Residential Archetyping for Energy Efficiency Programs

A Guide for Canadian Municipalities

June 2022

Clean Air Partnership

Clean Air Partnership

Clean Air Partnership (CAP) is a charitable environmental organization whose vision is that Canadian communities are sustainable, healthy, and resilient. CAP was launched in 2000 to enable communities to improve air quality, advance active transportation, and take bold climate action. CAP serves as the facilitator for the Clean Air Council (CAC), which is a staff level network of over 35 municipalities and health units from across Ontario working collaboratively on the development and implementation of clean air, climate change, sustainability, and resilience actions.

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Executive Summary

To design residential energy efficiency programs, we must attain estimates of current energy use and greenhouse gas emissions. This allows for prediction of potential energy and carbon savings from future efficiency upgrades Bottom-up energy modelling methods allow us to estimate energy demands for housing types. To do this, housing classes, or archetypes must be created which classify existing buildings into representative clusters for the residential sector.

Once archetypes are defined, energy changes, carbon reductions, and uptake scenarios can be modelled for each archetype. Different program design approaches can be modelled, incorporating additional municipal priorities such as low-income housing affordability, or aging in place. The archetyping process proposes that, through the interaction of various parameters and factors, potential energy demand can be obtained from a dwelling, thus generating archetypes representative of the simulated housing stock, which can be extrapolated to different levels to test different theories.

This Guide will take municipal users through the process of defining residential archetypes within their communities. Operational characteristics characterizing user behaviour also influence energy use but are not covered by this guide. We will categorize input data across the following four groups:

1. **General information:** year of construction, type of dwelling, location, and climatic zone.
2. **Geometric characteristics**: floor area, facade area, shape, number of floors, window area, story height and orientation.
3. **Thermal characteristics of the envelope:** materiality of the envelope and internal temperature.
4. **Systems and equipment:** heating system, hot water, and associated fuels.

This Guide will describe the importance of archetyping within program design, identifying the utility and necessity of each variable, appropriate data sources, and methods for defining archetypes within a community. This will allow the reader to characterize and contextualize housing stock so that archetypes generated are as representative as possible for use in energy efficiency program design.

While this Guide does not provide a prescriptive methodology detailing every step required to complete a community energy efficiency market analysis, it will enable staff to more effectively and efficiently collaborate with staff or consultants who are experienced in this area. Although many of the datasets and archetyping examples described in this Guide are specific to Ontario, most of the content can be broadly applied to any Canadian jurisdiction.

1 Introduction

Residential Emissions

Climate change is significantly impacting communities around the world and affecting our infrastructure, health, and safety. The Intergovernmental Panel on Climate Change has stated that limiting global temperature increases to 1.5°C above pre-industrial levels requires expedited and transformational changes to land use, energy, industry, buildings, and transportation. Municipalities are critical leaders in addressing this transformation.

Nationally, Canada's homes and buildings account for about 18% of greenhouse gases (GHG) emissions. This figure accounts for energy used in space and water heating, building cooling, lighting, and appliance use. In Ontario, buildings contribute 24% of total GHGs. At the municipal level, in many municipalities, building energy use accounts for up to 50% of community emissions.

Fossil gas is the most common home heating fuel in Canada, widely used for the heating of space and water. Much of this heat energy is lost by inefficiency, through walls, foundations, attics, windows, doors, and other leaks. To address residential emissions, existing homes must be retrofitted to increase their efficiency, reducing, or removing fossil gas use (as well as oil and propane). This task is arduous, requiring thousands of homeowners to engage in energy efficiency retrofits.

In response to this challenge, municipalities across the country are acknowledging that they must play a key role in tackling climate change. Over 650 Canadian communities have passed climate emergencies and have developed (or are developing) climate action plans or community energy plans. Through climate actions such as a building energy efficiency retrofit programs, municipalities can help their residents achieve climate commitments, while also reducing their vulnerabilities to energy and carbon price increases over time and increasing economic development and job creation within their communities.

Residential Retrofitting

Creating new energy resources is expensive. Because of the high costs of extraction, processing, generation and distribution of new energy resources, the most cost-effective source of a unit of energy is the one saved. Therefore, reducing energy demand through building envelope and equipment improvements is paramount in any retrofit program design.

Adding insulation, using high performance windows and doors, and sealing air leaks significantly reduces the energy use and associated GHG emissions of a home. **Optimal results are obtained when homes are treated as a system and retrofits are coordinated on the entire structure.** Where electricity sources are fossil free, emissions can be reduced to zero when efficient homes switch to electric heat sources. The benefits of home energy efficiency retrofits go beyond energy savings, and include greater comfort,increased property values, healthier indoor air quality, and greater resilience to power outages. For the community and the municipality, these retrofits can stimulate the local economy, improve the local building stock, and help municipalities to achieve their climate mitigation targets.

Essentially, we must make our buildings as efficient as possible, and use efficient heating, ventilation, air conditioning (HVAC), lighting and appliances, all powered by clean electricity.

Retrofits have the greatest impact when done in the following sequence:

- Adding insulation
- Sealing air leaks
- Upgrading the mechanical systems
- Replacing windows and/or doors
- Water upgrades
- Thermal controls

The best results are obtained when a whole home approach to energy efficiency is taken, and often the best time to approach homeowners is when they are already planning renovations. There are many homes in Canadian communities that could substantially reduce their GHGs through energy efficiency retrofits.

Program Design Process

At a high level, there are four steps in any energy efficiency program: market analysis, planning, implementation, and monitoring and evaluation.

Step 1 – Market analysis

In Canada, many municipalities are currently at the Market Analysis stage. Attaining an understanding of the local market is an essential first step in program design. In characterizing the market, basic demographics analysed, including the number of households in the community, income distribution, and the fraction of homes that are rented Residential archetypes are defined, broadly categorizing the housing types within the community. Energy and carbon intensities are estimated for each archetype, and uptake scenarios are created and visualised using maps and graphics.

Step 2 – Planning

Upon completion of a market analysis, municipalities (or 3rd party program administrators) conduct a legislative & regulatory assessment identifying any relevant regulatory frameworks (such as the availability of provincial PACE financing legislation for example).

Potential funding sources are identified. Program administration models are evaluated, and an initial identification of roles and responsibilities is drafted. Initial program eligibility is now defined and stakeholder consultation with relevant groups can be undertaken.

Step 3 – Implementation

In the Implementation Phase, operational flows are finalized. Program forms are created, e.g., bylaw templates, application, disclosure, agreements. The program marketing strategy and website is launched, and monitoring and evaluation criteria are decided. If the program uses preapproved contractors, then contractors must be recruited, on-boarded and trained. Programs are then launched, either as pilot programs, or at full scale.

Step 4 – Monitoring and Evaluation

Monitoring focuses on the systematic collection of program indicators and is used at set intervals throughout program delivery. Evaluation is a more complete interim or final analysis of a program's impacts, identifying outcomes, successes and lessons learned. To ensure objectivity, evaluations are typically performed by 3rd parties. Energy efficiency programs should plan and budget for monitoring and evaluations from the outset, typically around 10% of total administration fees. Based on the outcome of program monitoring and evaluation, programs should be adjusted, and implementation strategies amended if needed.

Archetyping Within the Market Analysis Process

Recognizing the importance of addressing emissions from residential buildings, many Canadian municipalities are taking action. Where green development standards and other tools are often employed to address energy efficiency in new developments, residential retrofit programs are required to reduce emissions from existing buildings. Archetyping is a fundamental and first step in this process.

Archetyping is a data driven exercise. Data collection and management is the first step in understanding the market for energy efficiency retrofits and creating a program. Before we can create a program, we need to understand our market, analyzing both the residential building stock, and key demographic and behavioral data about the community members who dwell within.

While many of these data sources are already municipally held, others will require specific requests. This Guide will provide an overview of key data holdings and their custodians. It cannot be stated strongly enough that the time required to complete the data collection process is typically underestimated. Certain datasets require nondisclosure agreements, legal review, or data sharing agreements. They can take time to acquire and may require additional processing before they can be used. Creating a robust dataset before program design begins can save both time and money for the municipality and program design partners. In Section 2 we describe each dataset, where it is generally held, and how it can be acquired.

2

Creating Residential Archetypes

One of the approaches to determining residential energy consumption is the bottom-up method which allows municipalities to model energy demand of a house then generate representative archetypes of the stock.

Bottom-up models seek to estimate energy consumption through the characteristics of a group of dwellings. Archetyping is one of the most used techniques to categorize the housing stock and describe the residential energy consumption. The inputs that are commonly considered to classify an archetype are: function of the building, area, geometry, age, and others. They are characterized according to the factors that affect energy consumption such as building envelope, ventilation, air conditioning, heating, operating characteristics, and internal loads. The characteristics and factors that define archetypes can be classified in four categories: general data, geometric characteristics, thermal characteristics of the envelope, and systems and equipment.

Data Overview

General Data

General data consists of year of construction, type of dwelling, location, and climatic zones. The year of construction and type of dwelling can be considered very useful because based on the building code at time of construction, they quickly provide information about the construction practices, materials, and characteristics of the building.

Location (i.e., urban, or rural) can be useful as it also provides an indication of the type of dwelling, construction practices, materials, and characteristics of the building. Urban houses are often attached or semi-detached, whereas rural houses are more often detached homes with greater floor areas.

Climatic zone can be considered useful because there are eight distinct climate zones in Canada, and it allows for the estimation of the thermal behaviour expected for a specific house as well as how it was constructed. For example, homes built in a climatic zone that experiences more rain will have a steeper sloped roof and homes in northern climatic zones will have more insulation.

Geometric characteristics

Geometric characteristics includes floor area, façade area, shape, number of floors, window area, storey height, and orientation. These characteristics are important to consider because they impact how much space needs to be heated and cooled, potential heat loss, the impact of solar radiation and renewable energy potential.

Thermal characteristics

Thermal characteristics of the envelope include materiality of the envelope and internal temperature. The materiality of the envelope affects the home's thermal performance and airtightness. Homes built prior to a certain year may have had no thermal requirements and are generally considered noninsulated. Other dwellings during a certain period may have had to meet a maximum thermal transmittance for certain envelope components in contact with the ambient air. Materiality of the envelope also greatly impacts the internal temperature and heat loss of the home.

Systems and Equipment

Systems and equipment include heating systems, hot water, and associated fuels. Information for this includes the primary and secondary fuels used for space heating and hot water, type and efficiency of space heating and hot water systems and type of ventilation system and typical airflows. This information is important because systems and equipment are directly tied to energy consumption and GHG emissions. For example, a house that uses natural gas for heating emits more GHGs than an electrically heated house.

Data Sources for Archetype Development

There are several resources available to obtain the data needed to develop archetypes for municipalities. The following section describes each data set, detailing the data custodian and nature of any agreements required to use the data.

EnerGuide Ratings

Name	Custodian	Agreement required
EnerGuide Rating Data	Natural Resources Canada	Yes

Every year, thousands of EnerGuide building energy ratings are created from data collected during building energy audits undertaken by Natural Resources Canada registered energy advisors. These audits are required for participation in certain federally funded programs, as well as many utility programs. Additionally, homeowners may request a building energy audit for their own information outside of participation in any program. Advisors collect data including:

- The level of a home's airtightness
- The insulation levels of walls, ceilings, and basement
- The number, type, and location of all windows and exterior doors
- The size and efficiency ratings of all space heating, space cooling, and water heating equipment
- Information about any ventilation equipment
- Any other information relevant to a home's energy performance

This is a robust dataset that can provide key insights into building energy characteristics in a program catchment area. This dataset is also important in benchmarking archetypes. This dataset is not readily available to the public so an agreement with Natural Resources Canada will be required.

LiDAR

Name	Custodian	Agreement required
Digital Models	Natural Resources Canada or Canada Open Data	No

Light Detection and Ranging (LiDAR) is a remote sensing method that uses light in the form of pulsed laser to measure ranges (variable distances) to the Earth. These light pulses, combined with other data recorded by the airborne system, generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. This technology can capture high levels of detail over large scale urban areas and the data improves the quality of input data for modelling standardized energy use. This dataset can be used to provide estimates of energy demand for dwellings in a community. While it is not essential, it provides insights worth capturing when available.

LiDAR data can be acquired in some cases through open sources as well as from commercial providers. It is possible this dataset has been previously acquired by the municipality for other purposes, so check with municipal GIS staff before proceeding to another method of acquisition.

MPAC/Property Tax Assessment Data

Name	Custodian	Agreement required
Municipal Property Assessment (MPAC) data	Provinces and Municipalities	Yes

The Municipal Property Assessment Corporation (MPAC) assesses and classifies all properties in the Province of Ontario, in accordance with the Ontario Assessment Act and provides an accurate and impartial property inventory. Each province in Canada has their own version of a property assessment database. Information in property assessments includes:

- Physical characteristics of a property
- Location
- Classification
- Assessed value and other related assessment information

These datasets can provide key insights into building characteristics including location, aspect (i.e., orientation), size, and age of the home.

Canadian Housing Survey

Name	Custodian	Agreement required
Canadian Housing Survey	Statistics Canada	No

Every two years, Statistics Canada releases a survey to collect information about housing needs and experiences from a sample of Canadian households. The Canadian Housing Survey provides information on how Canadians feel about their housing and how housing affects them. Information collected includes:

- Core housing need
- Dwelling characteristics and housing tenure
- Perceptions of economic hardship from housing costs
- Dwelling and neighbourhood satisfaction
- Perceptions of neighbourhood issues and safety
- Housing moves including forced moves
- Community engagement
- Life and community satisfaction
- Self-assessed health
- Various dimensions of physical and mental wellbeing
- Experience with homelessness
- Socio-demographic characteristics
- Impacts of COVID-19

The Housing Survey questionnaire asks questions regarding dwelling-type, number of bedrooms, state of repair, utility information, whether the dwelling is energy efficient, ability to maintain a comfortable temperature in the winter and summer, indoor air quality, etc. All these questions can provide insight into energy usage and loss in a household.

Housing Stock Data

Name	Custodian	Agreement required
Dwelling Characteristics	Statistics Canada	No

Under the Housing and Dwelling Characteristics in Statistics Canada, there are several datasets that contain useful information for housing type, year of construction, systems, and equipment, etc. such as:

Percentage of households that used an air conditioner, and type of air conditioner used
Presence of and usage characteristics of thermostats
Main source of water
Residency participation (owner occupied vs non etc)
Dwelling counts by geography, property type, period of construction

Census Data

Name	Custodian	Agreement required
Census of Population	Statistics Canada	No

Every five years, thousands of Canadians complete a census designed to provide information about people and housing units in Canada. Demographic, social, and economic characteristics are gathered.

This survey can provide key insights into demographic information, dwelling type, and housing characteristics.

Utility Consumption Data

Name	Custodian	Agreement required
Census of Population	Statistics Canada	No

Acquiring utility data will provide useful information on the type and quantity of energy being consumed in the home (i.e., electricity, natural gas, water). This information will give an indication on the type of equipment and systems in place that are being used to heat and cool the home.

Fuel Price

Fuel Type	Name	Website	Custodian:	Agreement required
Furnace Oil	Weekly Average Retail Prices for Furnace Oil	NRCan Furnace Oil Pricing	Natural Resources Canada	No
Propane	Weekly Average Retail Prices for Furnace Oil	NRCan Propane Pricing	Natural Resources Canada	No
Natural Gas	Natural Gas Rates	OEB Natural Gas Rates	Ontario Energy Board	No
Electricity	Electricity Rates	OEB Electricity Rates	Ontario Energy Board	No
Carbon Intensity	Greenhouse Gas Emissions Coefficients	NRCan GHG Equivalencies Calculator	Natural Resources Canada	No

Determining the price and carbon intensity of fuel types used to heat and cool a home can provide an understanding of the cost of energy and emissions for each archetype. For example, homes that use natural gas or other fossil fuels will have greater emissions than a home that is electrically heated and cooled by low carbon electricity sources such as hydro.

Method for Developing Archetypes

The following section outlines the steps to take when developing archetypes for the community to determine which housing types to target for energy efficiency upgrades.

Step 1: Data Collection
Step 2: Data Pre-processing
Step 3: Feature Selection
Step 4: Grouping by Dwelling Types and Construction Year
Step 5: Outlier Deduction
Step 6: Aggregation
Step 7: Results Interpretation and Archetype Development

Step 1: Data Collection

To develop representative archetype houses, housing databases are required. Use the databases to develop a master spreadsheet with a full set of housing stock variables which impact energy use, energy rating, physical characteristics, etc. Various sources for this data are outlined in the previous section.

Step 2: Data Pre-processing

The buildings data obtained through measurement systems or surveys is often incomplete and lacks certain important variables. Data pre-processing is a data mining technique that involves transforming raw or real-world data into a usable format. During pre-processing, the data goes through a series of steps such as data cleaning, data integration, data transformation and, data reduction.

Step 3: Feature Selection

Feature selection is the process of selecting a subset of most relevant variables or attributes for the model. The feature selection method aims to remove irrelevant and redundant attributes to get accurate results. Features can include geometric, thermal, and operating characteristics that influence a house's performance. Redundant features can be removed through regression analyses or other statistical measures.

Field survey or remote sensing data can be employed to develop typical geometry details for main housing forms. These can include the development of geometric rules and co-relation-based formulas for various components. Primary required inputs can be footprint dimensions (depth and width, or perimeter), house form, number of levels, shape of the house, type of attic and the foundation. Based on these primary inputs, all required dimensions of house components can be generated. Using the geometric details of a variety of types of homes, standard configurations can be developed to define different forms and style of houses.

Thermal characteristics include the make and composition of envelope components (size and insulation values), predominant heating and hot water equipment data (type and steady state efficiencies), and airtightness and ventilation parameters. These data can then be considered to develop a profile of thermal archetypes based on the location and the year of construction (or year of major renovation).

The operating parameters include the profiles of base loads (lighting and all house related appliances), occupancy, and indoor temperature data. The operating parameters are intended to capture homeowner's lifestyle behaviour. The following data can be assembled:

- Indoor temperatures (heating and cooling seasons)
- Use of ventilation systems, kitchen, and bathroom fans, and so on
- Domestic hot water use
- Occupancy levels (number and percentage of time in the house)

The above information can assist in generating typical operating profiles and basic assumptions for the energy analysis.

Step 4: Grouping by Dwelling Types and Construction Year

Low-rise housing is typically grouped into the following types:

- Split-level bungalows
- Detached or single-family homes
- Semi-detached (two attached houses)
- Row houses (more than two attached and vertically separated)
- Walk-ups (more than two dwellings vertically and horizontally separated)

Vintage period or construction year can be based on various changes in the applicable codes and standards. The following vintages are typically used:

- Pre-1945
- 1946 to 1960
- 1961 to 1970
- 1971 to 1980
- 1981 to 1990
- 1991 to 1995
- 1996 onwards

Step 5: Outlier Deduction

Outlier detection is the process of identification of observations in the data that deviates by a significant amount from a given set of data. Outliers should be identified and removed as they skew overall data trends, lowering accuracy and model performance. Outliers can be point outliers, contextual outliers, or collective outliers. Standard statistical methods should be used to determine outliers, either through distance and density of data points, or though construction of a model to predict data distribution, highlighting those data points that do not meet a defined threshold.

Step 6: Aggregation

The aggregation process involves categorizing the data into groups and then applying arithmetic or geometric mathematical operations. The obtained aggregated value represents the characteristics of one building archetype.

Step 7: Results Interpretation and Archetypes Development

A database of houses could allow for dozens of archetypes, but a large number of typical archetypes defeats the main purpose of simplification. The following criteria can be used for developing archetypes:

- Primary requirements should only include the age and location of the house.
- Secondary requirements are the typical dimensions (width and depth or perimeter), house levels, shape of plan, type of ceiling, and type of foundation – as well as heating source and fuel cost.

3

Incorporating Archetypes Into Program Design

Incentive Design

All energy efficiency programs should examine potential incentives. These incentives can be from utilities, other orders of government, or from the municipality. Once all currently available incentives are identified, municipalities should examine those households that are underserved by utility programs.

Similarly, many utility programs cannot be accessed by those who rent homes, or those who cannot afford the upfront costs of undertaking measures to access incentives. Once archetypes are identified, potential incentives may vary for each archetype. It is unlikely that all archetypes can access all available incentives.

For example, in Ontario, Enbridge's Home Efficiency Rebate Program provides up to $5,000 in possible rebates to improve a home's energy efficiency through measures such as increasing the efficiency of the furnace and building envelope improvements. The offering, however, is only available to Enbridge Gas customers. Many of those most burdened by high energy costs in Ontario fuel their homes with oil and propane, so are thus ineligible for this program. Municipalities could consider designing incentives for these customers. Similarly, the federal government's Greener Homes program also doesn't provide financing but does provide incentives up to $5,000 for building envelope. However, funding cannot be stacked with utility programs.

Marketing

High home energy use and its environmental impacts are not traditionally pressing issues for many communities. Contemporary energy costs and their resultant financial pressures are transforming this paradigm.

While those archetypes where homes are heated by propane, or particularly, by oil, are experiencing extreme cost increases and unpredictable energy future costs, homeowners in all archetypes are feeling energy cost increases more than they have in the past.

Traditional marketing approaches for energy efficiency incentives (or entire programs) have been passive, untargeted campaigns. These approaches have had limited success. It is inadequate to sell an energy efficiency program as just that – it must be sold as something people want. More resonant points include cost savings, health, comfort, and energy security. More targeted approaches, tailored for ,specific archetypes are likely to bring greater success. Specific archetypes and the demographics who reside within them can form natural market segmentation opportunities.

Municipalities are trusted messengers in the community mindset. Creating outreach materials, delivered through appropriate channels, highlighting the success of early adopters to the program can be extremely effective. Word of mouth, use of contractors as ambassadors, and targeted online advertising can be powerful channels to advance program uptake.

Operational Considerations

Archetyping generally does not consider many operational considerations, which can have a considerable impact on post-retrofit energy consumption.

In the single family home residential sector, most archetypes assume the same level of home occupancy. However, households can have different numbers of tenants, with different energy needs, using different equipment. Homes that are completely retrofitted, with high levels of insulation and efficient heating and cooling equipment can still have quite different energy needs. For example, electronics using ‘standby power’ can account for up to 10% of a home’s electricity use. Equipment such as TVs, lighting, range hoods, fridges, dishwashers, ovens, washers, and dryers use a considerable amount of a home’s power and may or may not be upgraded at the time of retrofit. Some homeowners may use sensible passive ways to cool a home, such as closing blinds, while others may choose not to.

Identification of Market Potential

For any given archetype, market potential should be estimated. Each archetype has a dwelling count associated with it. Archetyping should estimate the annual carbon emissions and energy costs associated with each archetype.

Based on dwelling counts per archetype, together with models of program penetration for each archetype, modelers can estimate the program uptake for each customer segment. This can give estimates of total carbon and energy savings potential per archetype. Program uptake scenarios will vary based on available capital, municipal priorities, financing models used and the availability of other incentives from utilities and other orders of government. The table below estimates total economic potential per archetype for the City of London, Ontario.

Archetype	Carbon Score t/ CO2/year	Annual Energy Cost $	Dwelling Count	Total Energy Costs $
A	10.5	3,800	3,778	14,300,000
B	5.0	2,500	64,645	160,800,000
C	1.9	5,100	107	540,000
E	11.8	7,600	130	980,000
F	7.2	3,000	7,937	23,600,000
G	16.1	5,100	639	3,230,000
H	7.2	3,000	7,221	21,800,000
Total			**84,458**	**225,200,000**

Table 1 Economic Potential by Archetype for the City of London, ON (Source: LightSpark Inc.)

Testing and Verification

Once archetypes are developed, they should be tested against known data to verify that archetyping is on track, and to determine which archetypes should be targeted for energy efficiency improvements.

Currently in Canada, EnerGuide is the official Government of Canada energy performance rating and labelling program for key consumer items, including houses. To participate in home energy efficiency incentive programs, many Canadians have had to (and continue to) complete an EnerGuide home evaluation.

The results of the home evaluation provide an estimate of the net amount of energy a home consumes in a year in gigajoules (GJ), a breakdown of how energy is consumed by source, and the proportion of energy consumed by heating, cooling, ventilation, etc. Homes that consume less energy in GJ (i.e., a number closer to zero) indicates that a home is more energy efficient. Homes with a higher energy consumption in GJ per year are less efficient.

Houses within each archetype that have completed an EnerGuide home evaluation can then be used to analyse energy consumption and verify the general accuracy of placing a given home within that archetype, and if that archetype should be targeted withing an energy efficiency program.

4
Archetyping Examples

Example A

Source: LightSpark Inc.

Archetype A

These homes have an above average floor area, and are natural gas heated with low/ mid efficiency furnaces and use natural gas hot water systems.

Average annual electricity costs: $1,540
Average annual natural gas costs: $2,200
Average annual energy costs: $3,776

Client Implications:
These homes consume 237.4 GJ (1.17 GJ/m2) of energy on average and produce 10.5 tCO2e (0.052 tCO2e/m2) on average. They represent 2.9% of the housing stock and 12.9% of the dwellings that have been audited in the City of London.

Archetype B

These homes have an above average floor area, and are natural gas heated with low/ mid efficiency furnaces and use natural gas hot water systems.

Average annual electricity costs: $1,540
Average annual natural gas costs: $2,200
Average annual energy costs: $3,776

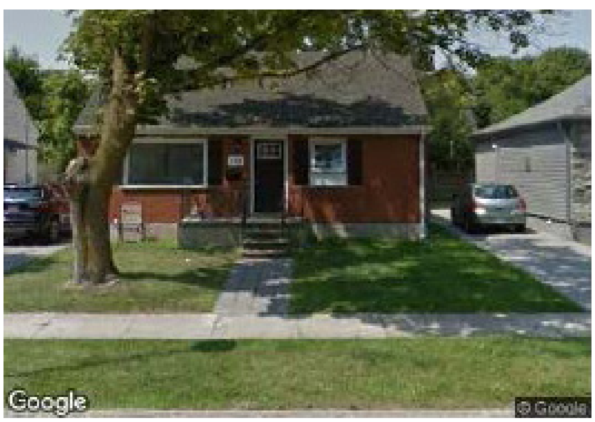
Client Implications:
These homes consume 237.4 GJ (1.17 GJ/m2) of energy on average and produce 10.5 tCO2e (0.052 tCO2e/m2) on average. They represent 2.9% of the housing stock and 12.9% of the dwellings that have been audited in the City of London.

Archetype C

These homes have an above average floor area and use electric baseboard / hydronic /plenum (duct) heaters and use electricity hot water systems.

Average annual electricity costs: $4,962
Average annual natural gas costs: $117
Average annual energy costs: $5,084

Client Implications:
These homes consume 136.7 GJ (0.58 GJ/m2) of energy on average and produce 1.9 tCO2e (0.008 tCO2e/m2) on average. They represent 0.1% of the housing stock and 0.5% of the dwellings that have been audited in the City of London.



Archetype E

These homes have an above average floor area, and are oil heated with low/mid efficiency furnaces and use electric hot water systems.

Average annual electricity costs: $2,034
Average annual natural gas costs: $56
Average annual oil costs: $5,462
Average annual energy costs: $7,555

Client Implications:
These homes consume 217.0 GJ (1.0 GJ/m2) of energy on average and produce 11.8 tCO2e (0.056 tCO2e/m2) on average. They represent 0.1% of the housing stock and 0.6% of the dwellings that have been audited in the City of London.

Archetype F

These homes have an average floor area, and are natural gas heated with low/mid efficiency furnaces and use natural gas hot water systems.

Average annual electricity costs: $1,478
Average annual natural gas costs: $1,492
Average annual energy costs: $2,969

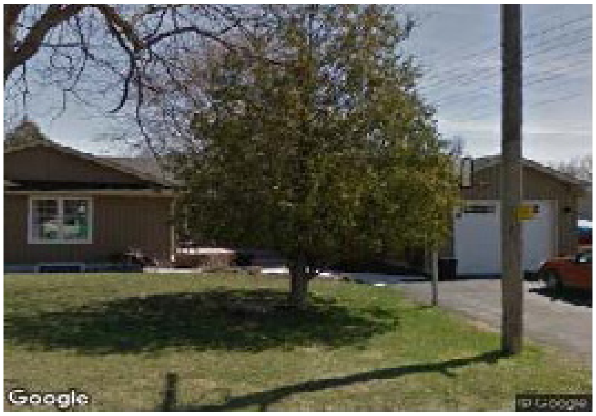
Client Implications:
These homes consume 170.2 GJ (0.88 GJ/m2) of energy on average and produce 7.2 tCO2e (0.037 tCO2e/m2) on average. They represent 9.6% of the housing stock and 26.9% of the dwellings that have been audited in the City of London.

Archetype G

These homes have a relatively large floor area, and are natural gas heated with low/mid efficiency furnaces and use natural gas hot water systems.

Average annual electricity costs: $1,596
Average annual natural gas costs: $3,457
Average annual energy costs: $5,055

Client Implications:
These homes consume 352.5 GJ (1.03 GJ/m2) of energy on average and produce 16.1 tCO2e (0.047 tCO2e/m2) on average. They represent 0.6% of the housing stock and 3.1% of the dwellings that have been audited in the City of London.



Archetype H

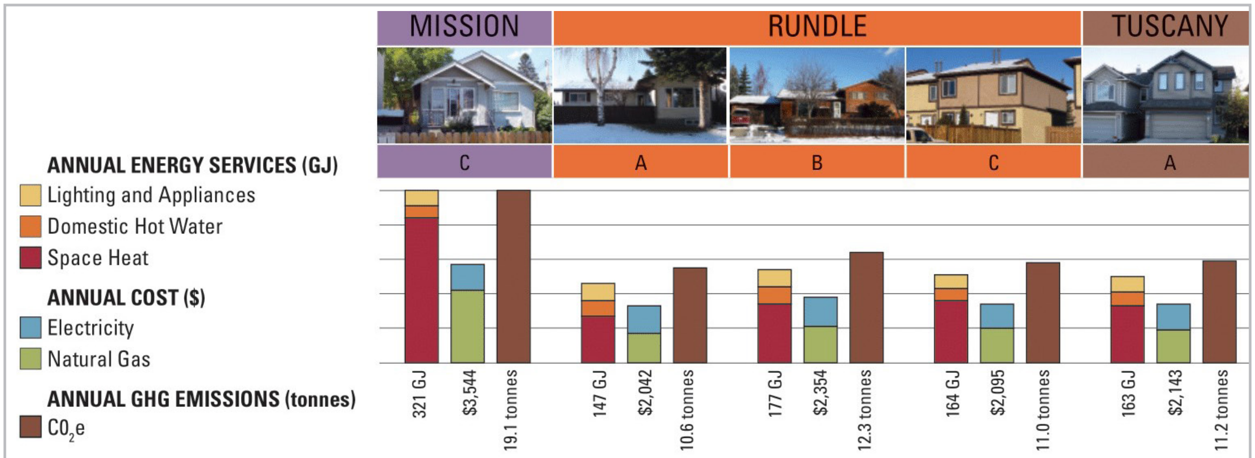
These homes have a relatively large floor area, and are natural gas heated with high efficiency furnaces and use natural gas hot water systems.

Average annual electricity costs: $1,520
Average annual natural gas costs: $1,494
Average annual energy costs: $3,014

Client Implications:
These homes consume 171.5 GJ (0.50 GJ/m2) of energy on average and produce 7.2 tCO2e (0.021 tCO2e/m2) on average. They represent 9.6% of the housing stock and 7.5% of the dwellings that have been audited in the City of London.

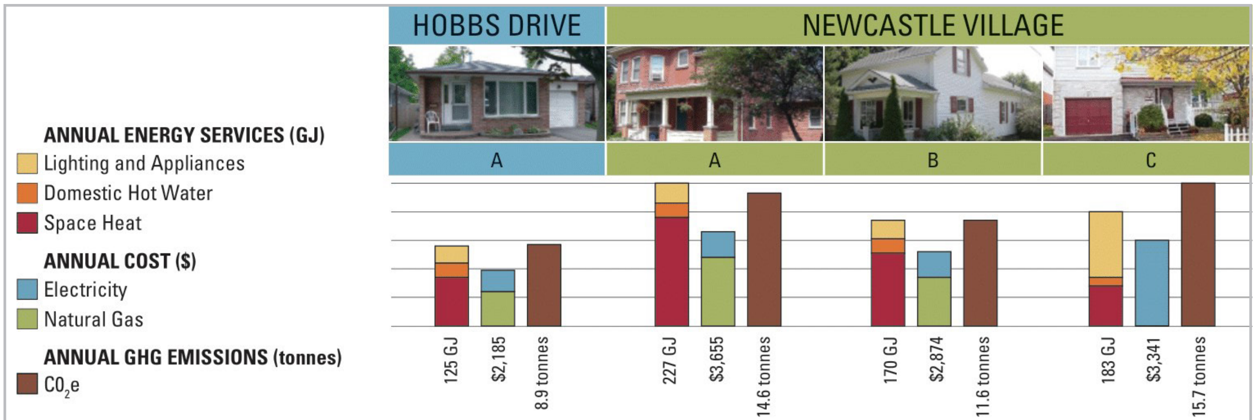
Example B

Source: CanmetENERGY



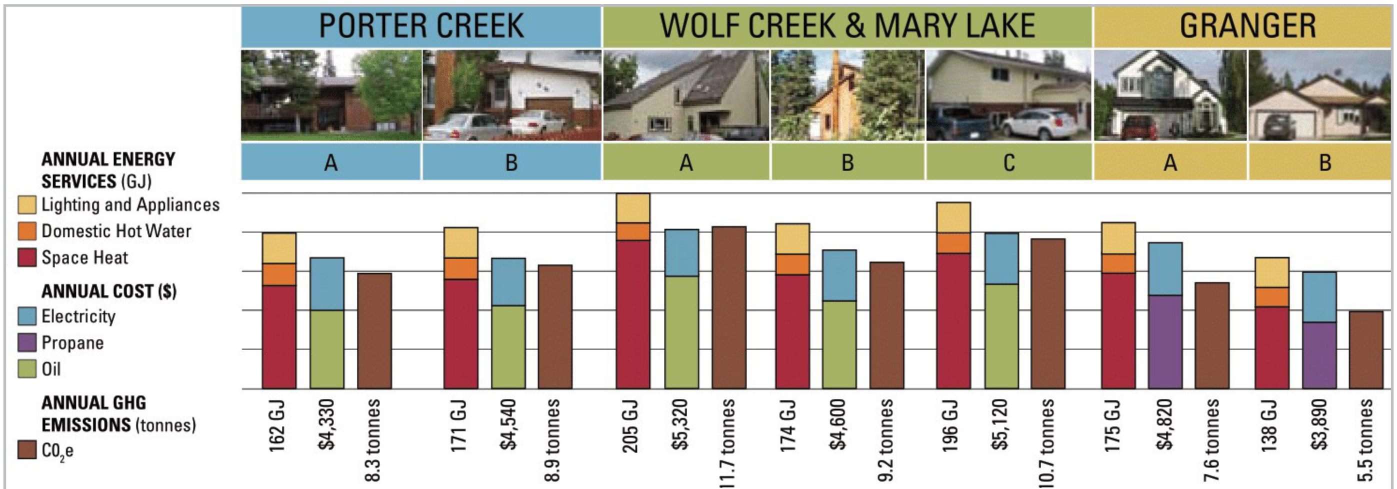
		MISSION (C)	RUNDLE (A)	RUNDLE (B)	RUNDLE (C)	TUSCANY (A)
EnerGuide Rating System		44	72	70	64	71
Energy Use Intensity		1378 MJ/m²	809 MJ/m²	797 MJ/m²	1177 MJ/m²	732MJ/m²
Building Type	Storeys	two storeys	one storey	one storey	two storeys	two storeys
	Attachment	Single Detached	Single Detached	Single Detached	Row house, end unit	Single Detached
	Built	Pre-1945	1961-77	1978-83	1978-83	1984-95
Heated Floor Area		233m² (2509 sq.ft)	182 m² (1956 sq.ft)	222 m² (2388 sq.ft.)	140 m² (1506 sq.ft.)	222 m² (2388 sq.ft.)
Insulation	Ceiling	2.1 RSI (R-12)	4.2 RSI (R-24)	4.5 RSI (R-25)	6.7 RSI (R-38)	5.3 RSI (R-30)
	Walls	1.0 RSI (R-6)	1.9 RSI (R-11)	1.9 RSI (R-11)	1.8 RSI (R-10)	2.6 RSI (R-15)
	Foundation	0.6 RSI (R-3)	1.8 RSI (R-10)	2.3 RSI (R-13)	1.3 RSI (R-8)	1.9 RSI (R-11)
Space Heating	Fuel	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Furnace	With continuous pilot	With continuous pilot	With continuous pilot	With continuous pilot	With continuous pilot
	Efficiency	78%	78%	78%	78%	78%
	Ventilation	None	None	None	None	None
Hot Water	Fuel	Natural gas	Natural gas	Natural gas	Natural gas	Natural gas
	Tank	Conventional	Conventional	Conventional	Conventional	Conventional
	Efficiency	55%	55%	55%	55%	55%
Lighting		Incandescent	Incandescent	Incandescent	Incandescent	Incandescent
Appliances		Conventional	Conventional	Conventional	Conventional	Conventional
Occupants		2	4	5	2	3

Figure 4: Annual energy services (GJ), annual costs and annual GHG emissions from various types of houses in Mission, Rundle and Tuscany neighbourhoods in Calgary



		Hobbs Drive A	Newcastle Village A	Newcastle Village B	Newcastle Village C
EnerGuide Rating System		72	55	67	71
Energy Use Intensity		684 MJ/m² floor area	936 MJ/m² floor area	681 MJ/m² floor area	957 MJ/m² floor area
Building Type	Storeys	one storey	two storeys	two storeys	two storeys
	Attachment	Single Detached	Single Detached	Single Detached	Single Detached
	Built	1961-77	Pre-1945	1945-60	1961-77
Heated Floor Area		182m² (1963 sq.ft)	242 m² (2604 sq.ft)	250 m² (2688 sq.ft.)	191 m² (2054 sq.ft.)
Insulation	Ceiling	4.4 RSI (R-25)	2.9 RSI (R-17)	4.2 RSI (R-24)	4.0 RSI (R-23)
	Walls	2.0 RSI (R-11)	1.1 RSI (R-6)	1.8 RSI (R-10)	1.9 RSI (R-11)
	Foundation	1.7 RSI (R-10)	0.1 RSI (R-1)	0.4 RSI (R-2)	1.7 RSI (R-10)
Space Heating	Fuel	Natural gas	Natural gas	Natural gas	Natural gas
	Furnace	With continuous pilot	Condensing furnace	Condensing furnace	Baseboard heaters
	Efficiency	78%	90%	90%	100%
	Ventilation	None	None	None	None
Hot Water	Fuel	Natural gas	Natural gas	Natural gas	Electricity
	Tank	Conventional	Conventional	Conventional	Conventional
	Efficiency	55%	57%	57%	82%
Lighting		Incandescent	Incandescent	Incandescent	Incandescent
Appliances		Conventional	Conventional	Conventional	Conventional
Occupants		2	3	3	2

Figure 5: Annual energy services (GJ), annual costs and annual GHG emissions from various types of houses in Hobbs Drive and Newcastle neighbourhoods in Clarington.



		Porter Creek A	Porter Creek B	Wolf Creek & Mary Lake A	Wolf Creek & Mary Lake B	Wolf Creek & Mary Lake C	Granger A	Granger B
EnerGuide Rating System		72	71	70	72	70	74	75
Energy Use Intensity		876 MJ/m²	855 MJ/m²	788 MJ/m²	740 MJ/m²	817 MJ/m²	583 MJ/m²	613 MJ/m²
Building Type	Storeys	one storey	one storey	two storeys	two storeys	one storey	two storeys	one storey
	Attachment	Single Detached	Single Detached	Single Detached	Single Detached	Single Detached	Single Detached	Single Detached
	Built	1978-83	1961-77	After 1995	1984-95	1978-83	1984-95	1984-95
Heated Floor Area		185 m² (2509 sq.ft)	200 m² (2150 sq.ft)	260 m² (2800 sq.ft)	235 m² (2500 sq.ft.)	240 m² (2600 sq.ft)	300 m² (3200 sq.ft.)	225 m² (2400 sq.ft)
Insulation	Ceiling	5.7 RSI (R-32)	4.6 RSI (R-26)	6.0 RSI (R-34)	7.0 RSI (R-40)	4.2 RSI (R-24)	6.0 RSI (R-34)	6.3 RSI (R-36)
	Walls	2.4 RSI (R-14)	2.3 RSI (R-13)	2.9 RSI (R-16)	3.6 RSI (R-20)	2.3 RSI (R-13)	3.6 RSI (R-20)	2.9 RSI (R-16)
	Foundation	2.1 RSI (R-12)	2.3 RSI (R-13)	3.1 RSI (R-18)	2.6 RSI (R-15)	2.4 RSI (R-14)	3.7 RSI (R-21)	3.1 RSI (R-18)
Space Heating	Fuel	Oil	Oil	Oil	Oil	Oil	Propane	Propane
	Furnace	Furnace with flame = retention head	Furnace with flame = retention head	Furnace with flame = retention head	Mid efficiency furnace	Furnace with flame = retention head	Condensing furnace	Condensing furnace
	Efficiency	83%	83%	83%	85%	83%	91%	91%
	Ventilation							
Hot Water	Fuel	Electric	Electric	Electric	Electric	Electric	Electric	Electric
	Tank	Conventional	Conventional	Conserver	Conserver	Conserver	Conserver	Conserver
	Efficiency	82%	82%	87%	87%	87%	87%	87%
Lighting		Incandescent	Incandescent	Incandescent	Incandescent	Incandescent	Incandescent	Incandescent
Appliances		Standard	Standard	Standard	Standard	Standard	Standard	Standard
Occupants		4	4	3	4	4	4	4

Figure 6: Annual energy services (GJ), annual costs and annual GHG emissions from various types of houses from Porter Creek, Wolf Creek and Mary Lake and Granger neighbourhoods in Whitehorse.

5

Additional Resources

Aguilera, F. and Ossio, F. (2017). Residential archetypes in urban energy simulation models in Chile: Determining factors of residential energy consumption. Research Gate. https://www.researchgate.net/publication/321978574_Residential_archetypes_in_urban_ener gy_simulation_models_in_Chile_Determining_factors_of_residential_energy_consumption

Ali, U. and Shamsi, M. H. (2018). GIS-Based Residential Building Energy Modeling at District Scale. Research Gate. https://www.researchgate.net/publication/329417382_GISBased_Residential_Building_Energy_Modeling_at_District_Scale

Famuyibo, A. A., Duffy, A., and Strachan, P. (2012). Developing Archetypes for Domestic Dwellings – An Irish Case Study. Dublin Institute of Technology. https://pure.strath.ac.uk/ws/portalfiles/portal/14676158/Strachan_PS_Pure_Developing_architypes_for_domestic_dwellings_An_Irish_case_study_Aug_2012.pdf

Parekh, A. (2005). Development of Archetypes of Building Characteristics Libraries for Simplified Energy Use Evaluations of Houses. Ninth International ISPSA Conference http://www.ibpsa.org/proceedings/bs2005/bs05_0921_928.pdf

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