FUTRHAUS: A HIGH-PERFORMANCE TOWNHOUSE

CASE STUDY

This Passive House certified townhouse in Mount Pleasant addresses Vancouver's need for increased densification while achieving energy and carbon performance targets in the City of Vancouver's Zero Emissions Building Plan. Composed of three units, this project utilizes a thermally insulated and airtight envelope, passive cooling strategies, heat recovery ventilation systems, and heat pumps for heating and domestic hot water supply.

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PREPARED BY

zebx

THE UNIVERSITY OF BRITISH COLUMBIA

b2 architecture

QUICK SUMMARY

EXISTING STRUCTURE

is retained to reduce the embodied carbon. Additional insulation was added to improve the R-value of the envelope - **page 05**

MINIMAL HEATING

is provided with energy-efficient air to water heat pumps (Sanden CO_2) for both domestic hot water and radiant in-floor heating - **page 08**

INCREASED INSULATION

in the exterior walls achieved R48, which is three times more than the minimum effective thermal resistance required in the B.C. Building Code - **page 06**

HEAT RECOVERY VENTILATORS

(Zehnder ComfoAir 350) with an efficiency of 84% continuously brings in fresh air from outside and warms it by recovering energy from outgoing air in winter - **page 08**

THERMAL BRIDGING

is minimized using Insulated Concrete Form foundation, double stud walls with staggered spacing, stainless steel point connection handrails and shades - **page 06**

PASSIVE COOLING STRATEGIES

are used, including natural ventilation and fixed shades and deciduous trees on the south facade - **page 05**

EFFICIENT FENESTRATIONS

argon-filled, triple-glazed windows & doors with multiple thermal breaks are used to achieve an installed U-value of 0.86 W/m²K and optimized g-value of 0.53 - **page 06**

EFFICIENT APPLIANCES

such as ductless condensing dryers, convection stove and recirculating hood are used to reduce energy demand and avoid wall penetrations - **page 08**

AIRTIGHTNESS

of 0.57 ACH @ 50 Pa is achieved using a roll-on air and vapor membrane ensuring minimal air loss through envelope air leakage - **page 07**

EIC Media

This case study describes the key features and lessons learned from a Passive House triple-unit townhouse building in Vancouver.

PROJECT CONTEXT

This project converted an existing 1974 stacked duplex house to three independent high-performance townhouse units. The project achieved Passive House certification, an alternate compliance path to Step 5 of the B.C. Energy Step Code.

Project Overview

Building Type	Townhouse – Triplex
Climate Zone	4: Cool-Temperate
Location	Mount Pleasant, Vancouver
Gross Floor Area **Treated Floor Area**	475 m^2 / 5,117 ft^2 333 m^2 / 3,583 ft^2
Building Height	10.2 m / 33.5 ft
Number of Floors / Suits	3 storeys + basement / 3 units
Construction Period	March 2017- August 2019

Project Team

Owner	Private Homeowners
Architect	b Squared Architecture Inc.
Structural Engineer	Thomas Leung Engineering Inc.
Builder & Contractor	Billingsley Construction Ltd.
Mechanical & Electrical Engineer	Reinbold Engineering Group
PH Consultant	Pacific Images Home Design
PH Certifier	CertiPHIers Cooperative
Air Tightness Test	Capital Home Energy Inc.

Project Context

In response to the global climate change emergency, the City of Vancouver developed the Zero Emissions Building Plan, which sets a roadmap to make new buildings zero emissions by 2030. In 2017, the Province of British Columbia enacted the Energy Step Code (Step Code) to incrementally move toward net-zero energy ready buildings by 2032.

The City of Vancouver catalyzes projects in pursuit of high-performance targets such as Passive House and the higher steps of the Step Code with incentives like zoning relaxations for additional building height, depth, and site coverage, as well as a wall thickness exclusion to accommodate thicker insulated assemblies. Additionally, the NearZero Research Program managed by the Zero Emissions Building Exchange (ZEBx) provides incentives for high-performance houses in B.C. in exchange for project data from the design, construction, and operation processes.

The City of Vancouver is also developing and implementing various strategies to respond to the housing affordability crisis, as the city continues to grow. By encouraging multi-family housing options, the City is densifying these neighborhoods. In historic neighborhoods such as Mount Pleasant, where this project is located, the City promotes an increased density while maintaining the integrity of character houses from the 19th century. This project has converted an existing 1974 stacked duplex house to three independent townhouse units.


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PROCESS HIGHLIGHTS

Reusing the simple, box-shaped existing structure helped the project achieve the thermal performance requirement of the Passive House standard. They increased the wall insulation thickness by adding 2 x 4 framing to the inside of the existing walls and filling both the existing and new framing with insulation.

Design Highlights

The retrofitted townhouse is comprised of three independent units, all of which have three stories. Each unit also has a basement with a recreation room, storage area, and a bathroom. The kitchen, living and dining arrangement is located on the main floor, two bedrooms with a bathroom on the second floor and a master bedroom with ensuite on the top floor.

The project retained the existing two-story wood-frame structure to maintain the character of the building and reduce the embodied carbon impacts. The structure was in good condition and the simple box shape helped to achieve the project's energy-performance goals by minimizing excessive heat loss or gain from the envelope and reducing the thermal bridges.

Construction Highlights

In general, the timely construction of high-performing buildings requires proper training of the trades. Simplicity in the design and detailing in this project made trades training more straightforward and reduced on-site errors by workers.

Site conditions added complexity to the project and increased the schedule. A three-meter wide storm way easement diagonally intersects the south-east corner of the site. The project team was required to remove part of the structure on the easement, but, in exchange, was allowed to maintain extensions beyond the zoning envelope on the north side.

The site is also located on a former riverbed with weak soil conditions, substantial moisture levels, and variability in compactness of silty sand fill. A vertical pile shaft foundation was required to support the raft slab.

The height of existing walls, comprised of studs and sheathing, was increased by adding a 12-inch bottom plate. Half-inch plywood was added on top of the sheathing to provide a good envelope surface for adding a liquid-applied air-barrier membrane layer. Additional stud framing was added on the inside with staggered spacing for additional insulation thickness. The design of the building and placement of the windows were carefully considered by the architect to ensure heat losses and gains are balanced for residents' comfort.

The retention of the frame proved to be more challenging than initially anticipated. Therefore, more incentives and support from the City may be required to encourage similar efforts in future projects.

The existing structure was raised to add the basement and the third floor was added on top. The existing walls were modified to add to the ceiling height. (Images: b Squared Architecture Inc.)

ENERGY PERFORMANCE

A high-performance envelope, highly-efficient mechanical systems, and effective utilization of passive cooling strategies made it possible for this project to meet the energy performance of the Passive House standard.

Certified to the Passive House standard, Futrhaus implemented design and construction strategies and technologies to achieve a high-energy performance. The Passive House standard is an internationally recognized certification program, developed by an independent research institute based in Germany. The program is intended to greatly reduce energy requirements for space heating and cooling thereby reducing environmental impacts while improving the indoor thermal comfort and air quality.

The Passive House standard is an alternate compliance path to the highest step of the Step Code, Step 5. The Step Code outlines a voluntary performance-based approach to increasing the energy efficiency of buildings through design and construction. The Step Code provides an incremental and consistent approach to allow British Columbia's building industry to grow its capacity in achieving net-zero energy ready performance.

The table below outlines the Step Code and Passive House energy performance metrics and shows Futrhaus' performance in each.

The building envelope is sealed off by air and vapour sheathing membrane to maintain the thermal performance and airtightness.

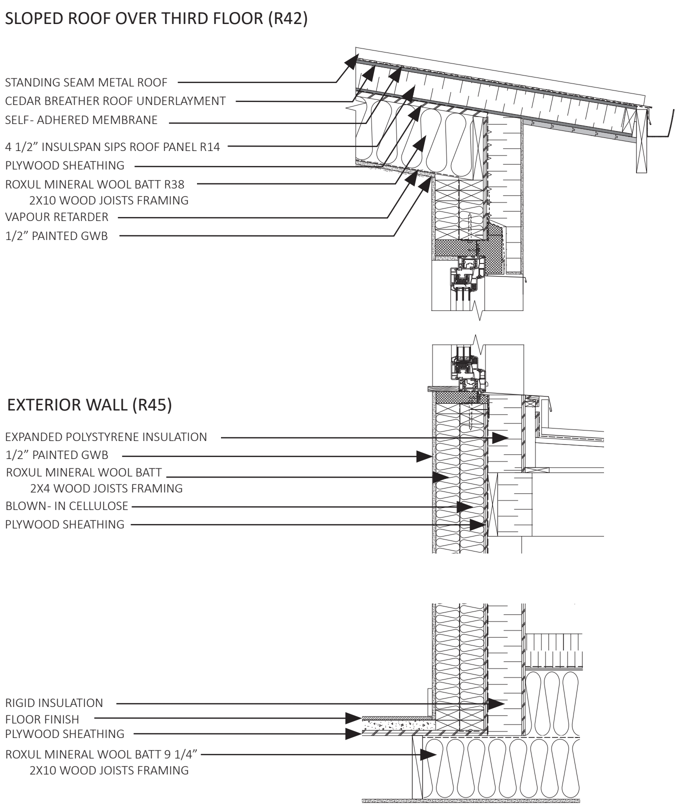
Building Energy Performance of Futrhaus (Source: b Squared Architecture Inc.)
Compared with BC Energy Step Code Guidelines for Ground - Oriented Buildings in Climate Zone-4 and Passive House Standard Requirements

	Metrics	**Airtightness**	**Equipment & Systems**			**Building Enclosure**			
Standard	**Parameter**	**Air Changes rate per hour at 50 Pa pressure difference**	**Mechanical Energy Use Intensity (MEUI)** [2]	**Primary Energy (PE)**	**Primary Energy Renewable (PER)**	**Thermal Energy Demand Intensity (TEDI)**	**Heating Load**	**Annual Space Cooling Demand Intensity**	**Cooling Load**
	Unit	**ACH @ 50Pa**	**kWh/m²/yr**	**kWh/m²/yr**	**kWh/m²/yr**	**kWh/m²/yr**	**W/m²**	**kWh/m²/yr**	**W/m²**
Passive House Standard	Criteria	≤0.6	-	120	-	15 [3]	-	15	-
	Alternative	-	-	-	60	-	10	-	10
BC Energy Step Code	Step 4 [1]	≤1.5	35	-	-	25	-	-	-
	Step 5 [1]	≤1.0	25	-	-	15	-	-	-
Townhouse Case study		**0.57**	**23.7**	**111**	**48**	**16** [4]	**10**	**-**	**-**

[1] Step 4 and 5 requirements for low-rise buildings that are larger than 210 m² (2,357 ft²) and located in Warm-Temperate climate.
[2] The MEUI targets are for buildings larger than 210m² (2,357 ft²) that does not have any active cooling systems.
[3] The TEDI requirement of the Step Code is equivalent to the Passive House Heating Demand.
[4] The heating demand criteria for Passive House was not met in the townhouse project, but the alternative space heating criteria of the heating load lower or equal to 10 W/m² was achieved.

ENVELOPE THERMAL PERFORMANCE

The energy demand of the building was minimized through a highly insulated, airtight and thermal bridge free envelope. Special attention was given to preventing thermal bridges in the wall and floor edges, as well as in plumbing and duct penetrations.

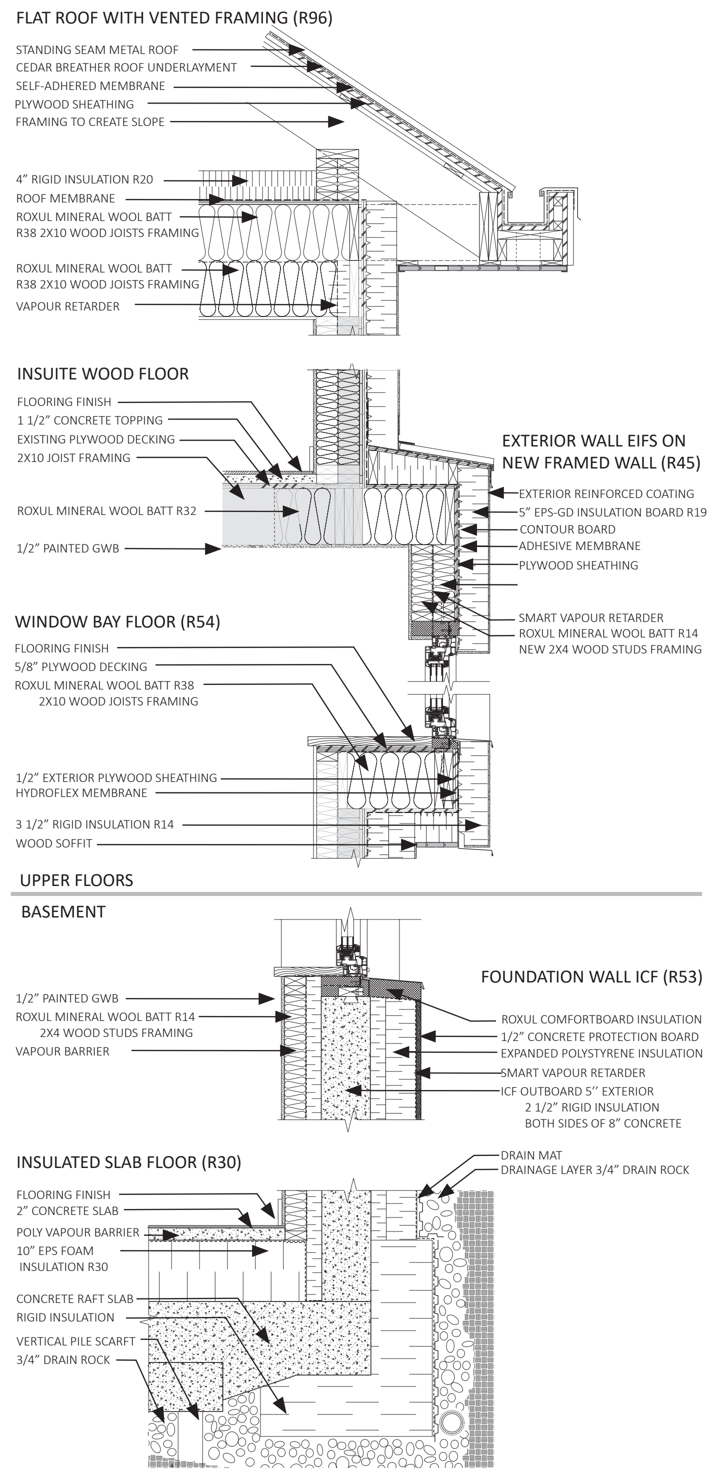


The exterior walls were constructed with Exterior Insulation Finish System (EIFS) wall construction. They have a continuous layer of expanded polystyrene (EPS) insulation that contributes to a thermal performance about three times higher than the current Vancouver Building Bylaw (VBBL) requirement.

The existing 2 x 4 studs on the outside are filled with blown cellulose insulation and the added inner 2 x 4 wood strapping is filled with fibreglass batt insulation. The exterior walls have drainage channels that facilitate moisture management.

The basement concrete floor slab is insulated with a thick layer of EPS foam. Foundation walls are cast-in-place using Insulated Concrete Forms (ICF) with EPS insulation. The roofing is made out of Structurally Insulated Panels (SIP), which is a thick rigid insulation layer sandwiched between two layers of Oriented Strand Board (OSB).

The triple-glazed windows have a multiple-chamber design for thermal breaks. The glazing has two low-emissivity (Low-E) coatings and the spaces between the glass layers are filled with argon gas to increase their thermal performance. The EPS insulation around window mountings were added to prevent thermal bridges and ensure continuous airtightness throughout the entire envelope.



Futrhaus Floor, Wall, and Roof Section (b Squared Architecture Inc.)
Thick layers of insulations without thermal bridges, continuous airtightness membrane and Passive House certified windows contributed to the high performing envelope.

ENVELOPE AIRTIGHTNESS STRATEGIES

The Passive House airtightness performance requirement was achieved by applying a liquid-applied, weather-resistant air and vapor barrier on the exterior wall. Testing was conducted by neutralizing pressure across the three units and measuring the airtightness as a whole.

Thermal Performance of Exterior Components of Futrhaus (Source: b Squared Architecture Inc.)

Envelope Component	Component Description	Thickness (cm / inch)	Average Assembly U-Value (W/m²K)
Exterior Wall	External EIFS wall construction built-up on the existing framing	36 / 14	0.127 (R45)
Basement Wall	ICF Foundation Wall located below grade with EPS insulation	56 / 22	0.107 (R53)
Basement Floor	Slab insulated with a thick layer of EPS foam	57 / 22.5	0.135 (R30)
Flat Roof	2 x10 I joists Flat roof above the second floor with thick batt insulation of high resitance	63.6 / 24	0.07 (R83)
Slope Roof	Sloped roof above the third floor insulated with a thick layer of batt insulation	38.5 / 15	0.120 (R42)
Exterior Windows	Euroline 4700 ThermoPlus Passive House certified Tilt & Turn windows	-	Glazing: 0.65 Framing: 0.77
Exterior Doors	Euroline 4700 ThermoPlus Passive House certified door	-	Glazing: 0.65 Framing: 0.74

Minimizing air leakage prevents loss of energy and avoids the risk of condensation. The Passive House airtightness performance requirement was achieved by applying a liquid-applied, weather-resistant air-vapor barrier using a roll-on method over shiplap sheathings on the exterior side of the walls and an additional permeable vapor barrier on the inside. In addition, peel-and-stick window flashings were applied around window frames to prevent moisture ingress.

Care was taken to avoid any punctures in the envelope. HRV ducts and all plumbing penetrations were sealed temporarily and liquid applied air-vapour membrane was added around the penetrations to completely seal the envelope.

All the common party walls separating units are fire-rated and made of 2 x 4 double-stud structural walls with staggered spacing and filled with acoustic fibreglass batting insulation to improve acoustic performance. Sealing off the party walls with moisture, vapor and air barriers were not required or necessary. Therefore, for the airtightness test, the entire building was tested as one whole building rather than independent suites.

An accurate test of the whole building could not be conducted with just one blower door fan, therefore three blower door fans were used simultaneously. Each fan was installed on the opening of each townhouse. After neutralizing the pressure across the units, the results were measured by first depressurizing and then pressurizing the units to 50 Pascals. The measured pressures from each fan were then averaged for the final result of 0.57 air changes at 50 Pascals pressure, which was below the 0.6 ACH @ 50 Pa Passive House standard requirement.

Liquid air barrier applied over sealed HRV duct outlet

ENERGY EFFICIENCY STRATEGIES

An efficient heat recovery system is employed to reduce the total heating demand. CO_2 heat pumps are used for domestic hot water and space heating through a radiant in-floor system.

Heating & Cooling

The units have large windows on the south façade to optimize solar heat gain in winter, which provides more than a third of the building's space heating needs. Additional heating is provided for each unit by a Sandon CO_2 G3 split-type heat pump, a highly efficient alternative to traditional electric or gas heaters. This heat pump system supplies domestic hot water as well as space heating through a radiant in-floor system in the basement and a heating coil in the Heat Recovery Ventilation (HRV) units for the upper floors. The three heat pumps' outdoor units are located under the south entrance decks and the hot water tanks are located in the mechanical room in the basement, which is within the thermal and airtight envelope.

This townhouse relies on passive cooling strategies and does not have active cooling systems. Passive strategies on the south side include overhangs over windows and a porch canopy on the main entrance. There are also deciduous trees in the yard which block direct sunlight and excessive heat gains during summer while allowing optimal heat gains in the winter when the sun is at a lower altitude. Additionally, operable high windows are located on top of the staircase for passive cross and stack ventilation.

Heatpump outdoor units located under south entrance deck

HRV closet in the basement with insulated pipes to prevent heat loss

Ventilation & Appliances

A Zehnder ComfoAir 350 HRV system with an efficiency of 84% is used for the ventilation of each unit. The HRV continuously brings in the fresh air, which is preheated with the recovered heat from the exhaust air. This efficient heat recovery system results in a significant reduction in energy demand for space heating. In warm days, the HRV automatically switches to bypass mode, stops capturing the heat from the exhaust air and flushes the heat overnight to cool the house.

Although these high-efficiency HRV units make very little noise, they are placed in the closets in the recreation rooms at the basement level. By locating the units in an accessible location, the designer simplified the changing of filters for the residents. Changing the HRV filters every six months, as advised by the suppliers, is crucial to maintain their efficiency and indoor air quality. Where the layout of the building allowed, the HRV units are located as close as possible to their intake and exhaust air. Additionally, the ducts are insulated to prevent unintended heat loss.

The boost mode of the HRV can be activated in the bathrooms and kitchens to effectively ventilate moisture and odors when these spaces are in use.

Energy efficient appliances such as Energy Star Bosch washers and dryers and induction stoves reduce the overall energy demand. By using ductless appliances, such as condensing dryers and recirculating range hood with charcoal filters for kitchen stoves, penetrations to the exterior walls are minimized. This contributes to the thermal performance and airtightness of the envelope.

NOTES

GLOSSARY

Key terms, definitions, and abbreviations used in this case study arranged alphabetically

Active Cooling
A system that involves the use of energy to cool the space, as opposed to passive cooling, which requires no use of energy. Active cooling systems circulate coolant to transfer heat from one space to another.

ACH50
Air changes per hour at 50 pascals pressure differential, the required standard of airtightness for Passive House certification. This unit represents the number of times the air volume in a building changes per hour at 50 Pa of pressure.

Airtightness
The resistance to inward or outward air leakage through unintentional leakage points or areas in the building envelope. Airtightness is represented in units of ACH and is commonly tested using a blower door test.

B.C. Energy Step Code ("Step Code")
A voluntary provincial standard in British Columbia that provides an incremental and consistent approach to achieving more energy-efficient buildings that go beyond the basic requirements of the BC Building Code.

Blower Door Test
A blower door test is used to determine the airtightness of a building. A powerful fan is mounted in the frame of an exterior door, pulling air out of the house to depressurize the inside space. The higher pressure air outside then flows in through openings in the building envelope, which allows the air infiltration rate of a building to be measured.

Cooling Load
The amount of energy required to remove heat from a space to maintain the temperature in an acceptable comfort range.

EnerGuide Reference Building
Natural Resource Canada's EnerGuide rating system and HOT2000 software develop an automatically-generated reference house to be compared with the proposed building design. In the B.C. Step Code, the reference building is used to generate Equipment and Systems metrics for Part 9 buildings.

Expanded Polystyrene (EPS)
A rigid and low-density insulating foam.

Heat Pump
A mechanical system that transfers thermal energy in the opposite natural direction of heat transfer from a colder space to a warmer space. Heat pumps are a more energy-efficient alternative for space heating, cooling, and domestic hot water.

Heat Recovery Ventilator (HRV)
A mechanical device that recovers heat from the exhaust air to pre-heat the filtered incoming fresh air stream. Using an HRV helps reduce the heating load and reduce the energy required to bring the outside air to the ambient room temperature.

Heating Load
The amount of energy required to heat a space to maintain the temperature in an acceptable comfort range.

Insulated Concrete Forms (ICF)
Insulating concrete forms (ICFs) are cast-in-place concrete walls sandwiched between two layers of insulation material. The rigid thermal insulation layer increases the thermal resistance of concrete assemblies and minimizes thermal bridging.

Low-Emissivity (Low-E)
A surface condition that emits low levels of radiant thermal energy. Glass is highly thermally emissive, so to improve the thermal performance of windows, thin-film coatings with low-emissivity are applied to window glasses.

Mechanical Energy Use Intensity (MEUI)
An energy use metric that includes the energy consumption from heating, ventilation, and air conditioning systems. This includes domestic hot water supply, pumps, and fans, but omits base loads such as plug loads and lighting. This a Step Code metric for Part 9 buildings.

GLOSSARY

Key terms, definitions, and abbreviations used in this case study arranged alphabetically

Net-Zero Energy Building
According to the B.C. Energy Step Code, a building with net-zero energy consumption. The total energy used by the building on an annual basis is equal to the amount of renewable energy created on the site or by renewable energy sources offsite.

Oriented Strand Board (OSB)
A type of engineered wood, formed by adding adhesives and then compressing layers of wood strands in specific orientations.

Passive Cooling
A building design approach that focuses on heat gain control and heat dissipation in a building to improve indoor thermal comfort with low or no energy consumption. Passive cooling includes strategies such as cross-ventilation, stack ventilation, solar heat gain control through shading, natural night flushing, creating microclimates, and building orientation.

Passive House
An internationally recognized certification program, developed by an independent research institute based in Germany. Complying to the Passive House standard confirms that the building has been designed to achieve high levels of occupant comfort and energy performance. It is an effective means of meeting City of Vancouver's Zero Emissions Building Plan targets.

Primary Energy Non-Renewable (PE) Demand
The total energy demand for operation of a building, including heating, cooling, hot water, lighting, and plug loads. To account for energy losses along the generation and supply chain, the Passive House Institute (PHI) multiplied the building energy requirement by a PE factor.

R-value
The capacity of an insulating material to resist heat flow. The higher the R-value, the greater the insulating power.

Structural Insulated Panel (SIP)
An engineered sandwich panel, typically consisting of rigid insulation sandwiched between two layers of the structural board (such as OSB sheathing). SIPs combine several components of conventional buildings, such as studs and joists, insulation, vapor barrier, and air barrier. They can be used for different applications, such as the exterior wall, roof, floor, and foundation systems.

Thermal Bridge
An area or a building component which has higher thermal conductivity than the surrounding materials, creating a path of least resistance for heat transfer. Thermal bridges in a building envelope result in significant heat loss and energy efficiency reduction.

Thermal Energy Demand Intensity (TEDI)
A metric of the modeled building's heating needs used in the B.C. Energy Step Code that is primarily influenced by the building enclosure insulation, airtightness, and ventilation system. A highly insulated, airtight enclosure, with heat recovery ventilation will achieve a lower TEDI value.

Total Energy Usage Intensity (TEUI)
A metric of the modeled building's energy needs used in the B.C. Energy Step Code that in addition to TEDI, includes plug loads, lighting, and other auxiliary systems like elevators and miscellaneous equipment.

U-value
A measure of thermal performance or heat transfer through a surface due to conduction and radiation. Lower U-Value rates indicate more energy efficient surfaces. U-value is the inverse of the R-value.

Zero Emissions Building (ZEB)
According to the City of Vancouver, a zero emissions building is highly energy efficient and uses only renewable energy.

Zero Emissions Building Plan
A phased approach by the City of Vancouver to reduce carbon emissions in buildings by establishing specific targets and actions to achieve zero emissions carbon in all new buildings by 2030.

Zoning Envelope
A legally defined volume within which a building must be contained.

FUTRHAUS :
A HIGH-PERFORMANCE TOWNHOUSE

Learn more at

https://zebx.org/resources/#case-studies

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