiting the potential *framing effects* that could influence preferences toward low-emission options. Without explicit cues about energy performance, participants appeared to rely on more conventional decision criteria such as price, location, and size. This behavioral tendency may also reflect the discounting of future energy expenses such as heating and electricity bills which, although not perfectly aligned with GHG emissions, are often used as proxies for environmental performance. In this context, homebuyers may undervalue long-term utility savings relative to more immediate and tangible concerns like mortgage payments or

location, further weakening the role of energy efficiency in housing decisions.

These behavioral dynamics help explain the observed disconnect between environmental performance and housing choices. Without such labels, assessing the environmental implications of housing options, each with its own thermophysical attributes, remains challenging for key stakeholders, including buyers and realtors, and would otherwise require costly consultations with energy professionals to complement standard home inspections. Prior research has shown that energy labels can improve transparency around a dwelling's efficiency and may act as effective signaling devices, with benefits capitalized into home prices [32] or reflected in a sales price premium [33]. However, a study from Sweden found that higher energy efficiency ratings did not translate into higher selling prices, suggesting that price impacts may depend more on observable features during house visits than on information uniquely conveyed by energy labels [34]. Additionally, the implementation of such labeling systems introduces additional costs, which must ultimately be borne by a stakeholder: either through government support or passed on to buyers. It is also important to note that these labels do not provide any information about commuting-related emissions, which can be a substantial part of a household's carbon footprint.

Fig. 7 compares total annual GHG emissions per household for each income group, contrasting the emissions associated with the chosen listings and the minimum-emission listings available within the same choice set. The violin plots illustrate both distribution and spread of emissions, while embedded boxplots highlight medians, interquartile ranges, and outliers. Across all income groups, the pattern is consistent: respondents' actual housing selections are associated with substantially higher GHG emissions than the most sustainable option available to them. Among lower-income households (<\$100,000), the median GHG emissions for chosen listings is 5.47 tCO₂e/annum, compared to just 0.74 tCO₂e/annum for the minimum-emission alternative, yielding a median difference of 3.94 tCO₂e/annum. This emissions gap is even more pronounced in the middle- and high-income groups, where the median difference reaches approximately 4.77 and 4.80 tCO₂e/annum, respectively. Notably, while the absolute emission levels increase with income (with median values of 7.39 and 7.23 tCO₂e/annum for the middle- and higher-income groups, respectively), the relative GHG savings potential remains substantial across all groups. While wealthier participants have access to listings with slightly higher baseline emissions, their choices still tend to fall well above the minimum possible impact.

These findings highlight the need for income-specific policy interventions to address GHG emissions in the housing sector. While higher-income households typically face fewer financial barriers to

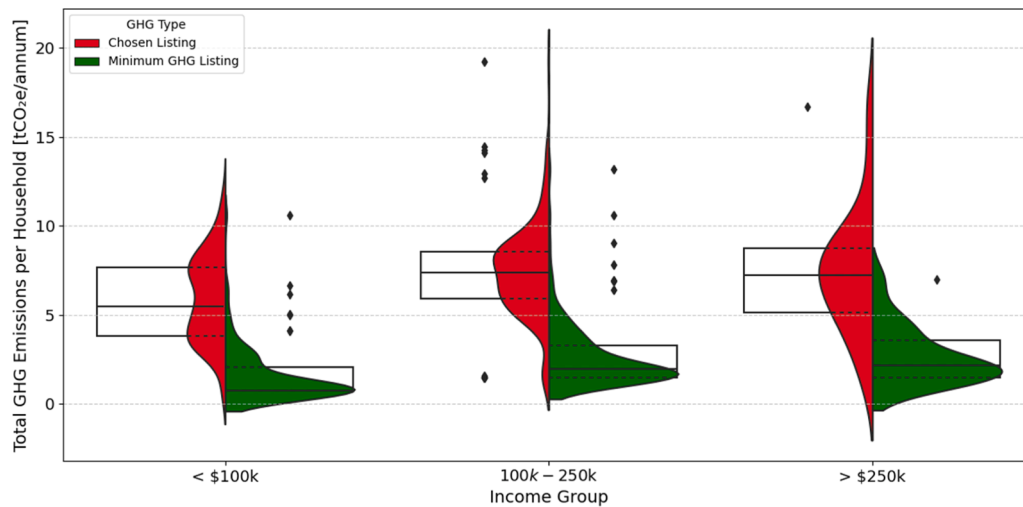


Fig. 7. Violin plots comparing total annual GHG emissions per household for chosen listings (red) versus minimum-emission listings (green) across income groups. Boxplots within each violin display medians, interquartile ranges, and outliers.

adopting energy-efficient options [4], their actual selections still reflect substantially higher emissions, suggesting that lifestyle preferences or trade-offs related to home size, location, or features often outweigh sustainability considerations [35]. In contrast, although the GHG difference between chosen and minimum-emission listings is smallest for lower-income respondents, the absolute value of their minimum-emission scenario is dramatically lower, just 0.74 tCO₂e/annum, highlighting a substantial opportunity for near-zero emission living. This group appears structurally positioned for low-carbon lifestyles due to factors like smaller homes and shorter commutes yet may be unable to fully capitalize on this potential without targeted support. Given their naturally lower willingness to pay for sustainable features [11], enhancing access to low-emission housing through retrofits, incentives, and affordability-focused energy efficiency policies could yield outsized reductions in GHG emissions within this segment.

Fig. 8 presents a scatter plot comparing each respondent's minimum achievable total GHG emissions with the total emissions associated with

their chosen listing, grouped by income level. Each point represents an individual household, color-coded by income group, with group-specific regression lines fitted to illustrate the relationship between potential and actual emissions. The dashed red line denotes the ideal case, where a respondent would have selected the most environmentally optimal option available. Across all three income groups, the trendlines fall well above the ideal line, indicating that most participants selected homes with higher GHG emissions than the best available option within their income bracket. The fitted linear models reveal important differences in selection patterns between groups.

For the lower income group, the regression equation with an $R^2=0.65$, indicating a relatively strong linear relationship. The slope near 1 suggests that emissions rise proportionally with the GHG levels of available options, but the intercept of 4.46 tCO₂e/annum reveals a significant emissions baseline even when the most sustainable options are available, possibly due to unavoidable housing and transportation needs. For the middle-income group, the regression equation and a

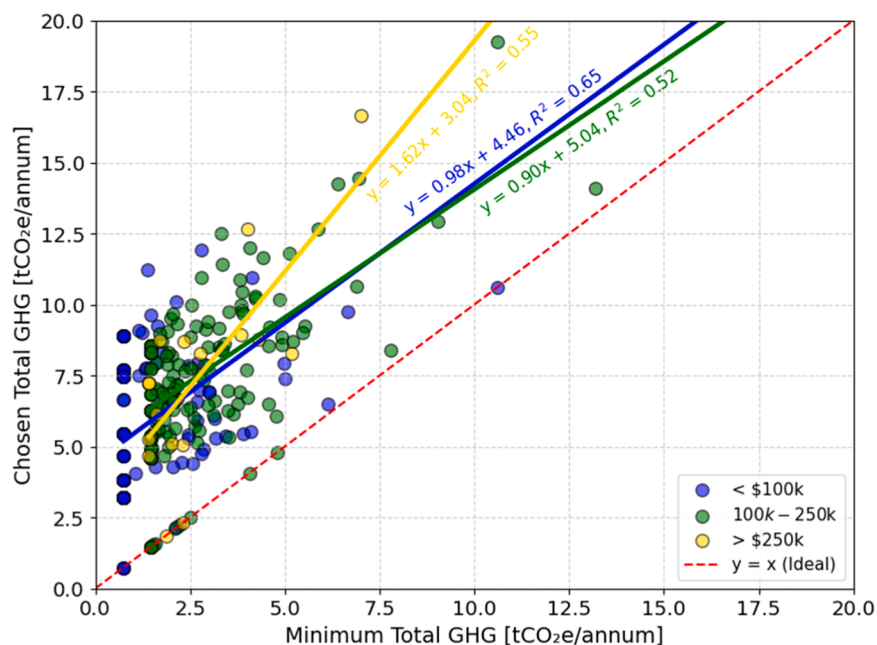


Fig. 8. Total GHG emissions of chosen listings versus the minimum available within each income group. Colored points represent individual respondents; trendlines show group-specific regressions.

slightly lower $R^2=0.52$ suggest greater variation in behavior and a modest decline in alignment between minimum and chosen emissions, potentially due to factors like housing quality, amenities, or commuting distance. The larger intercept further supports the idea that respondents consistently selected homes with emissions that exceed what could have been achieved, even for similar levels of minimum emissions. The pattern is most pronounced in the high-income group, where the regression line has a steeper slope of 1.62, indicating that households with access to higher-emission listings are disproportionately more likely to choose them. Despite a small sample size ($N = 18$), the relatively higher $R^2=0.55$ suggests a clear, albeit more variable, pattern. The regression indicates that higher-income households not only overlook low-emission opportunities but are also more reactive to high-emission listings, thus further increasing the emissions gap.

Overall, these results confirm and extend the insights from previous figures, illustrating that across income groups, respondents consistently select homes with significantly higher total emissions than necessary. Moreover, the regression intercepts and slopes reveal a persistent systematic deviation from optimal behavior, especially pronounced in higher income brackets. This finding further underscores the need for interventions, incentives, or information strategies to realign housing decisions with lower-carbon outcomes. For lower-income households, support should focus on improving access to low-emission housing through subsidies or retrofitting programs. For high-income groups, who tend to select higher-emission homes, incentives for luxury green housing could help shift preferences. Meanwhile, middle-income households may benefit most from policies that enhance the appeal and affordability of sustainable options, such as green financing and improved access to low-carbon transportation.

To complement the quantitative analysis especially findings presented in Fig. 5 showing the frequency of chosen listings, participants were asked two open-ended questions in the last step of the survey: 1) “What was the most attractive feature that influenced your choice?” and 2) “Name one energy-efficient feature that factored into your decision.” Table 4 summarizes the most frequently mentioned words for each question. In response to the first question, location was the most frequently cited feature (60 mentions), followed by price (31), house/home (32), bedrooms and bathrooms (16 each), and general indicators of size such as number, size, and space (42 combined). Aesthetic or structural aspects like modernity, backyard, or style also appeared frequently, suggesting that traditional housing preferences remain dominant. These results align with previous studies [10].

In contrast, energy efficiency was less central in respondents’ considerations. For the second question, terms like windows (15), natural

and gas (18), heat (12), and insulation (10) were among the most common. Broader concepts such as newness, modernity, or age of construction appeared 21 times in total. Mentions of energy efficiency or efficiency-related systems (e.g., appliances, solar, heat pumps) were relatively infrequent, typically below 5 mentions each. This aligns with earlier findings that GHG emissions were not the primary drivers of housing choice, even when more sustainable options were available. It also suggests that homebuyers lack knowledge about technologies for energy retrofitting as a way to achieve sustainability [22].

5. Limitations and generalizability

While this study provides valuable insights into the behavioral drivers of housing-related emissions in Canada, its generalizability to other urban settings should be interpreted with caution. With these limitations in mind, Ottawa represents a typical Canadian urban center (82 % of Canadians live in urban areas) and lies within Climate Zone 6, making its context broadly relevant to many parts of the country. Nonetheless, Ottawa’s housing market, cold continental climate, urban form, and regulatory landscape, including the absence of mandatory energy or emissions labeling, shape the specific patterns observed. In jurisdictions with different real estate pressures, transit infrastructures, or environmental policies, household decision-making may follow different trajectories. Moreover, such a naturalistic survey design, which mimics a real-world home search, inherently requires participants to be familiar with the city and its neighborhoods, an aspect that limits the feasibility of such a method to single-city or region-specific studies. Since homebuying is a deeply personal process, spatial familiarity is crucial for realistic decision-making. Future comparative studies across diverse geographies are needed to assess the transferability of these findings.

The study also identified distinct patterns among high-income participants. While this subgroup was proportionally represented based on national statistics, the absolute number of respondents was small. As such, these findings should be interpreted cautiously, as the limited sample size may not fully capture the diversity of preferences and behaviors within this demographic or across other urban contexts. Broader generalizability is especially limited in regions with different real estate markets or cultural norms around energy and housing.

To assess sample adequacy, a retrospective power analysis was conducted based on the annual GHG difference between chosen and lowest-emission listings: a key behavioral outcome. Assuming a 1-ton detection threshold, Table 5 showed power exceeded 99 % for low- and middle-income groups, indicating strong ability to detect meaningful differences. Power for the high-income group was lower (49.6 %), reinforcing the need for caution when interpreting subgroup findings. Nonetheless, observed effect sizes were consistently large across all income groups, with GHG differences between 4.4 and 4.8 tons and Cohen’s d values above 1.8, which is well beyond conventional thresholds for large effects. These strong observed effects, combined with high power in the full sample, support the statistical robustness of the study’s primary conclusions, particularly regarding the behavioral gap between environmental performance and housing choice.

Table 4

Most frequently mentioned words in open-ended responses to housing choice and energy efficiency questions.

Rank	Attractive Feature Influencing Choice	Mentions	Energy-Efficient Feature	Mentions
1	Location	60	Windows	15
2	Price	31	Natural / Gas	18*
3	House / Home	32*	Insulation	10
4	Bedrooms	16	Heating	9
5	Number / Size / Space	42*	Heat	8
6	Bathrooms	16	New / Newer / Modern / Age	21*
7	Modern	13	Energy / Efficient / Solar	16*
8	Single / Bungalow	18*	Appliances	5
9	Backyard	8	Built	5
10	Area	7	Smaller / Size	7*
11	Garage	6	Heat Pump	4
12	Kitchen	6	–	–
13	Style	6	–	–

* Combined counts of all the terms in the row that were mentioned by respondents, as they broadly refer to the same feature or concept. However, ranking is based on the frequency of individual terms, not the combined totals.

Table 5

Summary of retrospective power analysis and observed effect sizes.

Income Group	Sample Size (n)	Observed Effect Size (Cohen’s d)	Power ($\alpha = 0.05$, for 1-ton Δ GHG)
< \$100k	115	1.84	0.997
\$100k – \$250k	181	2.35	1.000
> \$250k	18	1.86	0.496

6. Conclusion

This study investigated the real-world housing preferences of prospective homebuyers in Canada through a naturalistic choice experiment in which participants selected from a curated set of real estate listings without explicit environmental framing. By integrating both housing and commuting-related GHG emissions, we found a consistent pattern across all income groups: participants selected homes with significantly higher total emissions than the most sustainable alternatives available to them. Our results also suggest that prioritizing energy-saving interventions for less sustainable homes that homebuyers are still likely to choose for other appealing features, could be an effective strategy.

While the emission gap between chosen and minimum-emission listings was present across income levels, it was most pronounced in middle- and high-income households in absolute terms. Lower-income respondents, despite showing the smallest gap, had access to near-zero emission options, suggesting a missed opportunity for low-carbon living that could be realized with appropriate support. Regression analyses confirmed a systematic deviation from environmentally optimal choices, particularly among higher-income respondents, who were more likely to select high-emission listings when such options were available. These behaviors underscore the limited role of environmental performance in current housing decisions and the strong influence of conventional drivers like location, size, and price, reflected in both the quantitative results and open-ended responses. Even when low-emission homes were present in the choice set, they were rarely selected, especially by low- and middle-income groups. This pattern may reflect the discounting of future utility expenses rather than actual GHG emissions, particularly in cases where low-emission technologies (e.g., electric heat pumps) do not necessarily translate into lower energy costs compared to conventional natural gas systems.

These findings suggest that it would be valuable to investigate whether including standardized energy and emissions labels in residential property listings could serve as useful decision-making aids for homebuyers and act as effective framing tools to promote greener housing choices. Such labels could follow standardized formats similar to vehicle emissions ratings or nutrition labels, using color-coded energy scores and annual GHG estimates. Integration into *Multiple Listing Services* could be mandated through municipal or provincial regulations.

The results underscore the importance of analyzing income groups individually to inform tailored policy interventions. While we observe a substantial GHG gap between chosen and low-emission homes across the full sample, targeted strategies may improve alignment with sustainability goals. For lower-income households, typically associated with smaller homes and shorter commutes, supports such as retrofitting programs, zero-interest loans, or property tax reductions tied to verified energy performance may be effective. High-income households, who often select larger, higher-emission homes, could respond to premium framing, such as green certifications or recognition programs. Middle-income households may benefit from improved access to green financing and better visibility of low-carbon alternatives in the housing market. Green mortgage products, zoning bonuses for developers including low-emission units, and enhanced emissions filtering tools or sustainability nudges embedded in search algorithms on real estate websites may offer additional leverage points.

Overall, this study highlights a critical gap between sustainability potential and realized choices in residential behavior. Addressing this disconnect requires a multi-pronged strategy: transparent energy and emissions labeling for homes, targeted financial incentives, and public education on the environmental implications of housing and commuting. By anchoring interventions in real-world mechanisms such as changes to building codes, real estate disclosure rules, or tax policy, policymakers can more effectively align residential behavior with climate goals. As cities and nations strive to meet climate targets, empowering households to make lower-carbon housing choices

represents a substantial and underleveraged opportunity.

CRediT authorship contribution statement

Pedram Nojedehe: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Burak Gunay:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Brodie W. Hobson:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **William O'Brien:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition. **Marcel Schweiker:** Writing – review & editing, Supervision, Methodology, Investigation. **Helen Stopps:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Pedram Nojedehe reports financial support was provided by Tri-agency Institutional Programs Secretariat. Pedram Nojedehe reports financial support was provided by Social Sciences and Humanities Research Council (SSHRC). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The data that has been used is confidential.

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