

Housing Choice and Environmental Impact Calculator

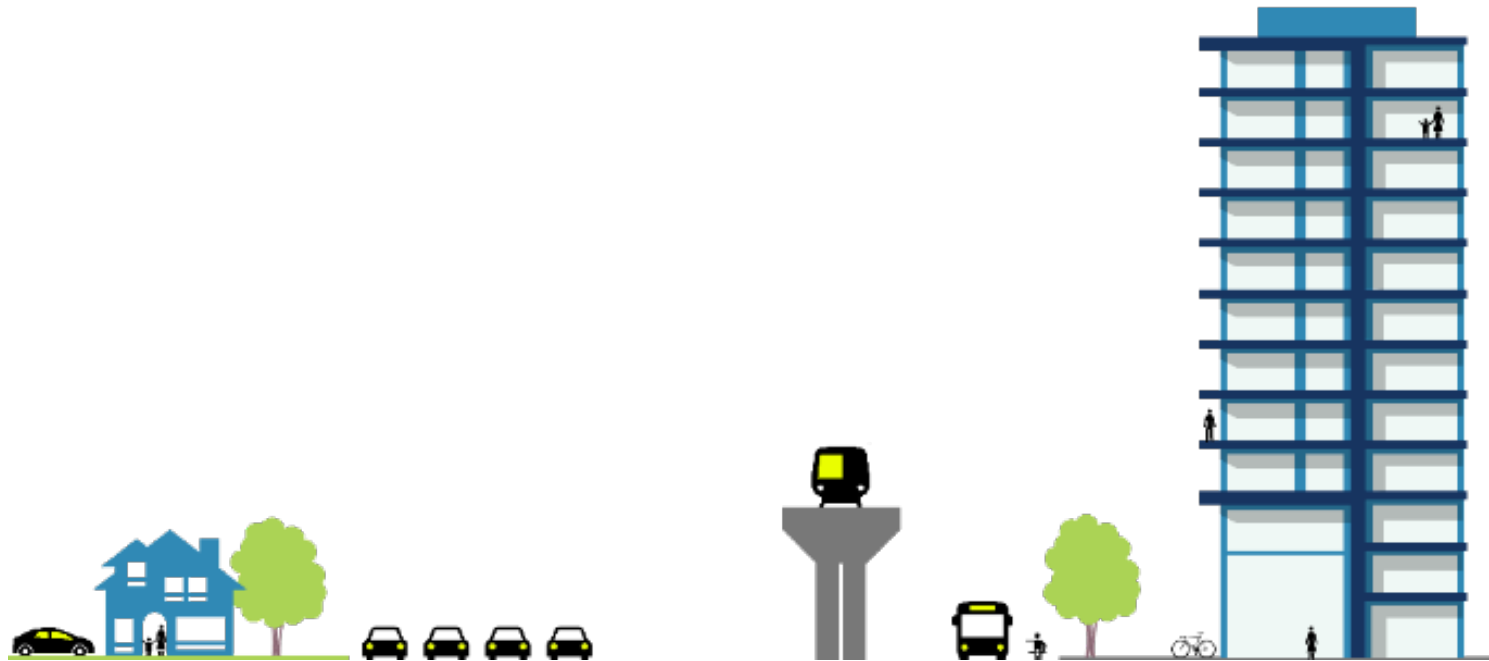
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1. Introduction

1.1 Purpose

The Housing Choice and Environmental Impacts Calculator is a new tool that communicates the trade-offs of different housing choices in the lower mainland of British Columbia, specifically Metro Vancouver.

The calculator provides a comparative analysis of all the major environmental impacts and benefits associated with housing choice, such as greenhouse gas emissions, water and electricity consumption and acres of land taken, for high density archetypes versus low density (single family or townhouse). At a basic level, the calculator works as follows:

- a user enters their proposed high-density housing (HDH) project attributes into the calculator;
- based on the inputs, the calculator generates quantifiable environmental benefits and impacts when compared to equivalent, conventional single-family housing.

1.2 Research Objectives

The intent of this tool is to provide information on the quantitative benefits and impacts of HDH, and to educate and raise awareness among developers and home-buyers on environmental impacts associated with housing choice.

This tool informs the debate around the benefits and costs of density, in that it provides quantitative and measurable data. The provision of real values on impacts such as GHG emissions reductions, automobile use reduction, will provide rigour to the discussion surrounding higher density housing in Metro Vancouver from strictly qualitative to both qualitative and quantitative.

The calculator will be useful to developers as well as consumers or tenants in providing information on the environmental impacts or benefits associated with a proposed project. It can help developers make informed development decisions specific to their project typology. This tool helps developers see how their project objectives and sustainability objectives align. It also provides legislators and lower mainland governments with a tool that can be applied in land use decisions.

2. Calculator Overview

The calculator compares a proposed, user-generated HDH project against a low density equivalent (shown below in Figure 1). The user will input their HDH project attributes into the calculator (shown below in Table 1). These attributes are used to calculate total energy, water and gas use, total emissions and other values for the proposed HDH building. The HDH project values are compared to a typical low-density single family dwelling or townhouse archetype. This comparison generates a series of sustainability metrics that convey specific environmental benefits or impacts such as land use, energy use, water use and transportation and building emissions.

Figure 1 – Input to Output Diagram



Below is a screenshot of the user input menu. Users must choose from a selection or input values associated with their project.

Figure 2 – Proposed Building Attributes

The screenshot shows a user input form with several fields and dropdown menus. The first row contains "Select High Density Building Type" (with a dropdown showing "Wood Frame Multi-Unit"), "Compare w/ Low Density Building Type" (with a dropdown showing "Single Family Dwelling"), "Number of Dwelling Units" (with a text input of "100"), and "Building Lot Area (m2)" (with a text input of "2,000"). The second row contains "Vancouver Rezoning (LEED Gold)" (with a dropdown showing "Yes"), "Building Floor Area (m2)" (with a text input of "10,000"), and "Irrigated Space (% of Lot Area)" (with a text input of "20%" and a slider bar below it). Navigation arrows are visible at the bottom right of the form.

2.1 Building Type

The user can select from three building classifications the most applicable for their proposed HDH building. The building types are:

- Wood-frame Townhouse
- Wood-frame Multi-unit
- Concrete Multi-unit

The three options represent the most common multi-family residential building typologies in Metro Vancouver, and each have distinct energy use intensities and annual electricity and gas consumption rates.

2.1.1 Wood-frame Townhouse

A townhouse, also known as a row house, is a single family dwelling built attached side by side and is typically 2-3 storeys in height. For the purposes of this tool, the energy, gas and electricity consumption rates are based on a wood-frame construction.

2.1.2 Wood-frame Multi-unit

A wood-frame multi-unit building has a lower energy use than that of concrete primarily as the typology typically includes higher levels of insulation and punched windows which increase the overall effective R-value of the building envelope. This decreases heating and cooling demands, thus decreasing gas and electricity consumption. For the purposes of this tool, a multi-unit residential building of any height, of wood-frame construction, can use this building classification.

2.1.3 Concrete Multi-unit

Multi-unit residential buildings built from concrete construction consume slightly more energy than that of wood-frame buildings, due largely to fact that these structures are often characterized by increased glazing and decreased insulation, which increases heating and cooling demands. For the purposes of this tool, a multi-unit residential building of any height, constructed of concrete, can use this building classification.

2.2 Total Units

The user inputs the number of units. The calculator then estimates occupancy based on typical household sizes for each dwelling unit typology. The assumptions built into the calculator are based on 2011 Canadian Census data¹ which showed average household sizes for townhomes to be 2.7 occupants, and 1.7 for multi-unit apartments.

2.3 Gross Floor Area

The user inputs the gross floor area (GFA) into the field to generate the size of the building. The GFA is used to calculate floor area ratio (FAR), total energy use, including estimated values for electricity and gas consumption and overall building emissions.

2.4 Lot Area and Irrigated Space

The user inputs the lot area in square metres and the percentage of the lot that is irrigated. This is used in calculating outdoor water use and density. If the user does not know the projected irrigation area, it is recommended that the default value be 20% of the total lot area, which is the value used by LEED and other tools.

¹<http://www.metrovancouver.org/services/regional-planning/PlanningPublications/DwellingTypesByHouseholdSizeCensus2011.pdf>

2.5 City of Vancouver Rezoning Policy?

In the city of Vancouver, projects applying for rezoning are required to certify LEED Gold and design the building to achieve a level of energy efficiency (22% better than ASHRAE 90.1 2010) and water efficiency (see below). These requirements can impact electricity, gas and indoor and outdoor water consumption. For multi-unit apartment buildings, the user can select from a dropdown list, "Yes" if their proposed project will be adhering to the City of Vancouver Rezoning Policy, or "No" if it is not. Selecting "Yes" will reduce the proposed HDH project's consumptions according to select associated LEED performance requirements. Projects not targeting LEED certifications are calculated based on current BC Building Code requirements and standard construction practices in Metro Vancouver climate zone.

While townhouse developments under rezoning in the City of Vancouver must target LEED for Homes Gold or Built Green Gold with EnerGuide 84, this requirement has been excluded for the purposes of this calculator. To achieve either of these certifications, compliance can be achieved through a variety of different measures. There are no set prescriptive requirements that could result in typical savings, hence omitting it from the calculator as it would not be an accurate representation of savings.

2.5.1 Multi-unit

The LEED for Building Design and Construction credits that impact the proposed building's consumption values are:

- Prerequisite WEp1 – Water Use Reduction
 - The requirement indicates that the building implements "strategies that in aggregate use 20% less water than the water use baseline calculated for the building (not including irrigation)."
 - This 20% reduction is applied to the total Indoor Water Use for the proposed building if "City of Vancouver Rezoning Policy" is selected.
- Credit WEc1 – Water Efficient Landscaping
 - The requirement indicates that the building must "reduce potable water consumption for irrigation by 50% from a calculated midsummer baseline case".
 - This 50% reduction is applied to the total Outdoor Water Use for the proposed building if "City of Vancouver Rezoning Policy" is selected.
- Credit EAc1 – Optimize Energy Performance
 - The requirements of this credit are to increase levels of energy performance beyond the prerequisite standard through three optional paths. The most common path is Option 1. Whole Building Energy Simulation where buildings must "demonstrate a percentage utility cost savings in the proposed building performance rating compared with the reference building performance rating". This calculator uses Path 2 of Option 1, to model according to Appendix G of ASHRAE 90.1-2007 Standards.
 - This calculator assumes a minimum of 22% energy cost savings which equates to 6 energy points.
 - This reduction (minimum of 22% based on cost saving calculations) is applied to the total Energy Use for the proposed building if "City of Vancouver Rezoning Policy" is selected.

3. Methodology

This section provides details on how the calculator was built and source information for supporting data.

Building attributes for a typical single family dwelling and townhouse were developed for the purposes of comparison to the proposed HDH building. A proposed multi-unit project will compare to both a townhouse and a single family dwelling, while a proposed townhouse project will compare to a single family dwelling only. The details of the typical single family dwelling and townhouse are described below.

3.1 Typical Single Family Dwelling (baseline for comparison)

To create a “typical” single family dwelling in Metro Vancouver, against which the HDH project would be compared, assumptions on average floor area, lot size, occupants, building footprint, gas and electricity use, GHG emissions and both indoor and outdoor water use were made. Table 2 shows the set of values generated by way of the assumptions. A description of the data sources and methodology used to determine each value follows.

Table 1 – Single family dwelling attribute assumptions

Single Family Dwelling - Attributes & Consumption Rates		
Metric	Amount	Unit
Dwelling Units	1	
Floor Area	350	m ²
Lot size	570	m ²
Occupants	3.1	people
Building Footprint	140	m ²
Open Space	430	m ²
Consumption Rates		
Gas	113.7	GJ/yr
Electricity	9,250	kWh/yr
GHG	5,718	kg CO ₂ e/yr
Indoor Water Use	384,710	L/yr
Outdoor Water Use	204,680	L/yr

3.1.1 Gross Floor Area (m²)

The average dwelling size was found by searching MLS listings² from six municipalities in Metro Vancouver for detached single family dwellings built after 2013. Six houses were selected at random from the MLS listings for Surrey, Burnaby, North Vancouver, Vancouver, Coquitlam and Richmond for a total sample size of 36 houses across Metro Vancouver. The listings’ gross floor areas were averaged to determine the average gross floor area for a new build single family dwelling for the region. The gross floor area is used in calculating the building footprint, land use density and total energy, electricity and gas consumption.

² Data from www.rew.ca accessed on July 20, 2015.

3.1.2 Building Footprint (m²)

The building footprint is calculated by dividing the Gross Floor Area by 2.5. This is based on the assumption that the average Metro Vancouver single family dwelling will have two and a half storeys. The building footprint is used in calculating the total outdoor water use.

3.1.3 Lot Size (m²)

The average lot size (570m²) was found using the same methodology as the average Gross Floor Area, by taking the average from a sample of new single family dwellings in the region. The site area is used in calculating the total outdoor water use by subtracting the building footprint area from the total site area, providing total outdoor space requiring irrigation.

3.1.4 Occupants

The average household size (3.1) is taken from 2011 Census of Canada³ average number of persons in a private single-detached houses in Metro Vancouver.

3.1.5 Gas Consumption (GJ/yr)

The annual gas use per dwelling (113.7 GJ/yr) is based on average modeled gas consumption⁴ for a single family home in the Surrey, BC climate zone, meeting the 2015 BC Building Code requirements.

3.1.6 Electricity Consumption (kWh/yr)

The annual electricity use per dwelling (9,250 kWh/yr) is based on average modeled energy use⁵ for a single family home in the Surrey, BC climate zone, meeting the 2015 BC Building Code requirements.

3.1.7 GHG Emissions (tonnes CO₂e/yr)

The emissions factor used to calculate the GHG emissions associated with natural gas use is 50.3 kg CO₂e/GJ⁶. Electricity supplied by BC Hydro is considered to be carbon neutral in British Columbia and thus for the purposes of this tool electricity consumption does not factor into the building's GHG emissions.

3.1.8 Indoor Water Use (L/yr)

Indoor water consumption (124,100 litres per person per year) is based on Metro Vancouver's daily water consumption per capita of 340 litres per day⁷.

³<http://www.metrovancouver.org/services/regional-planning/PlanningPublications/DwellingTypesByHouseholdSizeCensus2011.pdf>

⁴ Modeling completed by E3 EcoGroup Consulting.

⁵ Modeling completed by E3 EcoGroup Consulting.

⁶ <http://www.fortisbc.com/NaturalGas/RenewableNaturalGas/Documents/BiomethaneGreenhouseGasEmissionsReview.pdf>

⁷ <http://www.metrovancouver.org/services/water/conservation-reservoir-levels/water-conservation-home/Pages/default.aspx>

3.1.9 Outdoor Water Use (L/yr)

The outdoor water use irrigation factor is calculated using LEED Water Efficiency credit 1.1 - Irrigation Efficiency methodology which assumes four months of irrigation during summer months, resulting in an annual water use of 476L/m². This baseline assumes a typical mixture of landscape types of grass and mixed trees and shrubs, as well as a sprinkler irrigation system.

3.1.10 Vehicle GHG Emissions (tonnes CO₂e/yr)

Residents of single family dwellings have higher automobile-related emissions than residents of all other housing typologies in Metro Vancouver. According to Translink's 2011 Trip Diary Report, 79% of occupants living in single family dwellings use a private vehicle, or are passengers in a private vehicle, for all recorded trips⁸.

The 2011 Trip Diary Report states that the average vehicle kilometres travelled (VKT) per capita for Metro Vancouver residents is 14.5 km/day and 57% of all Metro Vancouver residents drive or use only private vehicles. By multiplying the 2011 Population of Metro Vancouver of 2,313,328 by 0.57, the VKT value for vehicle drivers is 25.5 km/day.

To find the VKT for single family dwelling occupants, the Metro Vancouver driver VKT of 25.5 km/day is multiplied by 0.79 (percentage of single family dwelling occupants who drive). Each occupant in a single family dwelling drives an average of 20.1 km/day.

3.2 Typical Townhouse Unit (baseline for comparison)

The baseline townhouse attributes follow the same methodology as the single family dwelling above. Below in Table 3 are the assumptions for a typical townhouse unit. The breakdowns for energy and gas use, etc. are described in more detail below in 3.2.1 High Density Housing Attributes, Wood-frame Townhouse.

⁸http://www.translink.ca/-/media/Documents/customer_info/translink_listens/customer_surveys/trip_diaries/2011%20Metro%20Vancouver%20Regional%20Trip%20Diary%20%20Analysis%20Report.pdf

Table 2 – Typical townhouse attributes and consumption rates

Town House - Attributes & Consumption Rates		
Metric	Amount	Unit
Dwelling Units	1	
Floor Area	147	m2
Lot size	107	m2
Occupants	2.7	people
Building Footprint	49	m2
Open Space	29	m2
Consumption Rates		
Gas	21.3	GJ/yr
Electricity	13,495	kWh/yr
GHG	1,072	kg CO2e/yr
Indoor Water Use	335,070	L/yr
Outdoor Water Use	13,685	L/yr

3.3 High-Density Housing Wood-frame Townhouse

3.3.1 Electricity and Gas Consumption (GJ/yr)

The annual gas use per townhouse (21.3 GJ/yr) is based on average modeled gas consumption for a townhouse in the Surrey, BC climate zone, meeting the 2015 BC Building Code requirements.

The annual electricity use per dwelling (13,495 kWh/yr) is based on average modeled energy use for a townhouse in the Surrey, BC climate zone, meeting the 2015 BC Building Code requirements.

3.3.2 Building GHG Emissions (tonnes CO2e/yr)

The GHG emission factor for natural gas in British Columbia is 50.3 kg CO_{2e}/GJ⁹. Electricity emissions are considered to be carbon neutral in British Columbia and are not considered for the purposes of this tool.

3.3.3 Water Use (L/yr)

The indoor and outdoor water consumption rates for townhouses are the same as single family dwellings.

Indoor water use is: 124,100 L/person/day

Outdoor water use is: 500 L/m2/yr

⁹ <http://www.fortisbc.com/NaturalGas/RenewableNaturalGas/Documents/BiomethaneGreenhouseGasEmissionsReview.pdf>

See sections "Indoor Water Use" and "Outdoor Water Use" under "Single Family Dwelling Attributes" above for detailed descriptions and methodology.

3.3.4 Vehicle GHG Emissions (tonnes CO₂e/yr)

According to Translink's 2011 Trip Diary Report, 74% of occupants living in townhouses use a private vehicle, or are passengers in a private vehicle, for all recorded trips¹⁰.

Like the single family dwelling methodology, to find the VKT for townhouse occupants, the Metro Vancouver driver VKT of 25.5 km/day is multiplied by 0.74 (percentage of townhouse occupants who drive). Each occupant in a townhouse drives an average of 18.9 km/day.

3.4 Wood-frame Multi-unit and Concrete Multi-unit

3.4.1 Electricity and Gas Consumption

The estimated per-unit-area electricity and gas consumption rates for both the wood-frame and concrete multi-unit typologies were calculated using a modeling tool that generates energy use per unit area for buildings. The tool uses ASHRAE 90.1 2010 and generates the energy use estimate based on specific building attributes as shown below.

Assumptions are made for each typology for building systems and construction attributes, and are adjusted to meet ASHRAE compliance if the user indicates that NO, the building is not subject to the City of Vancouver's rezoning requirements, or are adjusted to meet 22% better than ASHRAE compliance if the user indicates YES to meeting rezoning requirements.

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http://www.translink.ca/-/media/Documents/customer_info/translink_listens/customer_surveys/trip_diaries/2011%20Metro%20Vancouver%20Regional%20Trip%20Diary%20%20Analysis%20Report.pdf

Wood-frame Multi-unit – NO, not subject to CoV Rezoning Policy

The per-unit-area energy consumption rate for a wood-frame multi-unit building meeting ASHRAE 90.1, and is not subject to the City of Vancouver Rezoning Policy is **155 kWh/m2/yr**. This is broken down into:

- Electricity: 60 kWh/m2/yr
- Space Heating: 72 kWh/m2/yr (Gas)
- DHW: 23 kWh/m2/yr (Gas)

The building attribute assumptions are:

- 50% glazing area
- Double-paned windows
- R-12 walls
- Parkade LED lighting
- Hydronic baseboard heaters
- In-suite standard lighting
- MUA unit without heat recovery
- Low-flow water fixtures

Concrete Multi-unit – NO, not subject to CoV Rezoning Policy

The per-unit-area energy consumption rate for a concrete multi-unit building meeting ASHRAE 90.1, and is not subject to the City of Vancouver Rezoning Policy is **160 kWh/m2/yr**. This is broken down into:

- Electricity: 58 kWh/m2/yr
- Space Heating: 79 kWh/m2/yr (Gas)
- DHW: 23 kWh/m2/yr (Gas)

The building attribute assumptions are:

- 60% glazing area
- Double-paned windows
- R-7 walls
- Parkade LED lighting
- Hydronic baseboard heaters
- In-suite standard lighting
- MUA unit without heat recovery
- Low-flow water fixtures

Wood-frame Multi-unit – YES, subject to CoV Rezoning Policy

The per-unit-area energy consumption rate for a wood-frame multi-unit building meeting ASHRAE 90.1, and is subject to the City of Vancouver Rezoning Policy is **122 kWh/m2/yr**. This is broken down into:

- Electricity: 49 kWh/m2/yr
- Space Heating: 50 kWh/m2/yr (Gas)
- DHW: 23 kWh/m2/yr (Gas)

The building attribute assumptions are:

- 50% glazing area
- Double-paned windows
- R-15 walls
- Parkade LED lighting
- Hydronic baseboard heaters
- In-suite LED lighting
- MUA unit with heat recovery
- Low-flow water fixtures

Concrete Multi-unit – YES, subject to CoV Rezoning Policy

The per-unit-area energy consumption rate for a concrete multi-unit building meeting ASHRAE 90.1, and is subject to the City of Vancouver Rezoning Policy is **120 kWh/m2/yr**. This is broken down into:

- Electricity: 48 kWh/m2/yr
- Space Heating: 49 kWh/m2/yr (Gas)
- DHW: 23 kWh/m2/yr (Gas)

The building attribute assumptions are:

- 60% glazing area
- Double-paned windows
- R-10 walls
- Parkade LED lighting
- Hydronic baseboard heaters
- In-suite LED lighting
- MUA unit with heat recovery
- Low-flow water fixtures

3.4.2 Building GHG Emissions

The GHG emission factor for natural gas in British Columbia is 50.3 kg CO₂e/GJ¹¹. Electricity emissions are considered to be carbon neutral in British Columbia and are not considered for the purposes of this tool.

3.4.3 Water Use

The indoor and outdoor water consumption rates for apartments are the same as single family dwellings.

Indoor water use is: 124,100 L/person/day

Outdoor water use is: 500 L/m²/yr

See sections "Indoor Water Use" and "Outdoor Water Use" under "Single Family Dwelling Attributes" above for detailed descriptions and resources.

3.4.4 Vehicle GHG Emissions

According to Translink's 2011 Trip Diary Report, 54% of occupants living in apartments use a private vehicle, or are passengers in a private vehicle, for all recorded trips¹².

To find the VKT for both wood-frame and concrete multi-unit apartment occupants, the Metro Vancouver driver VKT of 25.5 km/day is multiplied by 0.54 (percentage of apartment occupants who drive). Each occupant in an apartment drives an average of 13.8 km/day.

¹¹ <http://www.fortisbc.com/NaturalGas/RenewableNaturalGas/Documents/BiomethaneGreenhouseGasEmissionsReview.pdf>

¹² http://www.translink.ca/-/media/Documents/customer_info/translink_listens/customer_surveys/trip_diaries/2011%20Metro%20Vancouver%20Regional%20Trip%20Diary%20%20Analysis%20Report.pdf

4. Calculations and Outputs

4.1 General Approach

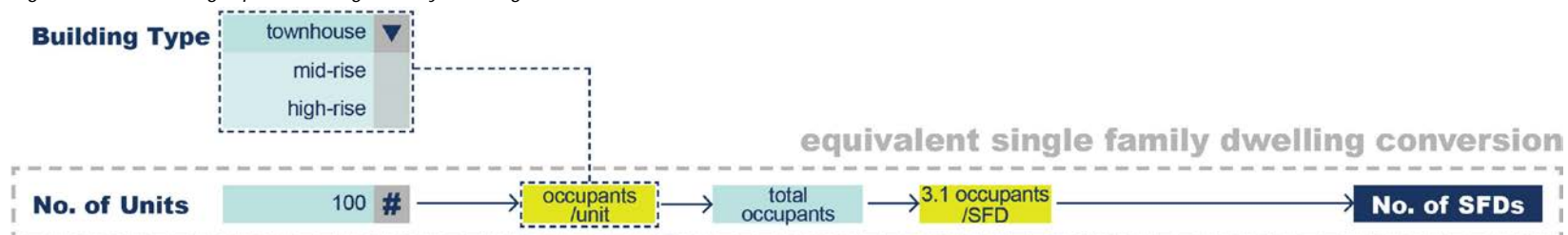
As a means of normalizing the conversion from HDH to a low density equivalent, the following approach was taken to determine equivalent housing metrics. According to census data, average number of occupants per dwelling differs between single family dwelling, apartments and townhomes. As such, to convert a proposed number of apartment or townhome units to the equivalent single family dwelling/townhouse units, unit counts are normalized based on average occupancy rates.

Occupants per unit according to the 2011 Canadian Census Data¹³:

- Single Family Dwelling: 3.1 occupants / unit
- Townhouse: 2.7 occupants / unit
- Apartment: 1.7 occupants / unit

The conversion methodology is depicted for single family dwelling below in Figure 2. The townhouse conversion will follow the same methodology.

Figure 3 – determining equivalent single-family-dwelling or townhouse unit counts



Example:

A proposed townhouse has 100 units. The typical occupancy for a townhouse is 2.7 occupants per townhouse, resulting in 270 occupants. The typical single family dwelling has 3.1 occupants per dwelling. Multiplying 3.1 occupants per single family dwelling into 270 occupants' results in 87 single family dwellings as an equivalent to 100 townhouses.

This value of 87 single family dwellings is then used to calculate the energy, water, etc. consumption totals for the low density equivalent housing to be compared to the proposed project's consumptions.

¹³<http://www.metrovancouver.org/services/regional-planning/PlanningPublications/DwellingTypesByHouseholdSizeCensus2011.pdf>

4.2 Consumption Calculations

The following calculations are completed based on the user's inputs. The tool calculates consumption values for the proposed high-density building and the low-density equivalent, as shown in Figures 3 through 5.

Figure 4 – Project consumption calculations

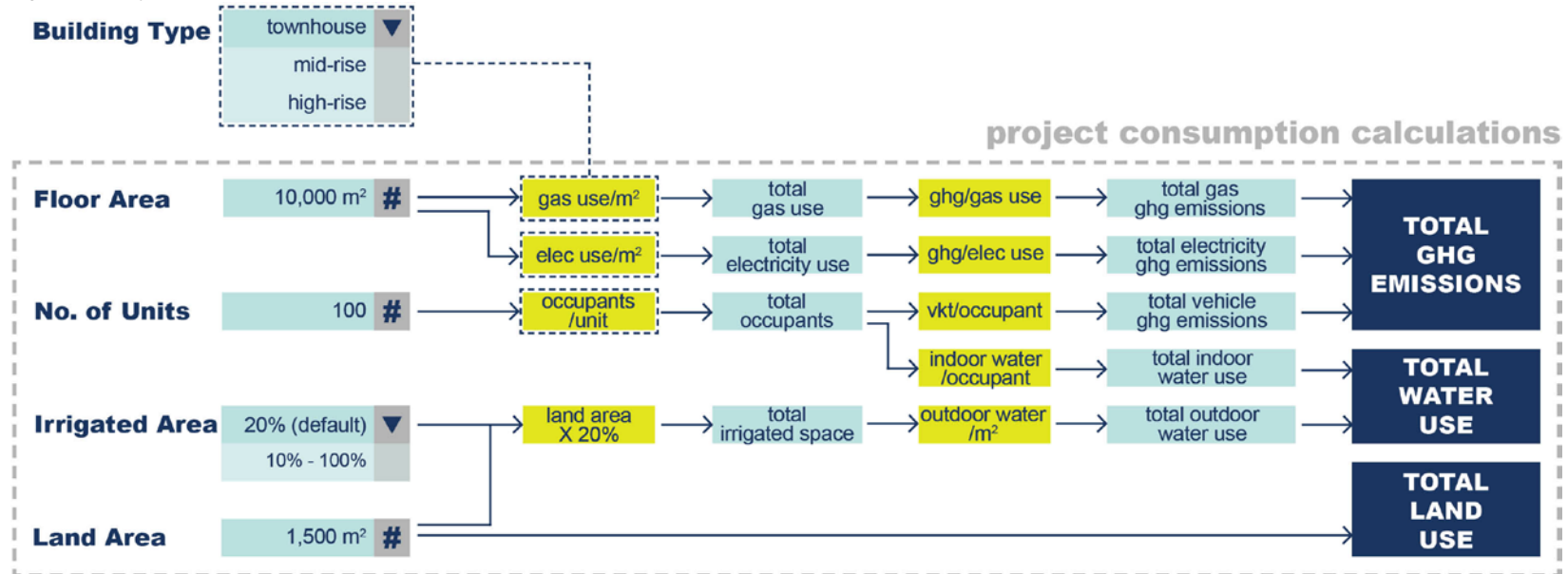


Figure 5 – Equivalent single family dwelling unit conversion

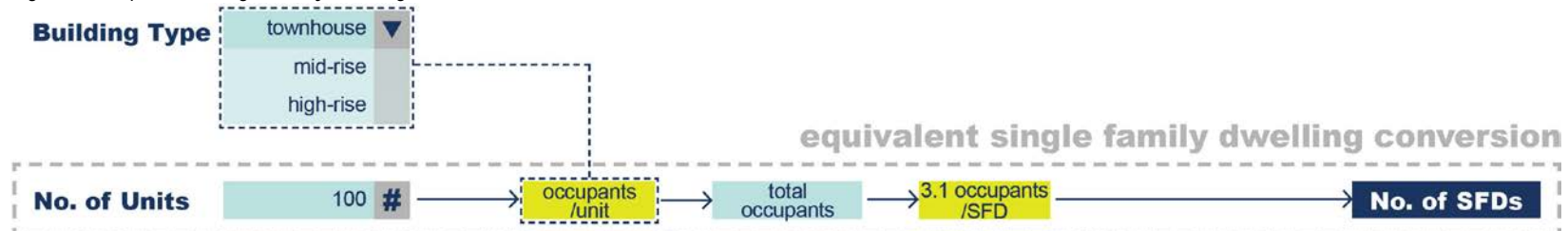
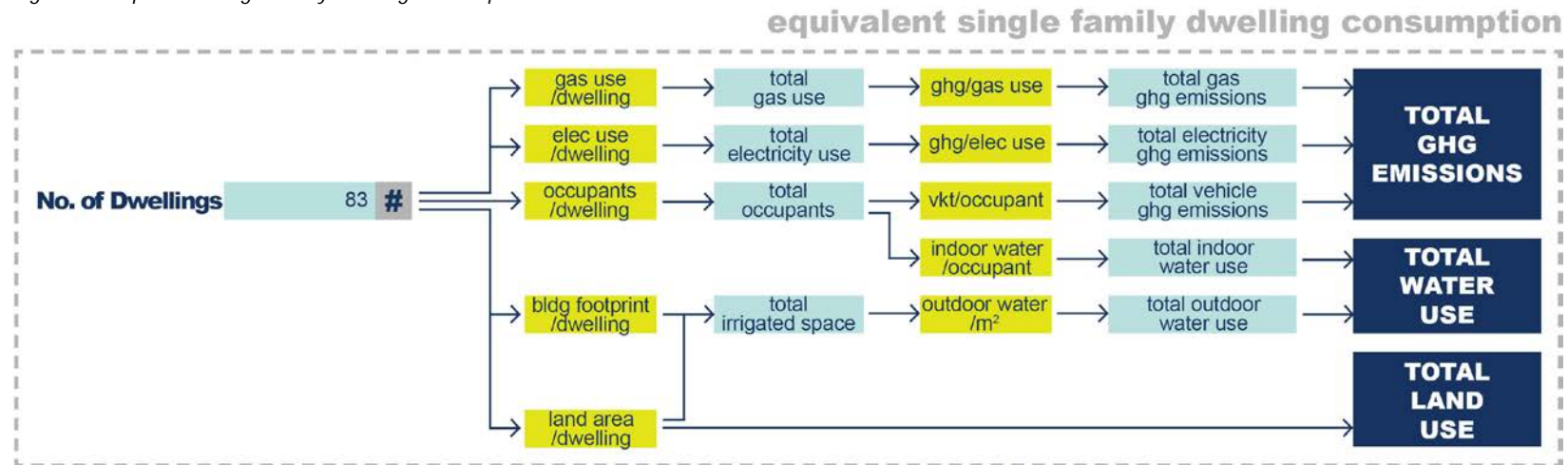


Figure 6 – Equivalent single family dwelling consumption



4.2.1 Total Electricity Consumption:

Building electricity consumption is calculated by multiplying GFA by the per m² electricity consumption rate for the specified building typology.

4.2.2 Total Gas Consumption:

Building gas consumption is calculated by multiplying GFA by the per m² gas consumption rate for the specified building typology.

4.2.3 Total GHG Emissions:

Building GHG emissions are calculated by adding Gas GHG emissions, Electricity GHG emissions and Vehicle GHG emissions.

- Gas emissions are calculated by multiplying the total annual gas consumption by the B.C. emissions factor for natural gas: 0.00503 tonnes CO_{2e}/GJ.
- Electricity GHG emissions are considered negligible in British Columbia due to carbon free hydro power. The emissions factor for electricity is 0.
- VKT emissions are calculated by multiplying the total number of occupants by annual VKT value to get the total number of kilometres being traveled per year. The total km are then multiplied by an emissions factor for GHG per litre of gasoline per kilometre driven.

4.2.4 Total Indoor Water Use:

Indoor water use is calculated by multiplying the number of occupants by the annual water consumption rate per occupant. The annual water consumption rate for indoor water is the same across all possible building typologies. For projects targeting EnerGuide 84 and LEED Gold, the total annual indoor water consumption value will be reduced by 20%.

4.2.5 Total Outdoor Water Use:

Outdoor water use is calculated by multiplying irrigated lot space by the per m² outdoor water consumption rate. This rate is the same across all building types as it applies to exterior space.

4.3 Calculating Savings:

The below diagram (Figure 6) characterizes the overarching approach to calculating benefits or impacts of the proposed high density building against a low density equivalent.

Figure 7 – Savings and/or losses methodology



4.3.1 Inputs

Below is a snapshot of the calculator's user **input** interface.

Figure 8 – Building attribute input interface

Select High Density Building Type	Compare w/ Low Density Building Type	Number of Dwelling Units	Building Lot Area (m2)
Wood Frame Multi-Unit	Single Family Dwelling	100	2,000
Vancouver Rezoning (LEED Gold)	Building Floor Area (m2)	Irrigated Space (% of Lot Area)	
Yes	10,000	20%	

4.3.2 Outputs:

Below is an example of **outputs** based on the values input in the above snapshot. The first set of data – “building parameters” is a comparison of the input number of units compared to the lower density equivalents (shown in Figure 8).

The “savings” data breaks down various environmental performance metrics on a per-unit, per-unit-area and per-person basis, to provide useful comparative metrics. (Figure 9)

Emissions Savings

GHG emissions (tonnes CO₂e/year) are converted into the equivalent amount of new trees planted each year. Trees throughout their life sequester carbon, and in turn produce oxygen which is re-emitted into the earth's atmosphere. The average tree sequesters approximately 48 lbs of carbon annually according to the U.S. EPA.

Energy Savings

Energy Savings (kWh/m²/yr) are converted into the equivalent amount of energy used to light a typical high-pressure sodium street lamp each year. The average amount of energy consumed by a HPS-lamp is 75,000W.

Water Savings

The amount of water saved is shown in the equivalent number of Olympic sized swimming pools, to help give users a visual understanding of the water being spared. Regulation Olympic pools hold 2,500,000 litres of water.

Land Savings

Land saved is shown in the equivalent number of regulation Canadian football fields to help users' visual the open space being spared. Regulation Canadian football fields are 0.59 hectares each in size (101m x 59m).

Figure 9 – Making sense of savings, useful comparative metrics for calculator users

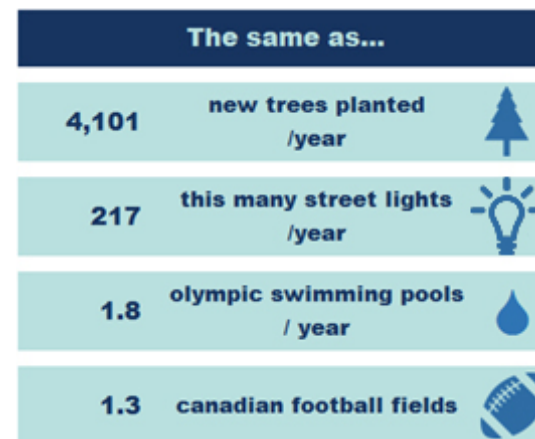


Figure 10 – Building parameter outputs.

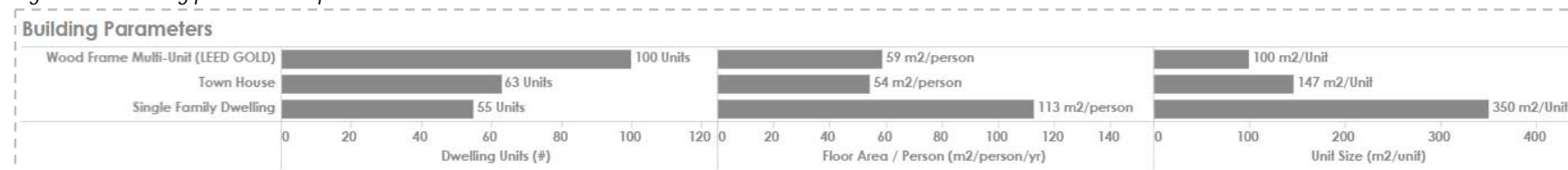
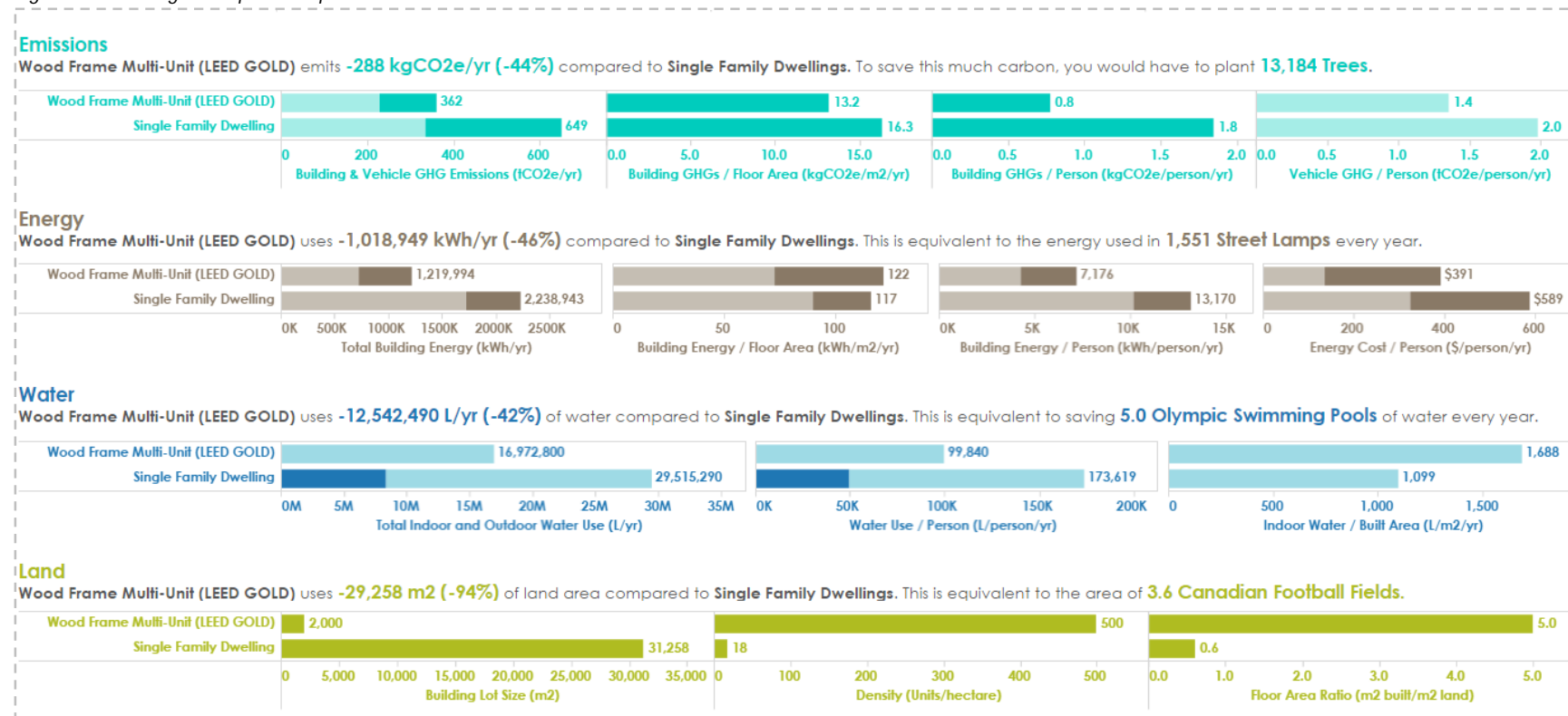


Figure 11 – Savings or impacts outputs



5. Example Project Calculations

The following inputs are based on actual built project metrics for developments in various cities around Metro Vancouver.

5.1 Example Townhouse Development

5.1.1 Townhouse Development 1 – Coquitlam

Figure 12 - Inputs:

Select High Density Building Type	Compare w/ Low Density Building Type	Number of Dwelling Units	Building Lot Area (m²)
Town House	Single Family Dwelling	31	3,300
Vancouver Rezoning (LEED Gold)		Building Floor Area (m²)	Irrigated Space (% of Lot Area)
No		4,530	10%

Figure 13 - Savings: (Note: The calculator will not compare a townhouse to equivalent townhouse.)

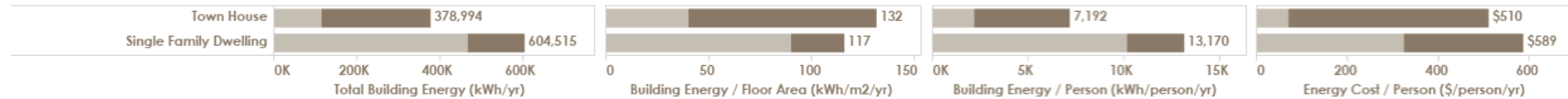
Emissions

This townhouse uses **131,800 kg/CO₂e/yr** compared to Single Family Dwellings. To save this much carbon, you would have to plant **6,041 Trees**.



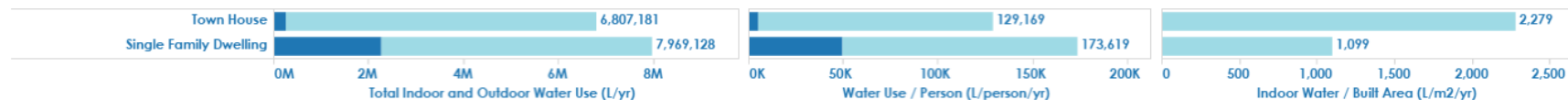
Energy

This townhouse uses **225,521 kWh/yr** compared to Single Family Dwellings. This is equivalent to the energy used in **343 Street Lights** every year.



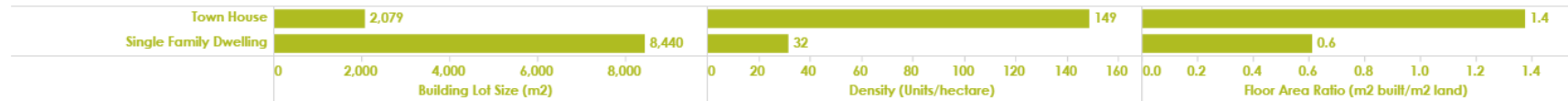
Water

This townhouse uses **5,369,280 L/yr** compared to Single Family Dwellings. This is equivalent to saving **2.1 Olympic Swimming Pools** of water every year.



Land

This townhouse uses **12,000 m²** of land area compared to Single Family Dwellings. This is equivalent to the area of **1.5 Canadian Football Fields**.



5.2 Example Wood-frame Multi-unit Developments

5.2.1 Wood-frame Multi-unit Development 1 – Vancouver

Figure 14 - Inputs:

Select High Density Building Type	Compare w/ Low Density Building Type	Number of Dwelling Units	Building Lot Area (m²)
Wood Frame Multi-Unit	Single Family Dwelling	66	1,447
Vancouver Rezoning (LEED Gold)		Building Floor Area (m²)	Irrigated Space (% of Lot Area)
Yes		6,931	20%

Figure 15 - Savings:

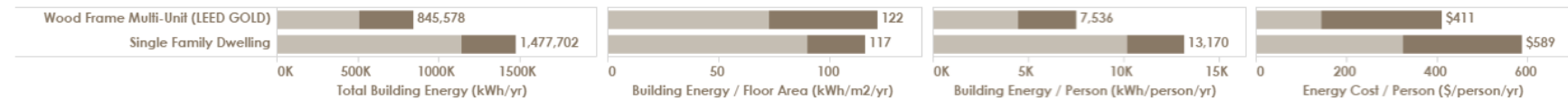
Emissions

Wood Frame Multi-Unit (LEED GOLD) emits **-185 kgCO₂e/yr (-43%)** compared to **Single Family Dwellings**. To save this much carbon, you would have to plant **8,501 Trees**.



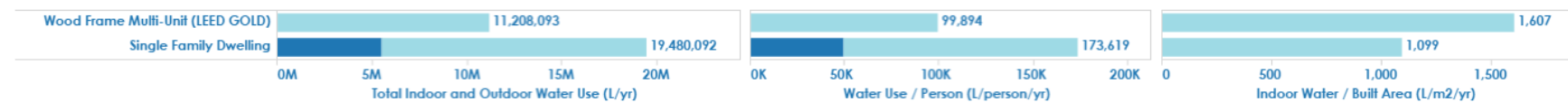
Energy

Wood Frame Multi-Unit (LEED GOLD) uses **-632,124 kWh/yr (-43%)** compared to **Single Family Dwellings**. This is equivalent to the energy used in **962 Street Lamps** every year.



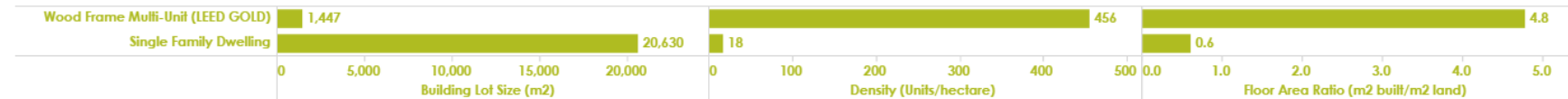
Water

Wood Frame Multi-Unit (LEED GOLD) uses **-8,271,998 L/yr (-42%)** of water compared to **Single Family Dwellings**. This is equivalent to saving **3.3 Olympic Swimming Pools** of water every year.



Land

Wood Frame Multi-Unit (LEED GOLD) uses **-19,183 m² (-93%)** of land area compared to **Single Family Dwellings**. This is equivalent to the area of **2.4 Canadian Football Fields**.



5.2.3 Wood-frame Multi-unit Development 2 – Vancouver

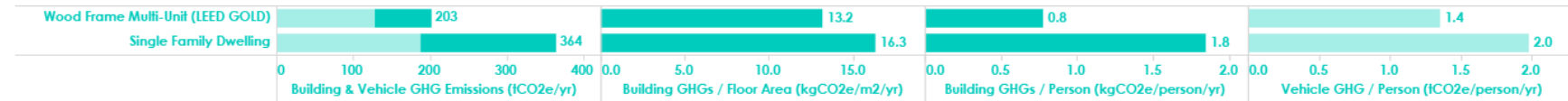
Figure 16 - Inputs:

Select High Density Building Type Wood Frame Multi-Unit	Compare w/ Low Density Building Type Single Family Dwelling	Number of Dwelling Units 56	Building Lot Area (m2) 2,174
Vancouver Rezoning (LEED Gold) Yes		Building Floor Area (m2) 5,610	Irrigated Space (% of Lot Area) 30%

Figure 17 – Savings:

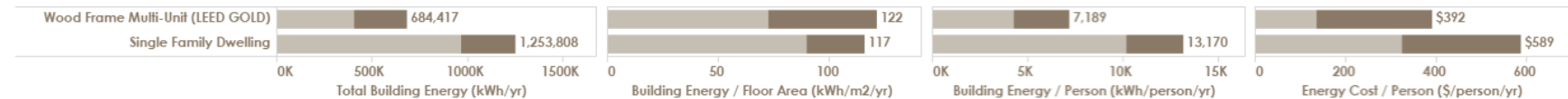
Emissions

Wood Frame Multi-Unit (LEED GOLD) emits **-161 kgCO₂e/yr (-44%)** compared to Single Family Dwellings. To save this much carbon, you would have to plant **7,377 Trees**.



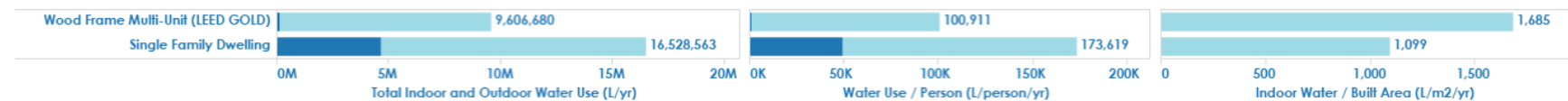
Energy

Wood Frame Multi-Unit (LEED GOLD) uses **-569,391 kWh/yr (-45%)** compared to Single Family Dwellings. This is equivalent to the energy used in **867 Street Lamps** every year.



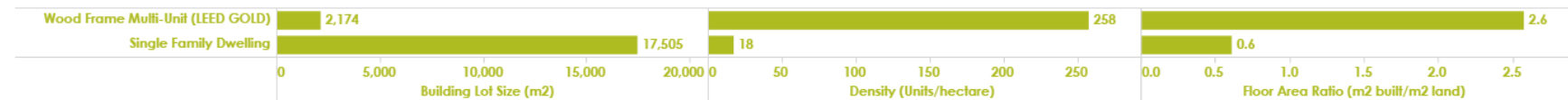
Water

Wood Frame Multi-Unit (LEED GOLD) uses **-6,921,883 L/yr (-42%)** of water compared to Single Family Dwellings. This is equivalent to saving **2.8 Olympic Swimming Pools** of water every year.



Land

Wood Frame Multi-Unit (LEED GOLD) uses **-15,331 m² (-88%)** of land area compared to Single Family Dwellings. This is equivalent to the area of **1.9 Canadian Football Fields**.



5.2.4 Wood-frame Multi-unit Development 3 – North Vancouver

Figure 18 - Inputs:

Select High Density Building Type	Compare w/ Low Density Building Type	Number of Dwelling Units	Building Lot Area (m²)
Wood Frame Multi-Unit	Single Family Dwelling	43	2,930
Vancouver Rezoning (LEED Gold)		Building Floor Area (m²)	Irrigated Space (% of Lot Area)
No		5,292	30%

Figure 19 - Savings:

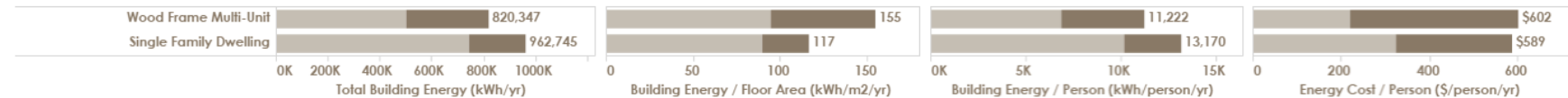
Emissions

Wood Frame Multi-Unit emits **-89 kgCO₂e/yr (-32%)** compared to Single Family Dwellings. To save this much carbon, you would have to plant **4,101 Trees**.



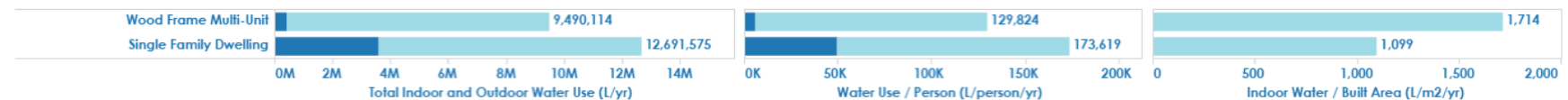
Energy

Wood Frame Multi-Unit uses **-142,399 kWh/yr (-15%)** compared to Single Family Dwellings. This is equivalent to the energy used in **217 Street Lamps** every year.



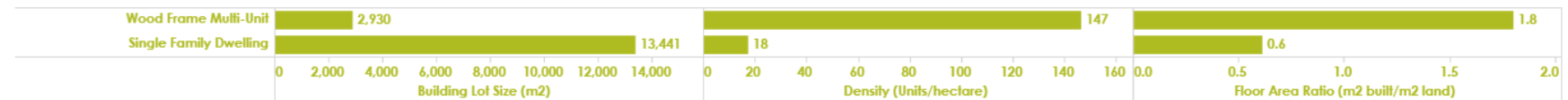
Water

Wood Frame Multi-Unit uses **-3,201,461 L/yr (-25%)** of water compared to Single Family Dwellings. This is equivalent to saving **1.3 Olympic Swimming Pools** of water every year.



Land

Wood Frame Multi-Unit uses **-10,511 m² (-78%)** of land area compared to Single Family Dwellings. This is equivalent to the area of **1.3 Canadian Football Fields**.



5.3 Example Concrete Multi-unit Developments

5.3.1 Concrete Multi-unit Development 1 – Vancouver

Figure 20 - Inputs:

Select High Density Building Type Concrete Multi-Unit	Compare w/ Low Density Building Type Single Family Dwelling	Number of Dwelling Units 213	Building Lot Area (m2) 1,605
Vancouver Rezoning (LEED Gold) Yes		Building Floor Area (m2) 15,422	Irrigated Space (% of Lot Area) 10%

Figure 21 - Savings:

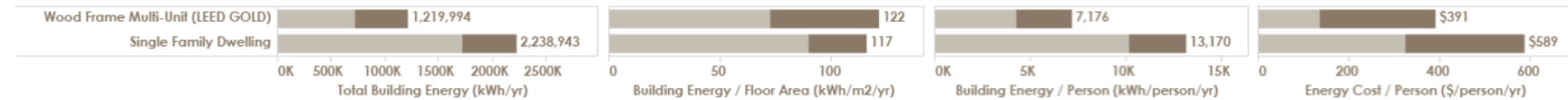
Emissions

Wood Frame Multi-Unit (LEED GOLD) emits **-288 kgCO₂e/yr (-44%)** compared to **Single Family Dwellings**. To save this much carbon, you would have to plant **13,184 Trees**.



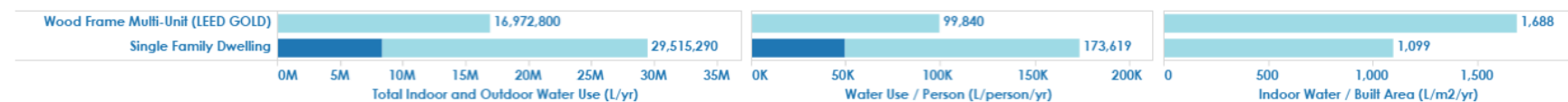
Energy

Wood Frame Multi-Unit (LEED GOLD) uses **-1,018,949 kWh/yr (-46%)** compared to **Single Family Dwellings**. This is equivalent to the energy used in **1,551 Street Lamps** every year.



Water

Wood Frame Multi-Unit (LEED GOLD) uses **-12,542,490 L/yr (-42%)** of water compared to **Single Family Dwellings**. This is equivalent to saving **5.0 Olympic Swimming Pools** of water every year.



Land

Wood Frame Multi-Unit (LEED GOLD) uses **-29,258 m² (-94%)** of land area compared to **Single Family Dwellings**. This is equivalent to the area of **3.6 Canadian Football Fields**.



5.3.2 Concrete Multi-unit Development 2 – Burnaby

Figure 22 - Inputs:

Select High Density Building Type	Compare w/ Low Density Building Type	Number of Dwelling Units	Building Lot Area (m2)
Concrete Multi-Unit	Single Family Dwelling	170	4,291
Vancouver Rezoning (LEED Gold)		Building Floor Area (m2)	Irrigated Space (% of Lot Area)
No		21,108	20%

Figure 23 - Savings:

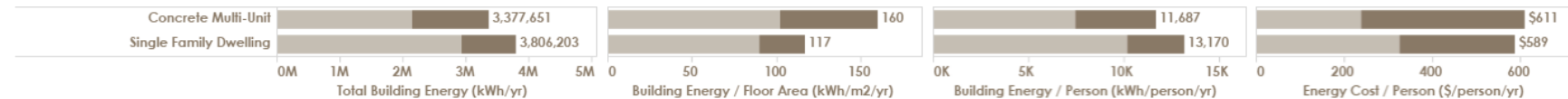
Emissions

Concrete Multi-Unit emits **-324 kgCO₂e/yr (-29%)** compared to Single Family Dwellings. To save this much carbon, you would have to plant **14,841 Trees**.



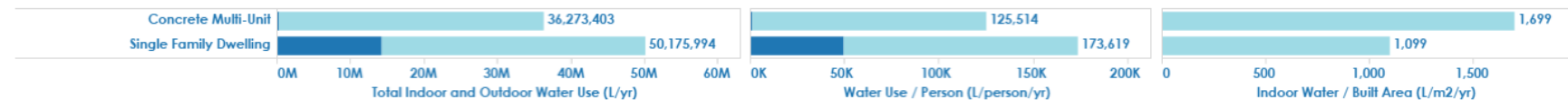
Energy

Concrete Multi-Unit uses **-428,552 kWh/yr (-11%)** compared to Single Family Dwellings. This is equivalent to the energy used in **652 Street Lamps** every year.



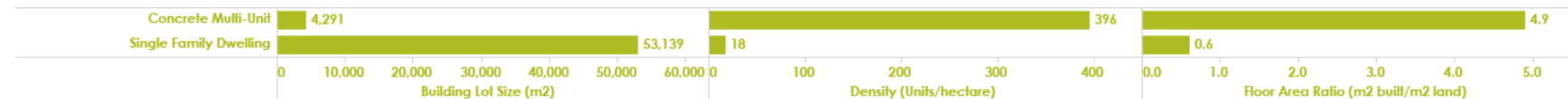
Water

Concrete Multi-Unit uses **-13,902,590 L/yr (-28%)** of water compared to Single Family Dwellings. This is equivalent to saving **5.6 Olympic Swimming Pools** of water every year.



Land

Concrete Multi-Unit uses **-48,848 m² (-92%)** of land area compared to Single Family Dwellings. This is equivalent to the area of **6.0 Canadian Football Fields**.



5.3.3 Concrete Multi-unit Development 3 – North Vancouver

Figure 24 - Inputs:

Select High Density Building Type	Compare w/ Low Density Building Type	Number of Dwelling Units	Building Lot Area (m2)
Concrete Multi-Unit	Single Family Dwelling	89	2,161
Vancouver Rezoning (LEED Gold)		Building Floor Area (m2)	Irrigated Space (% of Lot Area)
No		9,408	30%

Figure 25 - Savings:

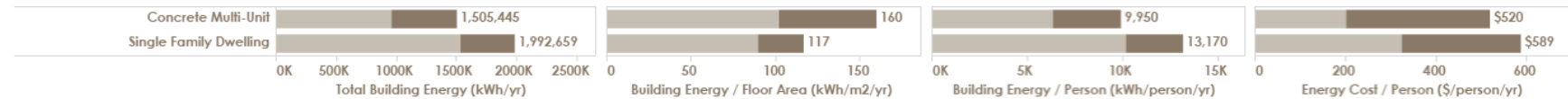
Emissions

Concrete Multi-Unit emits **-200 kgCO₂e/yr (-35%)** compared to Single Family Dwellings. To save this much carbon, you would have to plant **9,160 Trees**.



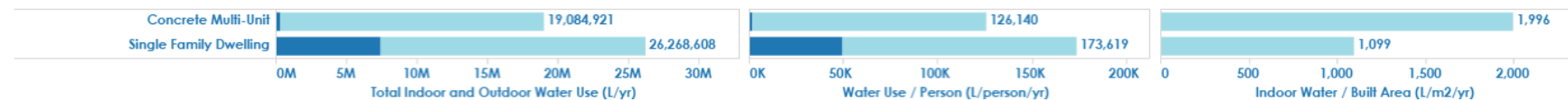
Energy

Concrete Multi-Unit uses **-487,214 kWh/yr (-24%)** compared to Single Family Dwellings. This is equivalent to the energy used in **742 Street Lamps** every year.



Water

Concrete Multi-Unit uses **-7,183,688 L/yr (-27%)** of water compared to Single Family Dwellings. This is equivalent to saving **2.9 Olympic Swimming Pools** of water every year.



Land

Concrete Multi-Unit uses **-25,659 m² (-92%)** of land area compared to Single Family Dwellings. This is equivalent to the area of **3.1 Canadian Football Fields**.



5.3.4 Concrete Multi-unit Development 4 - Vancouver

Figure 26 - Inputs:

Select High Density Building Type
Concrete Multi-Unit

Compare w/ Low Density Building Type
Single Family Dwelling

Number of Dwelling Units
105

Building Lot Area (m2)
1,364

Vancouver Rezoning (LEED Gold)
Yes

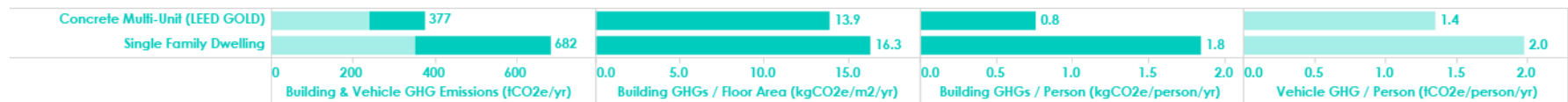
Building Floor Area (m2)
9,755

Irrigated Space (% of Lot Area)
10%

Figure 27 - Savings:

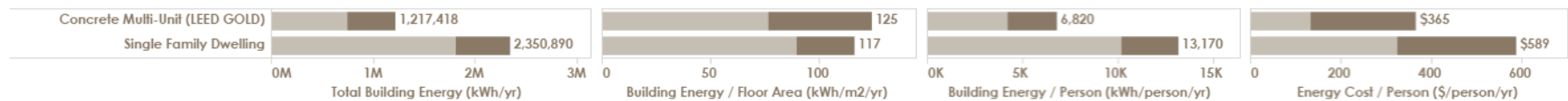
Emissions

Concrete Multi-Unit (LEED GOLD) emits **-305 kgCO₂e/yr (-45%)** compared to Single Family Dwellings. To save this much carbon, you would have to plant **13,987 Trees**.



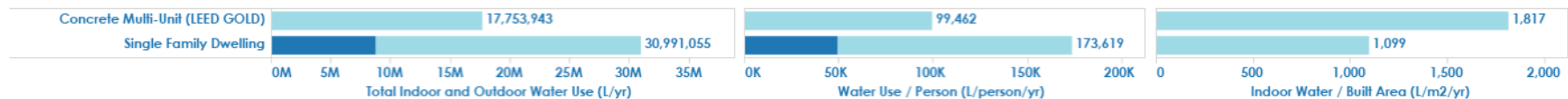
Energy

Concrete Multi-Unit (LEED GOLD) uses **-1,133,472 kWh/yr (-48%)** compared to Single Family Dwellings. This is equivalent to the energy used in **1,725 Street Lamps** every year.



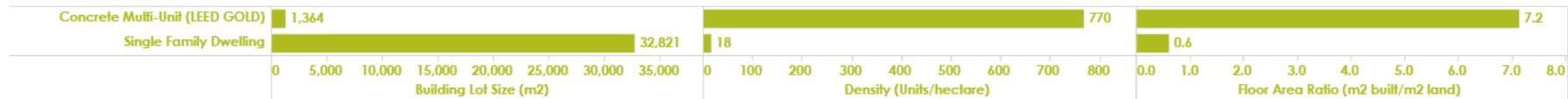
Water

Concrete Multi-Unit (LEED GOLD) uses **-13,237,112 L/yr (-43%)** of water compared to Single Family Dwellings. This is equivalent to saving **5.3 Olympic Swimming Pools** of water every year.



Land

Concrete Multi-Unit (LEED GOLD) uses **-31,457 m² (-96%)** of land area compared to Single Family Dwellings. This is equivalent to the area of **3.9 Canadian Football Fields**.



6. Conclusion

The calculator will be a useful tool to aid decision making on the part of developers and home buyers. The tool addresses a gap in industry knowledge and awareness about the specific benefits of various decisions with regard to housing design and typology. The specific utility of the tool is that it can be used to test the relative benefits of specific scenarios and housing choices, and allows a user to compare the benefits of different approaches. To maximize its impact, the calculator should be available for industry and the public to access and use – available for free use or download on the internet.

The link to the calculator:

<https://public.tableau.com/profile/integral.group#!/vizhome/HousingChoiceandEnvironmentalImpactCalculator/HDHCalculator>