LIMITING THE ENERGY DEMAND OF SINGLE-FAMILY HOMES

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1. Executive Summary.

The District of West Vancouver has recently adopted a set of mandatory requirements for new construction to comply with the BC Energy Step Code. Aligned with this and other local policies, the District is studying the possibility to implement a community-wide energy budget to limit the energy demand of single-family homes.

Over the last years, houses have increased significantly its size compared to the homes they replace and could be offsetting more energy efficient construction. This report presents the profile of existing housing stock as well as provincial policies and green building rating systems.

These are three factors to consider in the implementation of an energy budget. This report presents an analysis of the interaction of these three components and how they can affect future construction considering a community-wide energy budget.

Finally, in the last section of the report, examples on how an energy budget could work in future construction are presented.

2. Introduction.

2.1. UBC Sustainability Scholars Program

The Sustainability Scholars Program is a partnership between the University of British Columbia (UBC) and the District of West Vancouver (DWV). Through UBC´s Sustainability Initiative, graduate students are given the opportunity to collaborate on applied research projects that support the long-term goals identified within the District of West Vancouver Community Energy + Emissions Plan (CEE Plan). As part of the District's efforts, the Planning & Development Team submitted a project to explore the applicability of a community-wide energy budget to limit the energy demand of single-family homes.

2.2. Supporting Plans and Policies

2.2.1. West Vancouver CEE Plan

To demonstrate the District of West Vancouver commitment to energy conservation and reducing related green house gas (GHG) emissions, the CEE Plan was adopted in 2016. In this document the District sets the target to lower its GHG emissions by 40% by 2040 from the 2010 baseline. This is an ambitious target for the construction sector which accounted for 52% of the total GHG emissions in the District in 2010.

The CEE Plan envisions a 16% reduction of GHG emissions associated with buildings by 2040, despite a modest growth of total built floor area. A more detailed analysis of the CEE Plan is presented in the upcoming sections of this report.

3. Research Design.

3.1. Objectives

Through the Sustainability Scholars project agreement, and aligned with the District's interest in reducing energy use in single-family homes, the following tasks were identified:

- Determine the ability to apply a community-wide energy budget for single-family housing; and

- Consider the effectiveness of different pathways to meet building energy targets and provide a professional recommendation for implementation.

3.2. Methodology

The methodology for this project consisted of an analysis of the interaction between the new provincial energy policies (BC Energy Step Code), local policies in West Vancouver to incorporate these provincial policies and the single-family detached homes construction in West Vancouver.

Information was collected from different sources:

- **Provincial Policies:** information regarding these policies was obtained using the *"BC Step Code: A Best Practices Guide for Local Governments"* published by the Energy Step Code Council and the Building and Safety Standards Branch. Also, for a more in-depth analysis, the *"BC Energy Step Code: 2017 Metrics Research Full Report*" was consulted to provide a better understanding of the Step Code.
- **Local Policies:** the courses of action and strategies to lower energy and GHG emissions related to buildings and single-family homes were retrieved from the CEE Plan drafted in 2016 and the Official Community Plan (OCP) drafted in 2018.
- **Existing and Future single-family homes:** general information was obtained using West Vancouver's Local Policies (CEE Plan and OCP) for future construction, and specific characteristics of existing homes was retrieved from a BC Assessment database.

3.2.1. Current Context Analysis.

To have a better understanding of the existing single-family housing stock, current practices and energy related policies that impact the applicability of a District-wide energy budget for single-family homes, a set of questions must be addressed. They consist of the following:

- How has single-family home construction changed over the years?
- How are the size and energy demand of these homes changing?

- What measures is the District currently taking to limit energy demand of single-family homes?
- What policies exist in British Columbia to address and limit energy demand of single-family homes?

These questions were focused on the District of West Vancouver to provide possible directions in the specific context of the municipality.

3.2.2. Limitations.

One of main limitations of the project was the time constraint. More comprehensive recommendations and specific future directions (e.g. GIS representations, review of recent building permits) would have required additional time and research.

Other important limitation was the time when the study was made because the BC Energy Step Code is currently in the process of providing updates for Part 9 buildings, which may modify the conclusions presented in this report.

The inability to access real energy consumption of single-family homes was another important limitation. In the context of an energy budget to limit energy demand of single-family homes, the ability to compare the energy consumption of existing homes against new construction could provide results on potential real energy savings as well as a baseline to compare when the size of the new homes can offset the higher efficiency and performance of new construction.

3.2.3. Report Structure.

This report is structured with separate sections and subsections. The audience of this report is the District and is intended to provide a profile of the existing single-family home to understand the transformation over the years, a review of policies, green building standards and examples of the applicability of a community wide energy budget.

4. Single-family homes profile in West Vancouver

4.1. Existing Housing Profile in West Vancouver.

The OCP, divides West Vancouver´s housing stock into six different categories. Single-family homes account for about 64% of the total available dwellings followed by high-rise apartments and condominiums which account for 20% of the total.

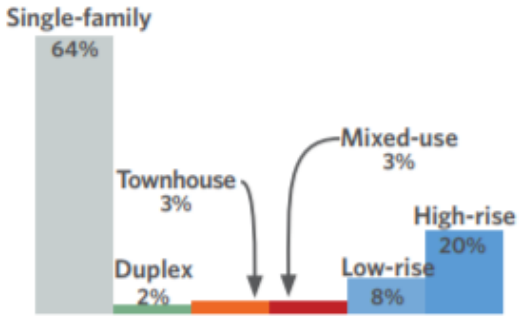
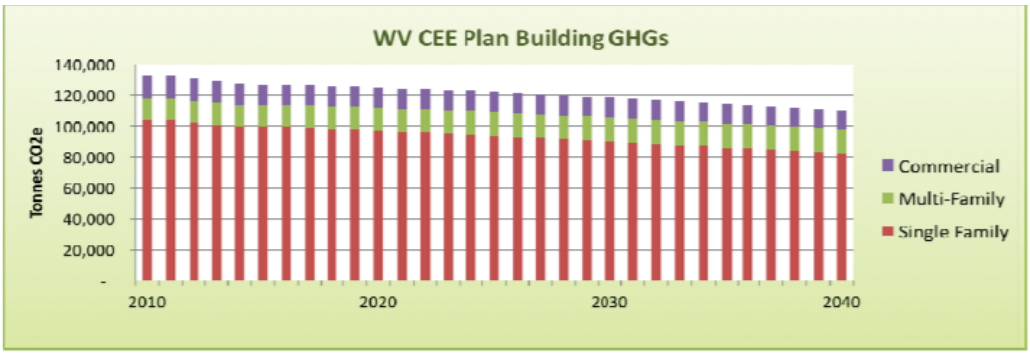


Figure 1. Existing housing profile (WV OCP,2018, p. 10)

Other dwelling types like duplexes, townhouses, mixed-use and low-rise condo buildings, together account for the remaining 16%. It is important to mention that duplexes are defined as a subdivision of single-family homes into two different dwellings, meaning some may be commonly understood as a variation of a single-family home. Townhouses – some commonly considered rowhouses – are out of the scope of the analysis presented in this report focused only in the single-family home archetype.

Representing the most common housing archetype in West Vancouver, single-family homes represent the main area of focus to significantly decrease the energy consumption and GHG emissions in the District. As presented in the graph below retrieved from the CEE Plan's Brick + Mortar section, single-family GHG emissions account for approximately 75% of the total building emissions in the District.



Graph. 1 West Vancouver Building related GHG emissions (WV CEE Plan, 2016, p.25)

Due to this, it is important to focus on the specific characteristics of existing single-family homes and identify opportunities and potential changes that support the applicability of an energy budget.

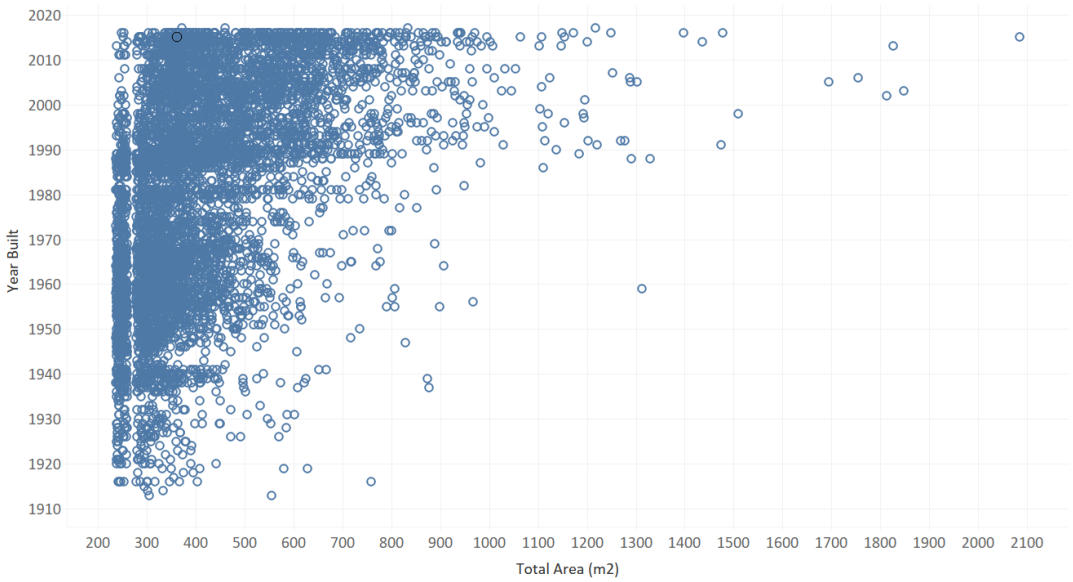
4.2. Existing Single-family homes profile.

4.2.1. Uses and size.

There are over 9,500 Single-Family homes in West Vancouver built between 1913 and 2018. Currently, as can be seen in the Graph 2, the type of 15% is a form of duplex that accommodates more than one family, home that includes a suite.

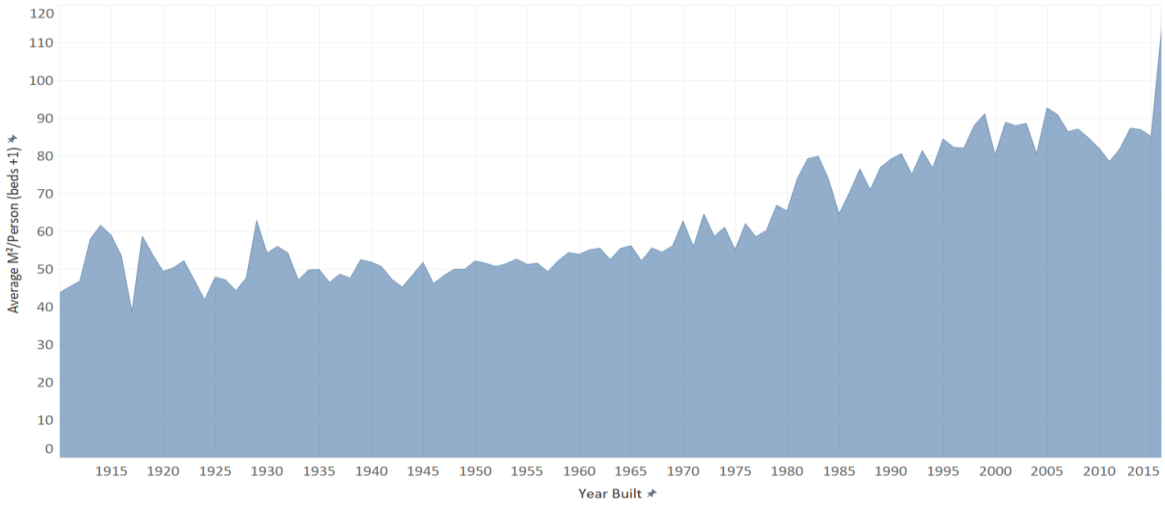
Graph. 2 Single Family Homes types (From BC Assessment data)

Graph 3 presents the profile of the total floor area of every house and its year of construction. Between 1913 and 2018, the size of homes has doubled from an average of 330 m² to over 635 m².



Graph. 3 Total floor area of single-family homes by year of construction. (From BC Assessment data)

Not only has the total floor area per home increased, but also the household size has remained the same, meaning constructions are bigger and are not accommodating more people even with a bigger area.



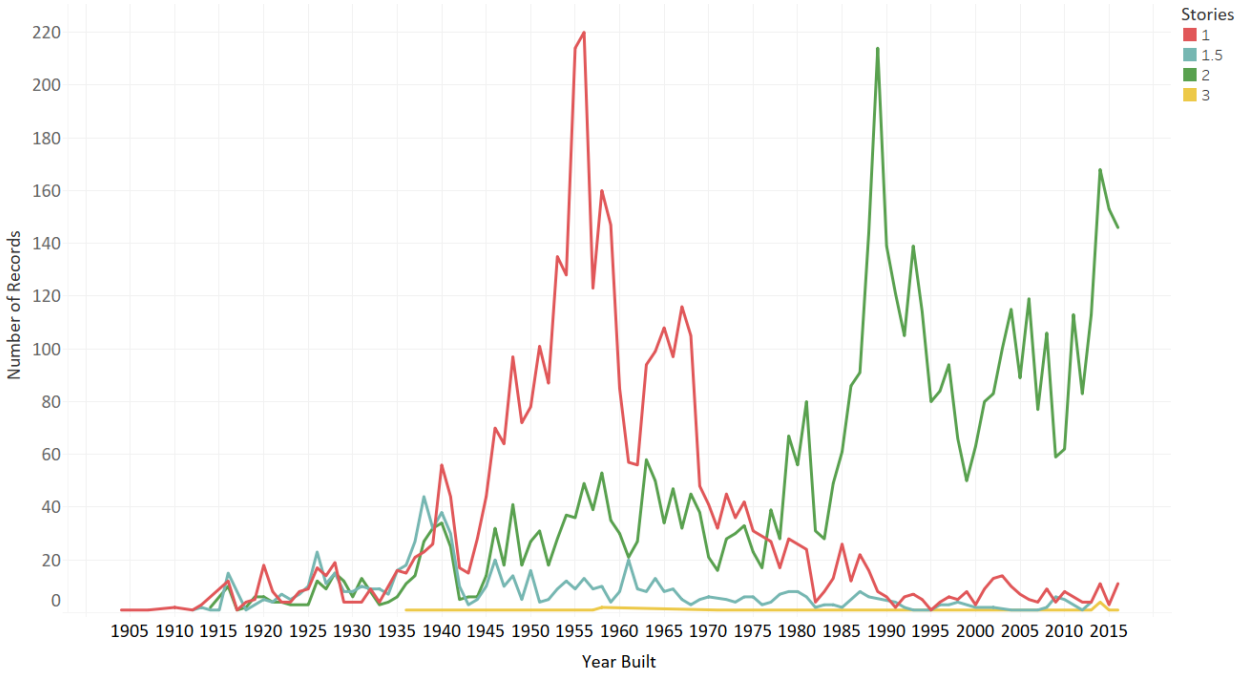
Graph. 4 Estimated floor area of construction per person per year of construction. (From BC Assessment data)

The Graph 4 presents this estimation. An average of occupancy capacity of homes was made to analyze the floor area designated to accommodate one person in a house depending on the year of construction. This graph shows that between 1910 and 2016 the floor area designated to accommodate one person has increased from roughly 40 m² to almost 90 m². This calculation was made using the number of bedrooms and adding 1 person. The actual ratio of floor to occupant likely increases if this calculation is made for real occupancies since West Vancouver has an average household size of 2.9 persons for single-family homes according to the census performed by Statistics Canada in 2011. Having an estimate of the floor area used to accommodate one person in the District is an important metric to consider in limiting size and consequently energy demand of single-family homes.

4.2.2. Heights and basements.

West Vancouver has a height limit of 7.62m for single-family Homes or two-storeys plus basement in all residential zone according to the Zoning Bylaw. 85% of single family homes have a basement and the remaining 15% have a crawlspace or slab for foundation.

BC Assessment indicates that approximately 38% of these houses are 1 storey, 8% are 1.5 storeys, 54% are 2 storeys and less than 1% are 3 storeys tall.



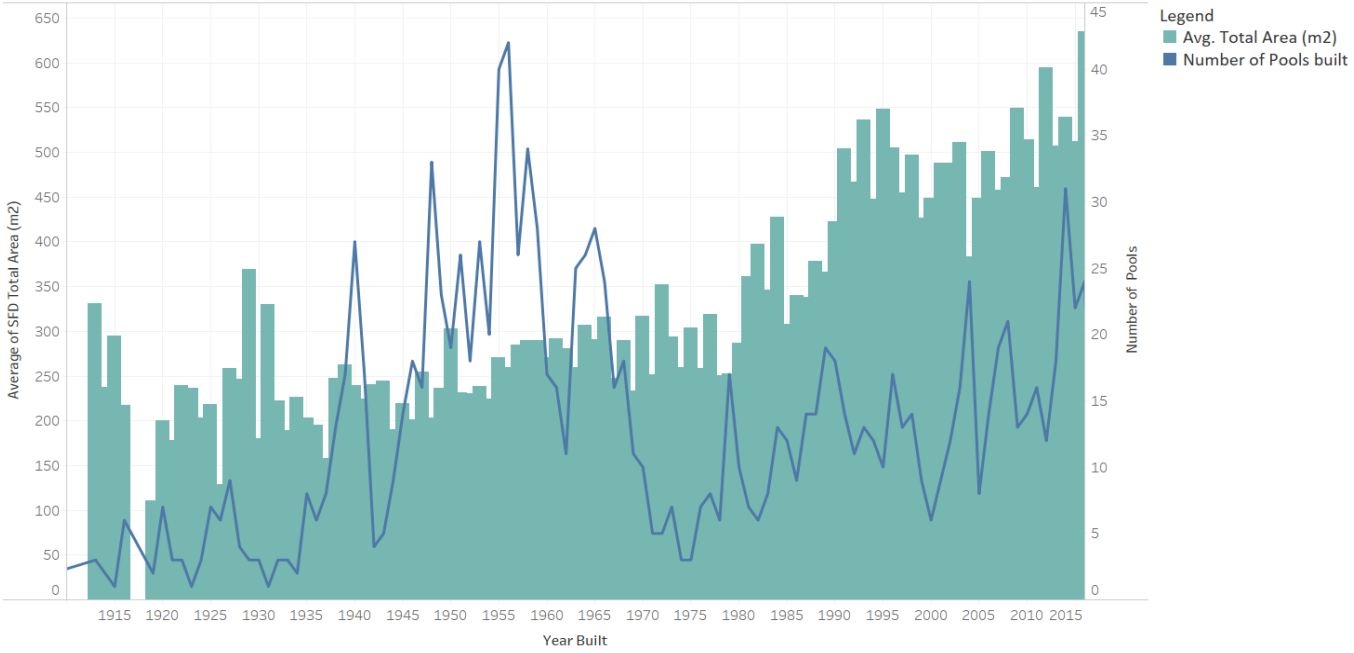
Graph. 5 Number of homes, quantity of stories and year built (From BC Assessment data)

As Graph 5 shows, there has been a tendency in the District to build 2 storeys homes in the recent years since 1975 and almost no homes with 1.5 or 1 storey. This was different prior to 1975 where the most used archetype was a home with 1.5 or 1 storey. This is aligned with the previously presented trend identifying homes are getting bigger over time. Homes built prior 1975, are more likely to be replaced, than those built after 1975. These 1 storey homes are of special interest to analyze in more depth when considering applying an energy budget because they are likely to be replaced with a larger more energy efficient 2 storeys homes.

The average size of these 1 storey homes built prior 1975 is 232 m^2 compared to new 2 storeys homes built after 1975 with an average area of 365 m^2.

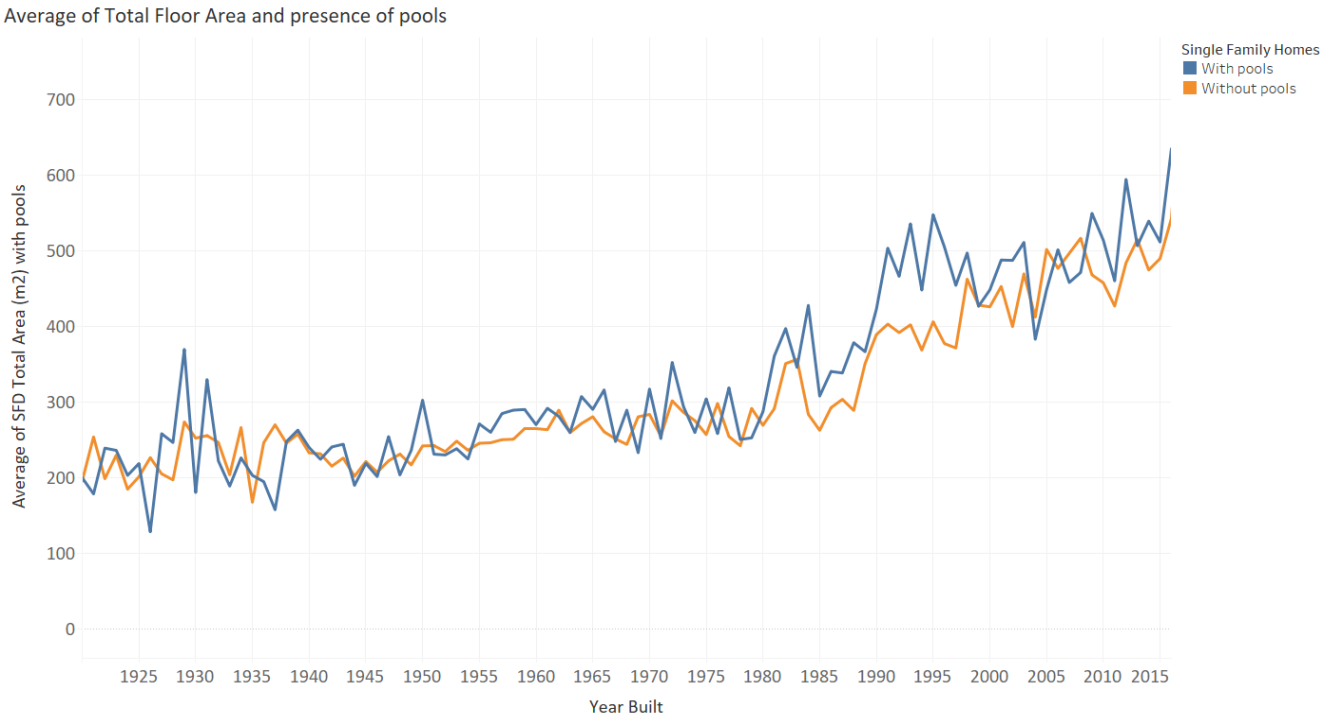
4.2.3. Pools.

Furthermore, it is important to consider the quantity of leisure pools with single-family homes. An estimated of 19% of single-family homes in the District have a leisure pool. Approximately, 45% of these pools are part of medium-sized homes built between the decades of 1940 and 1970 and are likely to be replaced before 2040. In recent years (1980-2017), the number of pools constructed as ratio to the number of homes has declined despite these homes having a bigger floor area. The presence of pools is not linked directly to the size of the home but is likely more related with preferences during the period of construction.



Graph. 6 Average of floor area and pools by year of construction (From BC Assessment data)

The Graph 6 shows the size difference between houses with and without pools over time. Houses with pools have, on average, greater floor area than houses without pools. This means that, lots with homes and pools are consuming more energy than lots with smaller homes and without pools if homes with the same year of construction are assumed to be built to meet the same energy performance standard.



Graph. 7 Average size of single-family homes with and without leisure pools. (From BC Assessment data)

Special attention is needed for lots with pools because in, almost 30% of new homes are expected to be constructed with a pool, according to the CEE Plan which could indicate a rise in the preference of the market to build a home with leisure pool.

4.2.4. Lots size.

The parcel or lot sizes for single-family homes is important to consider the size of the house and construction they can accommodate. An analysis was made to see how this is behaving in West Vancouver. The median lot size is West Vancouver 1,160 m² and the median house is 372 m². The median lot size was used as the limit between "small lot" and "big lot" and the median house size was used to differentiate "small homes" from "big homes".[1]

Small homes in small lots: Most of these homes are older and are likely to be replaced in the coming years. When replaced these homes are going to possibly become larger, even

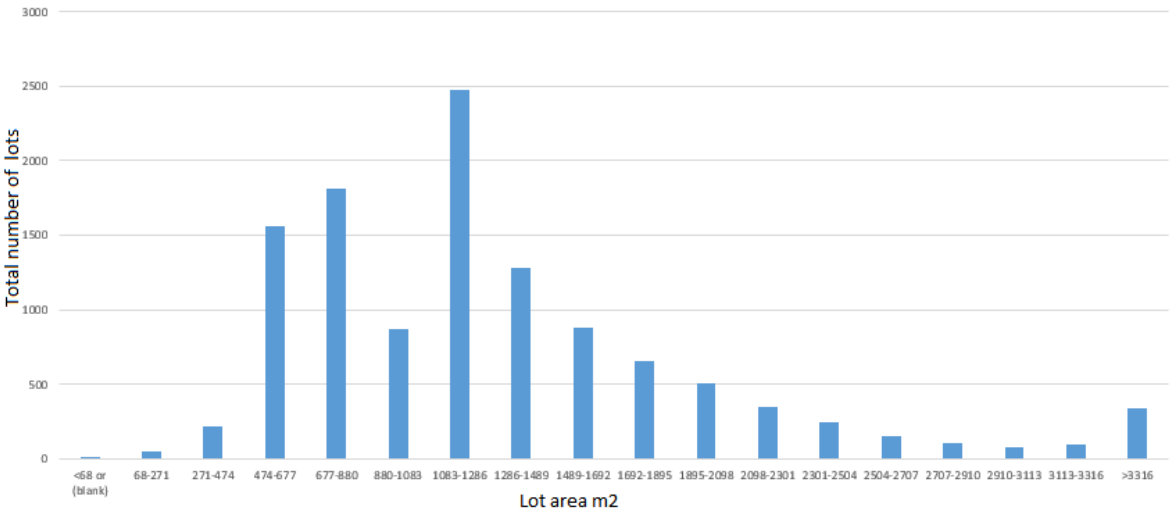
[1] This methodology was derived from the research called *"Analysis of West Vancouver Building Archetypes for Energy and Emissions Reduction Potential"* by Nicolle Miller and Stephen Sheppard in 2015.

with the restraints of the lot size. These homes represent over 3,300 of the total single-family homes in West Vancouver or 30%. This segment of single-family homes is an important target for an energy budget an ensure their future performance and moderate size.

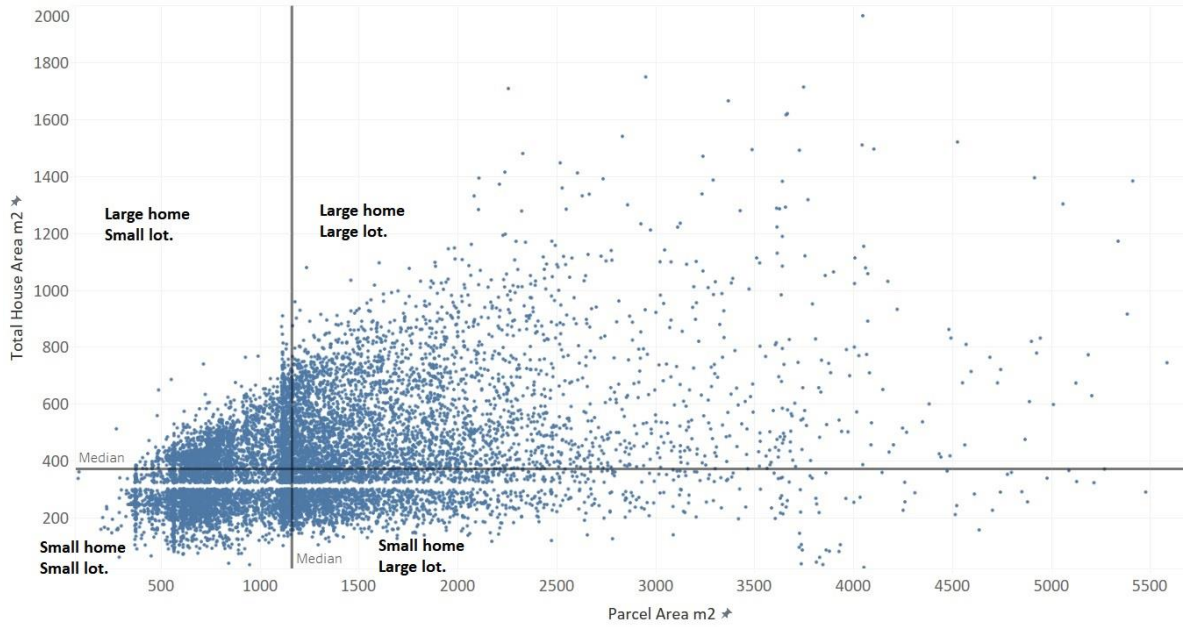
Small homes in large lots: The case for these homes is comparable to the small house in small lots segment but with increased potential to have bigger, more energy consuming homes. These homes have huge potential to add floor area. An energy budget for this segment will help to limit the size of single-family homes. It can also be a great opportunity for trade-offs between energy consumption or size and on-site renewable energy and more energy efficient construction. This segment represents 20% of the total single-family homes.

Large homes in small lots: These homes can be seen as the built replacement homes from the small homes in small lots segment. They are newer and for most of them, they won't be retrofitted or replaced in the short or medium term. The opportunities to limit the energy demand of single-family homes in this segment would highly depend on renewable energy, possibly to heat domestic hot water or electricity for other uses. These homes in theory, should have better building envelopes and high-efficiency heating equipment. This segment represents 30% of the total single-family homes.

Large homes in large lots: These segments of houses are situated outside the core of the District both in eastern and western ends. They are the largest consumers of energy due to their size and propensity to have pools. They are relatively newer than the other segments and reducing their energy consumption requires renewable energy and better heating equipment. These homes represent an opportunity to stratify existing structures rather tan subdivision or infill construction. These directions are presented in the following sections of this report. This segment represents 20% of the total single-family homes.



Graph. 8 Size and quantity of lots. (Own Production)



Graph. 9 Lot and house size (Own production).

4.3. Single-Family Homes Zoning Bylaw in West Vancouver

West Vancouver has ten residential zones (RS-1 to RS-10) defined in Section 200 of the Zoning Bylaw[2]. This bylaw specifies minimum site area for subdivision and minimum

[2] Retrieved from: https://westvancouver.ca/government/bylaws-strategies-reports/bylaws/zoning-bylaw

setbacks as well as maximum floor area, site coverage and heights. The following table presents a summary of relevant information of this Bylaw:

Residential Zone	Minimum Site Area	Site Coverage	Floor Area ratio
RS-1	8,094 m²	(1) 30% of site area maximum, if site area is > 885 m²; or (2) 266 m² maximum, if 664 m² < site area < 895 m²; or (3) 40% of site area maximum, if site area < 664 m².	(1) 0.35 of site area maximum, if site area > 677 m²; or (2) 237 m² maximum, if 474m² <site area < 677 m²; or (3) 0.5 of site area maximum, if site area < 474 m²
RS-2	1,858 m²		
RS-3	1,115 m²		
RS-4	836 m²		
RS-5	558 m²		
RS-6	Existing as of April 1977.		
RS-7	929 m²		
RS-8	929 m²		
RS-9	371.5 m²		
RS-10	1,115 m²		

Table 1. Zoning Bylaw summary for single-family homes (Zoning Bylaw No. 4662 -Section 200)

As presented by the Table 1 above, the Zoning Bylaw controls subdivision by defining a minimum site area. Existing lots may be smaller than the minimum site area referenced in the bylaw.

Under this zoning consideration an energy budget couldn´t be implemented depending on the residential zone and minimum lot size because inside each residential zone there can be smaller lots than allowed with higher site coverage values.

An energy budget could be determined using the lot size because the same site coverage and floor area ratio (FAR) is assigned to all residential zones.

5. Analysis of projected future construction of single-family homes.

5.1. 2018 Official Community Plan

The District defines in the OCP the baseline (of the existent housing stock) as well as targets for 2041. In order to diversify the District's housing stock by 30%, the OCP aims to transition from a housing mix dominated by single-family homes to one that is split equally between

single-family and multi-family dwellings by the target year. This repartition is not going to be equally distributed but will depend on adopted and future zones, policies and plans.

The OCP shows as well the need to increase density in the centres close to transit, commerce, shops and schools: *"Housing built with environmentally-sensitive features and higher energy performance, as well as more units located in centres and near transit, can reduce the community's overall impacts on the environment and GHG emissions."(WV OCP,2018, p.23)*

One of the key actions the OCP identifies regarding single-family homes is the following:

- *"Regenerate our primarily detached, single-family home-oriented neighbourhoods with sensitive infill options, such as smaller houses on smaller lots, coach houses and duplexes;"(OCP, 2018, p.23)*

The OCP also presents the policies the District will follow to achieve these targets. The first set of policies target the regeneration of the District's neighborhoods with an estimated of 300 to 400 new infill units.

- "*Amend neighbourhood subdivision standards (including consideration of site-specific applications) to enable the development of smaller houses on smaller lots in existing detached residential areas"*
- *"Update zoning provisions (including consideration of site-specific applications) to increase the supply of coach houses ("detached secondary suites") in existing detached residential areas by:*

  a. Allowing coach houses to be stratified to increase home ownership opportunities;

  b. Providing floor area exemptions for rental coach houses secured through Housing Agreements;

  c. Considering allowance of a coach house and a basement suite on a single lot; and

  d. Removing other potential regulatory barriers to the supply of coach houses (e.g., enabling more flexible off-street parking requirements)."

Figure 2. Infill units and subdivisions (WV OCP, 2018, p.25)

The OCP also addresses the development of future neighborhoods. One of the focus is the undeveloped land under 1,200 feet of elevation that are zoned for single-family detached homes, but where important environmental and recreational values are present. The future consideration of this land represents an opportunity for the implementation of an energy budget to assure that the total community energy demand does not increase significantly. Rezoning for multi-family buildings or allowing for smaller lots can secure higher densities and consequently, a better energy performance of future construction in these zones.

Furthermore, the OCP identifies the key policies and actions to compact these new neighborhoods and support environmental features such as renewable energy and high-performance buildings, mitigating GHG emissions compared to a typical scenario.

West Vancouver's OCP includes policies to sensitively increase housing opportunities, protect environmental values and limit the impacts of single-family homes in the District. With these actions, the District is trying to shift the nature of new construction from single-family homes to mixed-use and multi-family buildings, which perform better in terms of energy consumption and GHG emissions and provide a wider array of housing options. Limiting the construction of single-family homes in the Upper lands can also benefit the District in terms of energy consumption. Based on the consideration of development at higher elevation in other jurisdictions in the region, some areas in the Upper lands have the potential to be assigned as Climate Zone 5, which in terms of energy means a higher consumption of thermal energy to heat the space in these colder regions. This could make the 2040 targets harder to achieve.

5.2. Estimation of projected single-family homes retrofits and new construction in West Vancouver.

5.2.1. Energy related retrofits.

The CEE Plan sets an annual target of 1.25% (roughly 125 homes) by 2020 and a 2% rate by 2025, compared to a baseline of 0.75% (75 homes), to energy related retrofits. These retrofits represent a big opportunity to lower the District's energy and GHG emissions. Decisions and policies need to be created regarding this if an energy budget is implemented. Major renovations must be often considered as new construction and should be required to reach higher performance. A more in-depth analysis of the possibilities to accomplish this is performed in the following sections.

5.2.2. Existing homes replacement.

According to the CEE Plan: *"the replacement rate for existing homes is high (>1% of existing single-family homes per year, about 130). Roughly half of new residential building units are comprised of building replacements."* This segment of new construction is a potential opportunity for energy savings and the effective implementation of an energy budget. This is true for existing small homes on large lots where the energy demand could significantly increase with larger constructions.

5.2.3. New construction in new lots.

The District of West Vancouver issued an average of 150 new single-family home permits per year between 2010 and 2017. Most single-family homes permitted consist of demolition and replacement of old homes. Only a minority consist of new construction on new lots, whether trough subdivision or on previously undeveloped land. Of the permits noted above, roughly 20% per year meet this criterion.

New homes of new lots may be considered in an energy budget because they work as new loads that go against absolute targets. By 2040, almost 31% of the single-family home stock will be built after 2010.

6. The BC Energy Step Code and West Vancouver.

6.1.1. Purpose of the BC Energy Step Code.

The BC Energy Step Code regulation was adopted in British Columbia in April 2,017. This new standard is designed to help industry and local governments to set a course where all new construction will be "net-zero energy ready by 2032". According to the BC Energy Step Code's Guide for Local Governments: *"Net-zero energy buildings produce as much clean energy as they consume. They are up to 80 percent more energy efficient than a typical new building and use on-site (or near-site) renewable energy systems to produce the remaining energy they need. A net-zero energy ready building is one that has been designed and built to a level of performance such that it could, with the addition of solar panels or other renewable energy technologies, achieve net-zero energy performance."*

The Step Code provides an incremental approach to achieve more energy-efficient buildings by 2032. It establishes a series of performance-based requirements for energy efficiency that local governments or communities may choose to adopt. These requirements are grouped into a series of "steps". The BC Energy Step Code was created to require or incentivise performance above code requirements and to decrease energy consumption and GHG emissions in all municipalities across BC.

Before the Step Code, most single-family homes in BC were designed using a "prescriptive" approach with individual specific requirements for insulation, windows, furnaces, heaters, lighting, etc. The elements were not considered as a system, and as result the buildings didn´t perform as well as expected in design.

Now, with the Step Code, the intention is to have a performance approach that establishes a desired outcome and leaves autonomy to the design team on how to achieve it. In order to do this, whole-building energy modelling and on-site testing is used to demonstrate compliance with the requirements in the code.

Some of the benefits recognized in the Step Code for its implementation in new buildings are:

- Better manage temperature and comfort improvement.
- Better manage of fresh air, improving health.
- Better manage soundproofing.
- Require less energy, lower utility bills.

6.1.2. BC Energy Step Code metrics and targets

The BC Building Code distinguishes between Part 3 and Part 9 buildings. For this study, the focus is single-family homes, which fall into the category of Part 9 buildings. For these buildings, energy models must be prepared by Registered Energy Advisors retained by the builder or designer.

The relevant metrics specified in the Step Code to consider in the context of an energy budget are:

Metrics for Building Envelope:

- **Thermal Energy Demand Intensity (TEDI):** The amount of annual heating energy needed to maintain a stable interior temperature, considering heat loss through the envelope and passive gains (i.e., the amount of heat gained from solar energy passing through the envelope or from activities in the home like cooking, lights, and body heat). It is calculated per unit of area of the conditioned space over the course of a year, and is expressed in kWh/(m^2·year).
- **Peak Thermal Load (PTL):** The maximum amount of energy needed to heat a building on the coldest day of the year, expressed in W/ m^2 of conditioned space. Energy modellers also refer to this as "Design Heat Loss."

Metrics for Equipment and Systems:

- **Percent Lower than EnerGuide Reference House:** An EnerGuide reference house establishes how much energy a home would use if it was built to base building code standards. This metric identifies how much less energy—stated as a percentage—the new home will require compared to the reference house.

- **Mechanical Energy Use Intensity (MEUI):** The modelled amount of energy used by space heating and cooling, ventilation, and domestic hot water systems, per unit of area, over the course of a year, expressed in kWh/(m²·year). This metric is different from the Total Energy Use Intensity (TEUI) which also includes other electrical loads like lighting and plug loads.

The Step Code has different targets for the metrics listed above, depending on the location and Climate Zone. The District of West Vancouver is in the Climate Zone 4 (<3,000 HDD below 18°C). The performance targets for the District are presented in the Table 2.

STEP	AIRTIGHTNESS (AIR CHANGES PER HOUR AT 50 PA PRESSURE DIFFERENTIAL)	PERFORMANCE REQUIREMENT OF BUILDING EQUIPMENT AND SYSTEMS	PERFORMANCE REQUIREMENT OF BUILDING ENVELOPE
1	N/A	EnerGuide Rating % lower than EnerGuide Reference House: not less than 0% lower energy consumption or Conform to Subsection 9.36.5.	
2	≤ 3.0	EnerGuide Rating % lower than EnerGuide Reference House: not less than 10% lower energy consumption **or** mechanical energy use intensity ≤ 60 kWh/m².year	Thermal energy demand intensity ≤ 45 kWh/m².year **or** Peak thermal load ≤ 35 W/m²
3	≤ 2.5	EnerGuide Rating % lower than EnerGuide Reference House: not less than 20% lower energy consumption **or** mechanical energy use intensity ≤ 45 kWh/m².year	Thermal energy demand intensity ≤ 40 kWh/m².year **or** Peak thermal load ≤ 30 W/m²
4	≤ 1.5	EnerGuide Rating % lower than EnerGuide Reference House: not less than 40% lower energy consumption **or** mechanical energy use intensity ≤ 35 kWh/m².year	Thermal energy demand intensity ≤ 25 kWh/m².year **or** Peak thermal load ≤ 25 W/m²
5	≤ 1.0	Mechanical energy use intensity ≤ 25 kWh/m².year	Thermal energy demand intensity ≤ 15 kWh/m².year **or** Peak thermal load ≤10 W/m²

Table 2 Requirements for Buildings Located Where the Degree-Days Below 18°C is under 3,000 (Table 9.36.6.3.A retrieved from the BC Energy Step Code's Guide for Local Governments)

The above table sets the performance targets for single-family homes. The indicators of total energy consumption for single-family homes are TEDI and MEUI.

This metrics provide the total consumption of energy over a year divided by the total floor area of the conditioned space. These are the metrics that could be related to a potential energy budget in the District of West Vancouver.

6.1.3. BC Energy Step Code metrics limitations.

To present how these targets were obtained, the *"BC Energy Step Code Metrics Report"* was prepared. The first step was to select the most common building archetypes across BC based on a research by BC Housing. Regarding single-family homes, these archetypes were:

- **Small Single-Family Dwelling (SFD):** Market, 102 m², single storey on heated crawlspace.
- **Medium SFD:** Market, 237 m², 2 storeys with basement.
- **Large SFD:** Market, 511 m², 2 storeys with basement.

The targets set for Part 9 buildings were then obtained through energy models of the different archetypes with different combinations of energy conservation measures (ECM) to identify which combinations would meet the Step Code's performance thresholds. In total over 53 million possible combinations were evaluated. This is a very compelling work, and the results should represent well the current construction industry for Part 9 buildings in BC.

This report acknowledges that the targets could be more complicated to be reached by certain archetypes than for others. For example, the report mentions that a house spread out over two storeys and a basement will have less difficulty than a single storey, slab-on grade with larger exposed envelope per floor area. The form, orientation and size can also modify the performance of a house with similar envelope and mechanical systems.

The report also indicates that small SFD have a clear disadvantage compared to larger homes in terms of possibility to meet higher steps at lower costs. This could be a potential problem for new construction and lower the GHG emissions of new smaller homes, due to the preference to use fuel powered systems to heat the space, which are less expensive and don't reduce significantly the GHG emissions of these homes. This could be a potential

problem to create an energy budget to limit the size and energy demand of single-family homes. The metrics report acknowledges this problem and suggest as a future action to determine whether the Step Code performance requirements should be adjusted to the size of a house because in some cases, there is no ECM parametric combinations able to meet the Step Code requirements for smaller homes.

While preparing this report, the metrics report was in process of being updated to reflect adjusted MEUI targets for small Part 9 Buildings. This update is expected to include a variable additional allowance for buildings with a total floor area under 210 m^2. This additional MEUI would be variable and lower for Upper Steps and colder climate zones. An extra allowance to the total MEUI is expected to be granted to buildings with cooling while TEDI values would remain the same. At the time this report was being prepared, these modifications and targets were drafts and are not included in this report. When these amendments will be official, a new analysis will have to be made to adjust a potential energy budget.

6.1.4. Adoption of the BC Energy Step Code in West Vancouver.

On July 1, 2018, the District of West Vancouver started requiring all new single-family home permit applications to demonstrate compliance with Step 3 of the BC Energy Step Code. This means the involvement of an Energy Advisor is required during design, construction and house completion. All new homes will require a performance report from modelling software and demonstrate compliance with Step 3[3].

In order to incentivise the construction of Coach Houses, the District is only requiring all these new constructions to meet the Step 1.

On the other hand, renovations and additions don't need to comply with the Step Code; only the prescriptive requirements apply in this case.

[3] https://westvancouver.ca/sites/default/files/dwv/council-agendas/2018/jan/22/18jan22-6.pdf

6.1.5. BC Energy Step Code's incentives plan in West Vancouver.

To have a faster adoption of the Step Code, the District has at the time of this report writing different requirements and incentive plans to increase performance in addition to utility incentives[4]:

Step 3:

- $400 BC Hydro rebate applied at permit application for use of an Energy Advisor (only for the first 50 qualifying permits)
- $2,100 FortisBC rebate when natural gas is used for space and water heating.

Step 4:

- 4% maximum floor area and site coverage increase.
- An increased roof ridge height of 150mm (6")
- A reduced front/side/rear yard setback by 150mm (6")
- $400 BC Hydro rebate applied at permit application for use of an Energy Advisor
- $4,500 FortisBC rebate when natural gas is used for space and water heating

Step 5:

- 8% maximum floor area and site coverage increase.
- An increased roof ridge height of 300 mm (12")
- A reduced front/side/rear yard setback by 300mm (12")
- $400 BC Hydro rebate applied at permit application for use of an Energy Advisor
- $8,500 FortisBC rebate when natural gas is used for space and water heating

Passive House Canada (increased performance by 90%)

- Expedited permit processing
- A 10% reduction in building permit fees

[4] West Vancouver Step Code implementation brochure. Retrieved from: https://westvancouver.ca/sites/default/files/dwv/assets/home-building-property/docs/construction/step-code/180709_stepcode-brochure.pdf

- An 8% maximum floor area and site coverage increase
- An increased roof ridge height of 300mm (12”)
- a reduced front/side/rear yard setback of 300mm (12”)
- $400 BC Hydro rebate applied at permit application for use of a certified Passive House Designer or Consultant
- $8,500 FortisBC rebate when natural gas is used for space or water heating

6.1.6. Limitations of the BC Energy Step Code in the implementation of an energy budget for single-family homes.

As noted in the previous sections, the BC Energy Step Code is a performance-based code, not an overall consumption code. When looked with a wider lens, single-family homes, may have other factors that are likely to increase the overall energy consumption such as pools, heated driveways, outdoor lighting, etc. These factors are not taken into consideration when making the now required energy modelling of the house. Neither are plug loads and interior lighting (the BC Energy Step Code uses the MEUI metric). Lighting, for example, becomes more important as the size of the house grows. Even if it is often not comparable with the energy required to heat the space, it increases the overall energy consumption.

If a total energy budget wants to be implemented for a lot and take into consideration all of these other energy consumer factors, the TEUI in hand with TEDI would be a more appropriate metric to give a total energy consumption value. This could be compared with existing construction to benchmark how much more or less energy the new construction will use compared to the house it is replacing. It would also give a better understanding and ease to calculate GHG emissions reductions from replacing an old inefficient home. The sum of the energy consumed by the home and these other major energy users in the lot, should be equal to the energy budget assigned to the lot.

Also, by its nature, the BC Energy Step Code is a stretch code, meaning an energy budget assigned to a lot should vary when the District requires a higher Step to be achieved. This will require new evaluations and amendments to accommodate these changes.

By 2032 new construction in BC including single-family detached homes, are expected to be net zero ready, meaning that buildings will generate as much energy as they consume from on-site or near site renewable technologies. This plays another important role and consideration to play a part when considering the application of an energy budget.

The use of on-site renewable energy will offset the energy required from the grid to provide power to homes. For practical uses, the energy budget should consider a total energy consumption regardless of the source of this energy while incentivising to switch space heating to electricity or more efficient natural gas equipment.

The analysis on renewable energy, future policies, incentives and application for an energy budget should be reviewed in the future if the District decides to pursue this direction.

7. Certifications for high performance homes and their applicability in the context of an energy budget.

7.1. Passive House Standard

The goal of the Step Code is having net-zero energy ready buildings by 2032. Net-zero ready buildings are achievable with the provisions of the Passive House Standard (PHS).

The term *Passive House* refers to a modern energy efficiency standard in construction. Realistically, these buildings refer to both buildings not requiring any mechanical equipment to maintain a comfortable and living climate outside as well as buildings that take advantage of advanced envelope performance to use small amounts of active heating or cooling using mechanical equipment.

The PHS uses an *"enclosure-first"* approach (Frappé-Sénéclauze et.al., 2016), based on the following facts:

- All building envelopes need to be long lasting due to there high cost to replace or refurbish unlike other systems like lighting or mechanical equipment that can be more easily replaced as new technologies are available

- Enclosures are simple systems; their performance doesn't require complex energy management and are tolerant to less maintenance
- Integrated solution for heating and cooling demand early in the design process to reduce space conditioning systems to further reduce construction cost and energy demand
- High performance enclosures offer also non-energy benefits, such as thermal comfort, acoustic isolation, increased resiliency o power outages and extreme temperature events.

Typically, a Passive House is designed using the following principles:

- High performance triple pane, double low-e glazing
- High performance walls, floors and roofs.
- Ventilation system with highly efficient heat recovery
- No thermal bridges
- Airtight envelope
- Good building orientation to maximize solar heat gains.

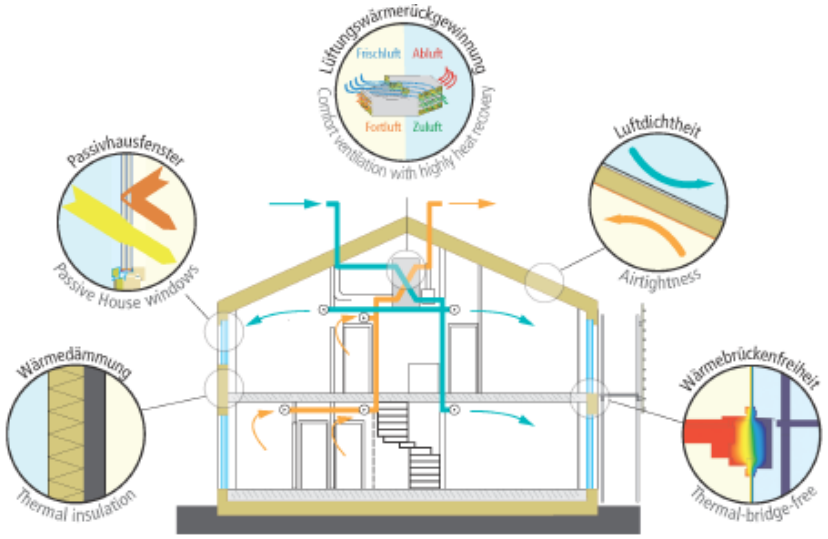


Figure 3. Passive House design principles (Frappé-Sénéclauze et.al., 2016)

Passive House is a performance-based standard with no limits on overall U-values for windows, walls, foundations or roofs.

The following criteria is used to certify buildings under the PHS:

- Passive House Institute
  - Annual heating demand: ≤ 15 kWh/m² OR ≤ 10W/m²
  - Annual cooling demand: ≤ 15 kWh/m² + dehumidification contribution
  - Airtightness: < 0.6 ACH @ 50 Pa
  - Total primary energy: ≤ 120 kWh/m² or;
  - Total renewable primary energy (PER): ≤ 60 kWh/m²

There are also other non-energy targets, but they are out of the scope of this report.

- Passive House Institute US (PHIUS+) 2015 certification criteria specific for Vancouver's climate zone:
  - Annual heating demand < 17.4 kWh/m2
  - Annual cooling demand (sensible + latent) < B kWh/m2
  - Peak heating load < 11.9 W/m2
  - Peak cooling load < 9.2 W/m2
  - Airtightness ≤ 0.05 cfm/sf enclosure @50Pa
  - Primary energy demand ≤ 6200 kWh/person for residential

PHIUS provides a cost-and climate-optimized passive building standard. The PHIUS+ 2015 program created a study that yielded a formula that has been used to generate cost-optimized performance targets for more than 1000 locations. These adjustments represent the difference between both standards.

The PHIUS standard uses occupancy as a factor to determine and limit energy demand per person. To specify the occupancy of a single-family home, this standard uses the same approach as ASHRAE and the total number of occupants is determined by the number of bedrooms in a dwelling + 1. This is useful to lower the amount of energy required by person to condition the space. PHIUS also adjusts the targets by climate zone to be more "fair" in the amount of energy consumed by a home. PHIUS approach is closer to the District of West Vancouver objective to create an energy budget. This standard by its nature limit the energy

attributed to a building by the number of occupants and therefore size. It would be more difficult for a single occupant to meet the target of primary energy demand living in a large home by himself. The following figure illustrates how this limit can work:

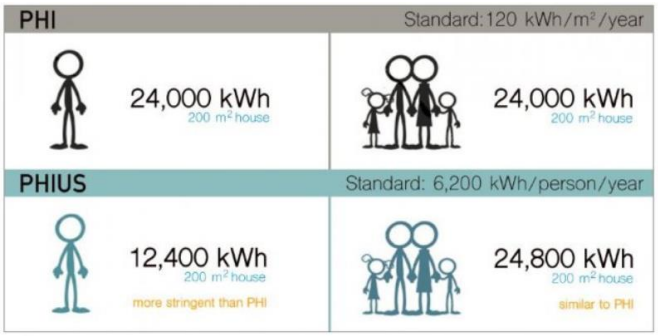


Figure 4. Differences between PHI and PHIUS criteria[5]

These differences make the PHIUS certification harder to reach for small households living in large homes. The use of this standard for an energy budget in West Vancouver is likely to reduce the energy demand of single-family homes,but may be unattractive due to the average household and new construction size in the District. Looking into more detail of this issue and evaluating possible trade offs in future studies can provide a better picture of which direction to follow.

7.2. LEED BD+C for homes

The Leadership in Energy and Environmental Design (LEED) is the most used green building rating system in the world. It provides a framework to create highly efficient and cost-saving green buildings. It is a certification created by the United States Green Building Council (USGBC) but is recognized as a globally symbol of sustainability achievement.

Among its certifications, the LEED Building Design + Construction (LEED BD+C) segment has a rating system specific to

[5] https://www.ecohome.net/guides/2191/everything-you-need-to-know-about-passive-house/)

homes. This rating system has different levels of certification (LEED Certified, LEED Silver, LEED Gold, LEED platinum). Currently LEED is using its v4 rating system to evaluate new construction with credits in different categories.

For the purpose of this report only the Energy and Atmosphere credits were evaluated to identify opportunities of rating system and how can they be applicable to an energy budget in West Vancouver. LEED has both mandatory (identified as prerequisites) and optional credits. Optional credits are used to achieve higher levels of certification.

LEED BD+C v4 has lower energy performance targets than the BC Step Code and is therefore not sufficient to satisfy the new requirements applied by the District since July 1, 2018. Nevertheless, incentives to pursue the certification or its principles can help to assure better measures, occupant behavior and maintenance of the home over its lifetime.

Also, LEED BD+C for homes takes into account important considerations to limit the demand of single-family homes under the **Annual Energy Use credit[6].** This credit is aligned with the principles of an energy budget for a whole construction or lot. It compares a home's projected energy use with a reference home to index it on a Home Energy Rating System (HERS). As explained in the USGBC credit library, the Annual Energy Use credit is appropriate for homes with major energy users that are outside of typical housing construction (e.g. pools, heated driveways and heated garages). It ensures that these additional loads are not externalities but must be considered in the LEED Energy Budget.

This budget is based on the ENERGY STAR for Homes, HERS Index Target Procedure with specific modifications. By indexing against this reference, homes with greater floor area or greater exterior wall area in comparison to a typical home with the same number of bedrooms (or occupants) will have to be built to be more efficient. Further, any major energy users not covered by the energy model, including heated driveways, pools, spas, and heated garages, must be added to the annual energy consumption of the proposed home.

[6] Retrieved from LEED credit library: https://www.usgbc.org/credits/homes/v4-draft/eac1

Homes without any other major users of users are given freedom in its design subject to a minimum performance target, although there is a penalty if the home size is bigger than the reference home. Homes can earn 1 point for every 4% reduction compared to the reference home and lose 1 point for every 4% increase compared to the reference home.

The principle of this LEED credit could be beneficial to create an energy budget in West Vancouver. It is based on the fairness of the total energy used by a home without pools or other major energy users, requiring less than the same home with these major energy users. At the same time, it limits the size of the conditioned space resulting in sustainable homes. LEED also incentivize higher energy performance than the one of the certification by automatically giving 20 points for homes that earn the PHIUS certificate.

West Vancouver's energy budget purpose wouldn't be to apply or request LEED certification for homes, but a similar concept could be used to build the energy budget where:

- **Houses without pools, heated driveways, heated garages or other major energy users:** according to the maximum home size allowed by the lot size, calculate the energy budget assigned to the lot depending on the required performance target in the Step Code.
- **Houses with pools, heated driveways, heated garages or other major energy users:** same amount of energy assigned per year on the same lot but would be required to achieve higher Steps of the Step Code or downsize within the same performance Step to be allowed to have one of these major energy consumers.

8. Examples of possible applications of an Energy Budget in West Vancouver.

8.1. Existing housing stock as the baseline for an energy budget for new construction.

One of the most relevant limitations on this project was to access information on existing single-family homes energy consumption. Also, existing District homes vary widely in terms of geometry, year of construction, envelope performances, mechanical equipment, making it difficult to assume or predict overall performance. Energy performance of these houses

has to be reviewed on case by case basis in order to be comparable against new construction.

Having existing construction data is necessary to evaluate the point on which the size of new homes and conditioned space can offset the overall energy consumption of smaller less efficient homes. This would be an interesting point to evaluate real energy savings and GHG emissions reductions.

Nevertheless, an estimation —not considering the contribution of lighting and plug loads— of the possible size increment without offsetting with more efficient construction can be used to understand how larger a home can get before consuming more energy than a smaller, less efficient home. The table below presents an example of this, using the MEUI metric as reference:

Existing home performance	Existing home Area	New home performance	New home Area with higher performance
Step 2	100 m²	Step 3	133.3 m²
		Step 4	171.4 m²
		Step 5	240.0 m²

Table 3. Example of possible home size increase under an energy budget

This example shows that under an energy budget homes with higher performance would be allowed to have a larger size than homes with lower performance. This size limit is restricted by the Zoning Bylaw meaning despite having allowance to have larger conditioning space, the home can't get larger than this limit.

8.2. Creating an energy budget based on lot size.

The creation of an energy budget could be based on the lot size where the dwelling is going to be located. As mentioned, in previous sections, the Zoning Bylaw determines the maximum site coverage and floor area ratio. The Table 4 presents as an example of an energy budget based on the MEUI metric (no lights and plug loads) for the Step 3 targets.

Lot Size	500 m²	1000 m²	1500 m²	2000 m²	2500 m²	3000 m²

One-storey home area	266 m²	300 m²	450 m²	600 m²	750 m² *	900 m²*
Two-storeys home area	237 m²	350 m²	525 m²	700 m²	875 m²	1050 m²
Max. annualenergy consumption (MEUI only)	10,665 KWh/year	15,750 KWh/year	23,625 KWh/year	31,500 KWh/year	39,375 KWh/year	47,250 KWh/year

Table 4 Proposed energy budget based on the maximum MEUI for Step 3

Based on this, the larger a lot the bigger the energy budget would be given to a home. Also, as mentioned before, the home size does not necessarily result in a higher number of occupants in the home but is more likely to be more conditioned space per person. Adjustments per occupancy could be made like the ones presented in the LEED BD+C or PHIUS standards for the Step 3. This would increase fairness in terms of energy consumption and size.

Occupancy could play an important weighing factor in the energy budget to reduce the size and energy demand of homes. Unfortunately for this study, these adjusted targets were not calculated but it is presented to guide the District in future directions and considerations.

8.3. Homes with infill unit.

As presented in the past sections the District is looking to diversify its housing options. The OCP estimates roughly 400 new infill units such as coach houses will be built by 2041. Utilizing a coach house as an example, these suites are required to achieve Step 1 and are limited to 111.5 m², and can be built with existing or replacement homes. If a similar analysis from the Table 3 is made, this new infill units with a performance under the Step 1 targets are built, it would be the same energy consumption in terms of MEUI as a 140 m² home with a Step 3 limit. Infill units have great benefits in GHG reductions for both transportation and buildings. They also diversify housing options and could be excluded from the total energy budget for a lot.

Even with a lower performance, these units can accommodate a person or family at a significantly smaller dwelling size than a traditional single-family home with lower energy consumptions.

With the future higher allowance for smaller homes under the Step Code currently proposed by the Province, achieving higher steps for these smaller constructions should be easier. The District could accommodate these new limits to demand a higher performance step (Step 2, for example).

8.4. Lot subdivision

The other direction the OCP mentions to diversify housing options and downsize nearly empty large homes is to create lot subdivisions. This would create a higher density of population and a more efficient use of land.

To analyze this condition, it is important to use real homes and lots in the District and then use the Zoning Bylaw to determine the size and energy consumption of the new homes built in the subdivided lot.

The Figure 6 shows a typical single-family home block. This block was used because it could be representative of most of residential zones in the core of West Vancouver. In the western and northern parts of the District larger lots exist but are more irregular. In this block three homes were selected randomly to analyze how a subdivision can affect the overall use of energy related to mechanical energy (MEUI) to heat the space in the same.

These results are presented in the Table 5 where new home size is scaled according to the maximum home size allowed in the Zoning Bylaw. For the first home, a theoretical subdivision would increase the total construction and conditioned space by 19%. The real effect would be much greater since, subject to various provisions, some conditioned space such as basements may be excluded from floor area calculation by the Zoning Bylaw. Even without this consideration, the new constructions would need to consume 19% less energy per square metre than the old construction to use thee same amount of mechanical energy

over a year. On the other hand, considering theoretical subdivisions for homes 2 and 3, the total conditioned space would be reduced leading to a higher performance energy savings.

However, due to the difference in determination of floor area described above, the real amount of conditioned space is still likely to increase in these scenarios.

It is important to note that this scenario is not allowed under the Zoning Bylaw. After the subdivisions are made, these lots do not have the minimum width and total area required by the Section 200 of the bylaw. Amendments to the bylaw would be necessary.

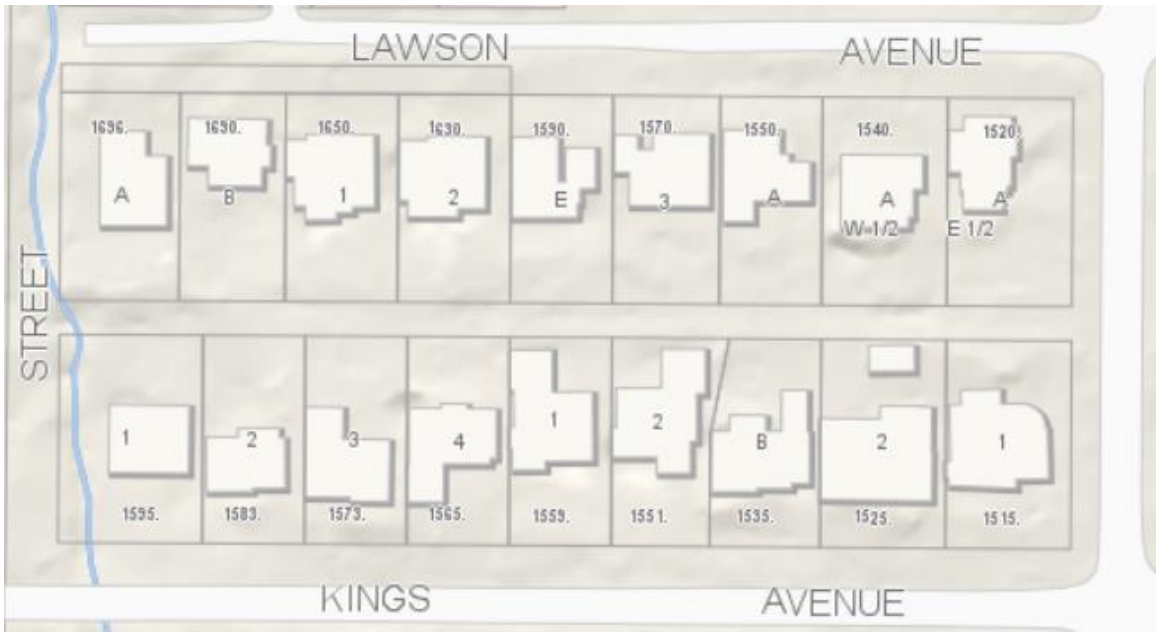


Figure 5. Sample of typical RS-5 block (Retrieved from WestMap website)

	Home 1	Home 2	Home 3
Lot size	1092.50 m²	748.50 m²	833.06 m²
Effective year	1997	1980	2000
Home area	398.48 m²	439.71 m²	498.58 m²
Lot size after subdivision	546.5 m²	374.25 m²	416.53 m²
Max. area per home after subdivision	237 m²	187.12 m²	208.26 m²
Max. total area of new construction	474 m²	374.25 m²	416.53 m²
% of higher performance to offset subdivision's new construction (MEUI metric only)	19%	-15%	-17%

Table 5 Lot size, home area and performance analysis after subdivision

Subdivisions of larger lots are often likely to increase the total conditioned space, demanding a higher performance and energy conservation to offset.

8.5. Homes with other major energy users (pools, heated driveways, etc.)

The presence of other major energy user should not change the energy budget assigned to a lot. If a pool or heated driveway is added within a construction, procedures similar to the ones presented in previous sections with LEED BD+C should be followed. In this case, the metric to consider the total annual energy use based on the EUI. There are two potential pathways to follow for these homes:

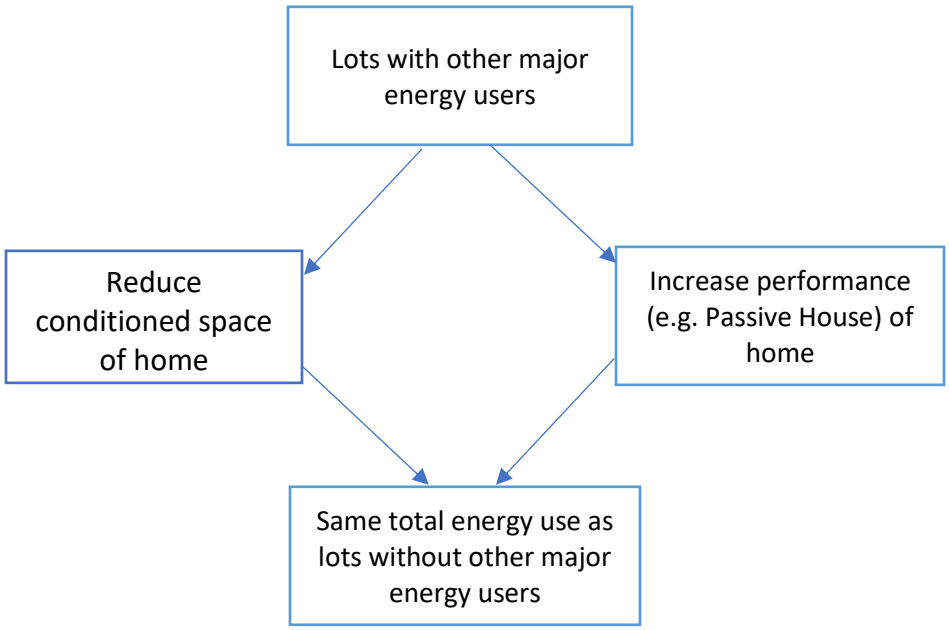


Figure 6. Different pathways for homes with other major energy users

9. Conclusion

The District of West Vancouver has made important changes over the last year on its local policies to accommodate the changes proposed by the BC Energy Step Code and GHG reductions targets.

As presented in this report, the District has the challenge to limit the energy demand of homes that are getting larger and their efficiency is being offset by their size. An energy budget could be an important step forward to prevent this, but it must overcome different issues to be applicable as a community-wide policy.

Recent updates of green building standards like Passive House US and LEED are taking steps to shift towards the approach of an energy budget related on size and occupancy rather than setting performance targets disregarding them. This is important considering the new implementation of the BC Energy Step Code and the current behavior of the housing market in West Vancouver towards major energy users not included in the energy model and increasing size.

Proposed updates to the BC Energy Step Code will also play an important role in the elaboration of this energy budget. The District may also consider amendments to its Zoning Bylaw regarding subdivision and infill units to mitigate increased home size and related energy use.

Future energy budget investigation should include actual energy consumption to calculate savings in both energy and GHG emissions, consider pilot tests to analyze more specific zones in which the energy budget would have the most benefits, and examine interaction between the energy budget and other energy efficiency programs active in the District.

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