COOLING STRATEGIES FOR HOUSES IN LOWER MAINLAND, B.C.

TECHNICAL PRIMER

This technical primer looks into the primary factors contributing to cooling loads and overheating in houses, and effective energy-efficient strategies for maintaining comfort in a warming climate and with increased extreme weather events such as wildfire smoke. The information applies to low-rise residential buildings including single-family houses, duplexes, townhouses, and laneway houses.

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Futrhaus Credit: EIC Media

This technical primer reviews key solutions for reducing cooling loads and delivering efficient cooling technologies for high-performance houses in Lower Mainland, British Columbia.

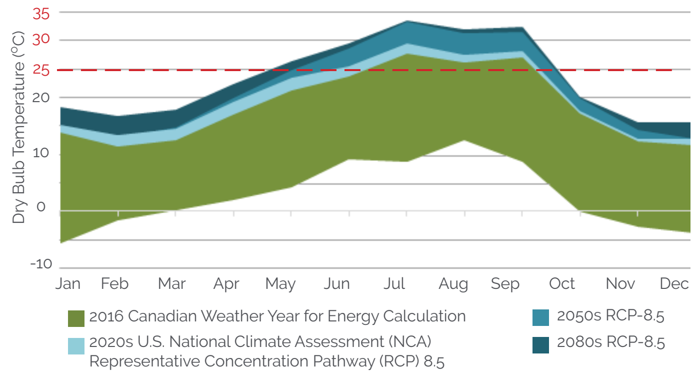
A CHANGING CLIMATE

The Lower Mainland, B.C., has historically been a temperate climate, typically precluding the need for air conditioning in houses. However, with a warming climate and an increase in extreme weather events like wildfires, active cooling is becoming increasingly necessary to maintain adequate comfort conditions at all times.

The Context

The construction industry in the Lower Mainland region of British Columbia (B.C.) is rapidly shifting toward low and eventually zero-emissions buildings to accommodate the increasing demand for housing while responding to the climate change crisis.

To date, in mild and cold climates such as the Lower Mainland, more attention is given to minimizing heating energy consumption through solutions, such as adding more insulation, using high-performance windows and doors, airtight envelopes, and heat recovery ventilation. However, as summer temperatures increase due to climate change, cooling energy needs are increasing and warrant efficient mitigation strategies.



Historical and future average monthly minimum and maximum temperatures for Vancouver, B.C. Future climate data predicts an increase in the length and intensity of warm days above the comfort temperature. (Data Source: RDH Building Science Inc.).

Thermal Comfort

Many environmental, physical, and social factors contribute to the thermal comfort of a space. These factors include air temperature, relative humidity, duration of high temperatures, demographics, and clothing culture. Controlling and maintaining internal thermal comfort is essential for the health, safety, and satisfaction of building residents. This is even more crucial for the health and comfort of vulnerable populations who are most at risk.

When the temperature of a space becomes too hot for prolonged periods of time, it is referred to as overheating. Overheating can cause health risks – such as heat stress, heatstroke, increased morbidity, and sometimes mortality. While lower levels of overheating may not pose serious health risks to all residents, it causes discomfort and impacts their quality of life.

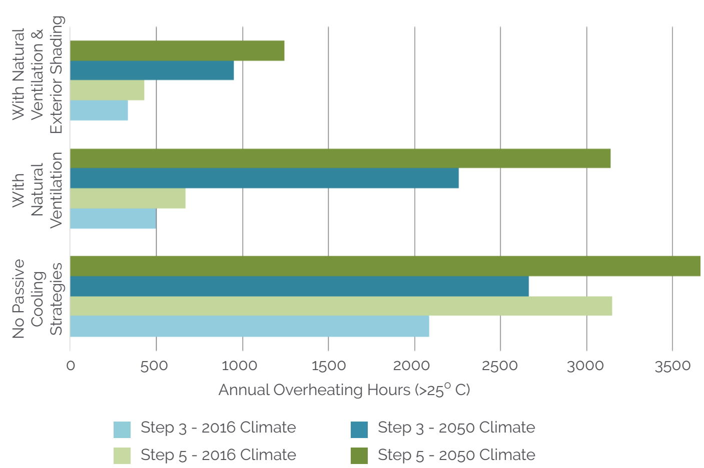
Definition of overheating in building standards

Due to the subjective nature of thermal comfort, there are variations in the definition of overheating in different standards.

Standard	Definition	Threshold
CIBSE AM10	>28°C in living spaces, >26°C in bedrooms	>1% of hours
ASHRAE 55	All occupied spaces >24-25°C in winter >27-28°C in summer	This is estimated to be acceptable for 80% of occupants.
City of Vancouver	Comply to ASHRAE 55	> 200 hours > 20 hours for vulnerable populations
Passive House	> 25°C (average for entire space)	> 10% of annual hours

Building Resiliency

Given the long operating lifespans of buildings, it is crucial to design and build them not only to meet the current needs but also to be resilient to extreme events, disasters and future climate conditions. Overheating occurrences in current climate conditions can be largely eliminated using passive cooling strategies. However, these strategies may no longer be sufficient in a warming climate and with the increase in extreme weather events such as wildfire smoke that we are already experiencing. These events make natural ventilation unsafe and thus can exacerbate overheating risks.



The results of a modeling exercise of a typical single-family house in Vancouver shows that using passive cooling strategies and climate are far more critical to overheating outcomes than envelope performance (Source: Morrison Hershfield).

ACTIVE COOLING

In our current climate, the majority of cooling loads can be reduced with mitigation strategies like shading and passive cooling strategies like natural ventilation. Active solutions like heat pumps can cover the remainder of the load and provide cooling when natural ventilation is not possible due to poor air quality or when temperatures outside are higher than inside.

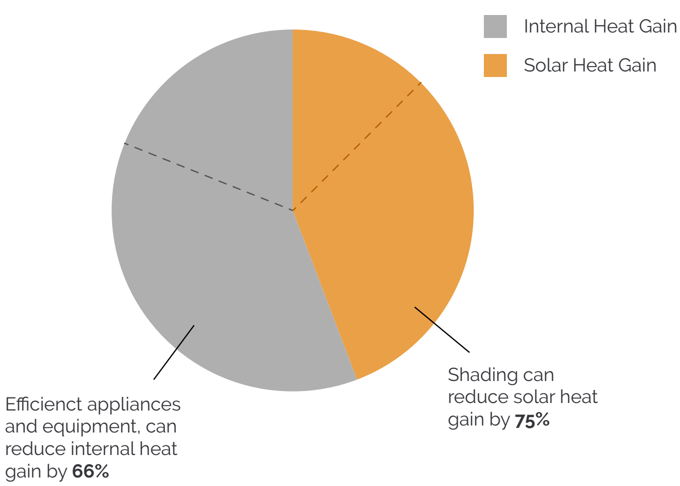
Cooling Loads

During the warm season, cooling loads or the amount of heat entering or being generated inside a house need to be removed to maintain adequate thermal comfort. Most of these loads are from solar and other heat gains from equipment and lighting inside the house.

In the current climate of the Lower Mainland, heat gains through the building envelope are negligible for most of the year since the outdoor temperatures are frequently below indoor temperatures. For much of the summer, heat is actually flowing out of the house through the envelope, helping to reduce cooling loads.

Additionally, 70% of the cooling load can be reduced with adequate cooling load mitigation strategies, like shading, and the remaining can often be dealt with using passive or near passive cooling strategies like natural ventilation.

However, when temperatures outside are higher than inside or when natural ventilation is not possible due to poor air quality (e.g. wildfire smoke events), then the remainder of the cooling load needs to be addressed with active systems such as air conditioning to maintain reliable indoor air quality and thermal comfort at any time.



Cooling load breakdown in a modelled Step 5 single-family house in Vancouver home with 16% window-to-wall area (Source: Morrison Hershfield)

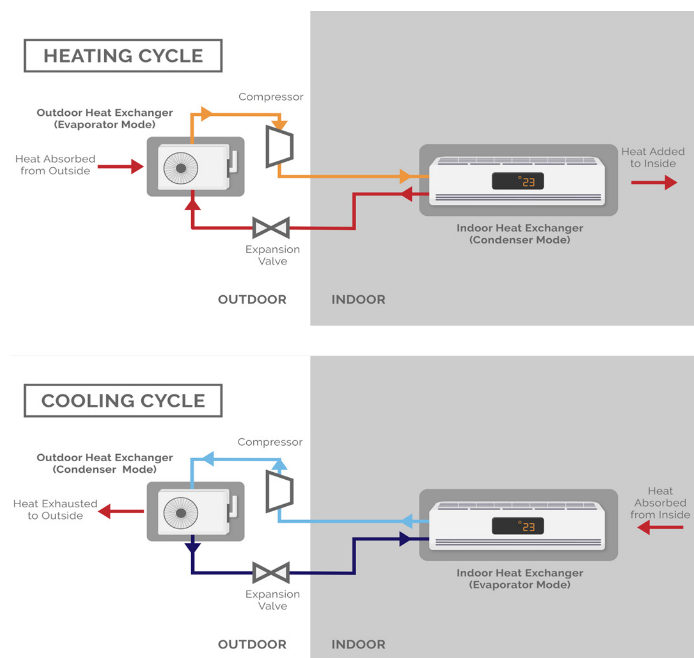
Air Conditioning

Natural events such as forest wildfires may increase due to climate change and inhibit the use of natural ventilation. Therefore, active cooling solutions will become increasingly necessary to maintain air quality and thermal comfort inside buildings.

Air conditioning systems are common in many climates, especially those with noticeable cooling demand. In the Lower Mainland region, cooling systems have mostly been provided in higher-end market housing. However, many new high-performance houses are integrating heat pumps for both heating and cooling.

A heat pump can be run in a reverse heating cycle to provide cooling during summer. The heat pump will effectively take the heat outside and eject it to the outdoor area. During the cooling cycle, the heat pump will also dehumidify the indoor air. Therefore, a single mechanical system can provide both heating, cooling, and dehumidification and thus reduce the complexity, cost, and maintenance requirements of mechanical systems

Additional information regarding the types and applications of heat pumps can be found in the ZEBx Heat Pump Technical Primer.



Heating and cooling cycles of an air source heat pump

MINIMIZING COOLING LOADS
Solar Heat Gains

Reduce cooling loads by preventing unwanted solar heat gains through building orientation, using deciduous trees in the landscape, and appropriate shading for different facades.

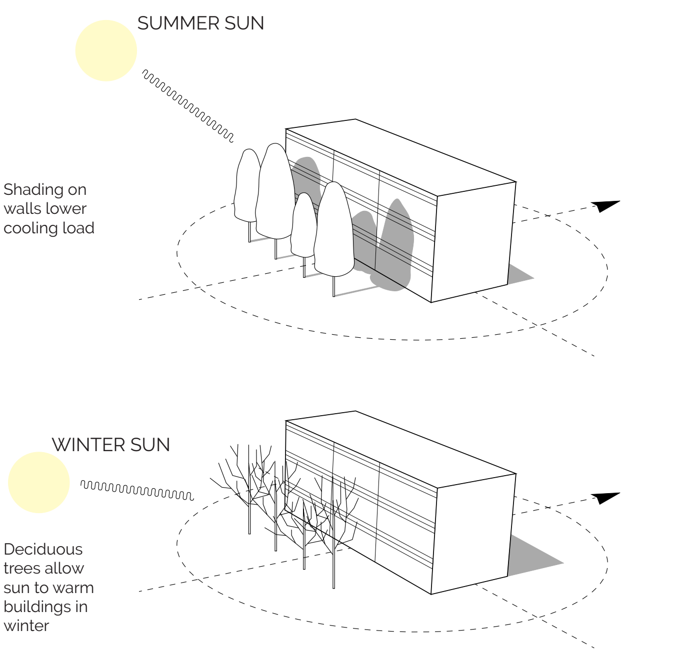
Site Conditions

The building location and orientation rely on many factors such as street orientation and zoning constraints. However, as much as possible, the building should be orientated along an east-west axis with predominantly exposed facades facing north and south. It is also important to consider using deciduous trees and other foliage vegetation in the landscape to provide summer shading while allowing solar heat gain in winter.

Glazing

Window-to-wall ratios on east and west façades should be minimized and on south façades, they should be optimized. As a general rule of thumb, high-performance houses should aim for a window-to-wall ratio between 15-25%. If the ratio gets too low, the solar heat gain during winters may not provide sufficient heating to reach the highest levels of the B.C. Energy Step Code or other low heating energy targets.

It is also critical to choose glazing with an appropriate solar energy transmittance rate, which is measured with the Solar Heat Gain Coefficient (SHGC) or G-value. Glazing with lower G-value reduces solar heat gain during summer. However, glazing with too low G-value can increase heating demand in winter.



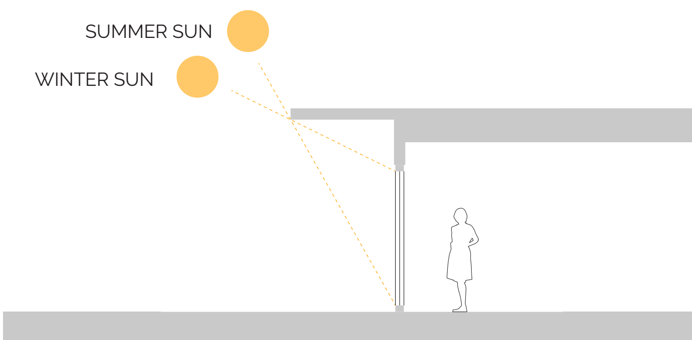
Deciduous trees provide summer shading & allow solar gains in winter.

Shading

Fixed shading on the envelope is one of the most effective strategies to block solar radiation before it passes through the glazing and enters the building. Using horizontal fixed shades on south façades can block the sunlight in summer and let it through during winter. Vertical fixed shades are more effective for east and west façades to block the low sun in the mornings and afternoons.

Operable shades are manually movable shading devices, like adjustable louvers on the exterior and blinds or curtains on the interior. These shades rely on residents to control them in response to the seasonal conditions and their needs.

Automated shades can be controlled as part of the building systems, which respond to light sensors or a set schedule. However, they may add additional complexity and maintenance and can be expensive.



Windows and shades should be properly sized to optimize solar heat gains in summer and winter (Source: Lanefab Design/Build).

Effective shading on the south facade of a Passive House townhouse in Vancouver. Visit Futrhaus Case Study for more information. (Credit: EIC Media)

MINIMIZING COOLING LOADS
Internal Heat Gains

Strategies to minimize internal heat gains from hot water piping, mechanical equipment, appliances and other electric equipment are described below.

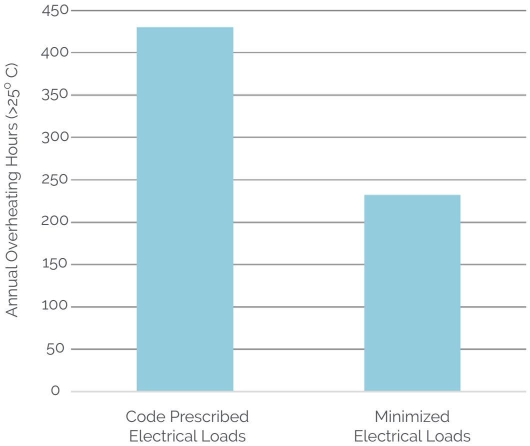
Domestic Hot Water Piping

Pipes that distributes Domestic Hot Water (DHW) have a high-temperature difference with their environment. Therefore, without sufficient insulation, the dissipation of heat from DHW piping can significantly contribute to the internal heat gain. Although it is not a requirement in the Passive House standard or B.C. Energy Step Code, it is recommended to insulate all DHW pipes, even inside the thermal envelope.

The Passive House Institute recommends an insulation thickness that is twice the nominal width of the pipe to minimize the heat loss. It is also important to have appropriate insulation around pipe fittings and hot water tanks to maximize efficiency and reduce excessive heat dissipation. Keeping pipe runs as short as possible also helps minimize heat loss and reduce insulation materials required.

Lighting

Indoor lighting energy use accounts for nearly 5-15% of the total energy use in buildings. Though conventional lighting provides heat in the winter months, most often it is counterproductive when the hotter months come along. Moreover, they consume a significant amount of energy. Using high efficient LED lighting and daylight dimming control technologies helps reduce the cooling demand and save energy.



The results of a modeling exercise of a high-performance single-family house (Step 5) in Vancouver shows that internal heat gains have a significant impact on overheating. The same house is modelled once assuming electricity use prescribed in B.C. Codes and another time using the European context values, default assumptions in the Passive House standard (which is approximately 75% less). The graph shows the reduction in electricity use reduces annual overheating hours by about 45% (Data source: Morrison Hershfield).

Effective appliances and lighting in a Passive House townhouse in Vancouver. Visit Futrhaus Case Study for more information (Credit: EIC MEdia).

Appliances & Electric Equipment

All devices that consume power will inevitably emit heat. This includes lights, mechanical equipment, appliances, and other electronic devices. These internal heat gains can be minimized by using high-efficiency devices, appliances, and lighting. Unplugging idle appliances and machines when they are not in use can mitigate standby consumption or the so-called “ghost power” draws.

Installing server or network wiring into basements or cooler spaces is another effective solution to mitigate these gains, as these devices are identified as key contributors to internal gains.

The effectiveness of the strategies for preventing excessive heat gain, especially in low-rise residential buildings, is affected by the residents’ engagement. It is useful to prepare a residents’ manual to provide information on how to best operate and utilize the design strategies, and how this will affect their thermal comfort and utility costs. This is especially important if there are mechanical shading features or other building systems that require adjustments or changes throughout the day or year.

REDUCING COOLING ENERGY

Natural Ventilation

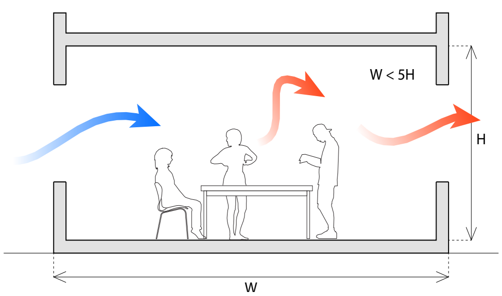
Cross ventilation and stack-effect ventilation remove the accumulation of excess heat from the building and therefore are the most effective solutions for reducing overheating or minimizing cooling energy.

Why Natural Ventilation?

In the current climate of Lower Mainland, B.C., the thermal comfort of the majority of low-rise residential buildings can be accommodated for most of the summer by natural ventilation. Therefore, it is important to size and locate the openings appropriately to create a sufficient volume of airflow to remove accumulated heat.

Natural ventilation allows residents to adjust the interior environment and manage their thermal comfort by using building openings, such as windows and doors, to remove the excess heat and moisture from the house. Purging excess heat at night is particularly effective when outdoor temperatures are lower than the indoor temperature.

Design principles for utilizing natural ventilation strategies can be found in Thermal Resilience Design Guide by Daniels School of Architecture of the University of Toronto.



For maximum efficiency of cross ventilation, the window-to-wall ratio should be optimized and the width of the room should be less than five times its height (Source: Thermal Resilience Design Guide).

Tilt & turn windows are typically a better choice for operable windows compared to tilt-only, as tilt-only windows have limited effectiveness for cross ventilation (Credit: Innotech Windows + Doors).

Roof hatch in a Passive House single-family house in Vancouver (Credit Lanefab Design/Build)

Natural Ventilation Types

Natural ventilation can occur with only one opening in the enclosure, however single-sided ventilation tends to be less efficient, as the venting flow path is constricted. In this case, the opening should be as large as possible to encourage sufficient airflow. Due to its limitations, this strategy should not be relied on as a sole cooling measure.

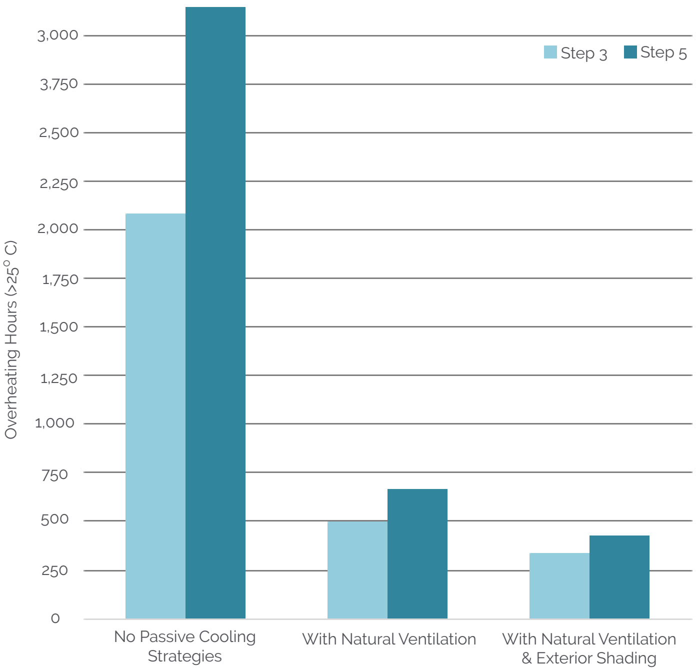
Implementing openings on multiple façades of the building optimizes flow paths and generates greater volumes of airflow. Due to increased airflow volumes, openings for cross ventilation can be smaller. The effectiveness of this type of ventilation is, however, reliant on weather (i.e. wind) and the residents' control of building openings.

The layout of rooms should be also considered to effectively maximize cross-ventilation potential, as well as daylight. Designers could consider placing the bedrooms on the north side for a cooler temperature or implementing skylights into stairwells to increase daylighting and stack-effect ventilation.

REDUCING COOLING ENERGY
Active & Semi-Active Ventilation

Incorporating heat recovery ventilators with summer bypass, circulation assistance fans, and automated operable windows can complement and increase the efficiency of natural ventilation solutions.

Automatic actuators for the high-level operable windows
Intelligent actuators can automatically control the operable windows using temperature, humidity, and CO_2 sensors. This allows implementing natural ventilation independently from the residents opening the windows (Credit: AA Robins Architect).



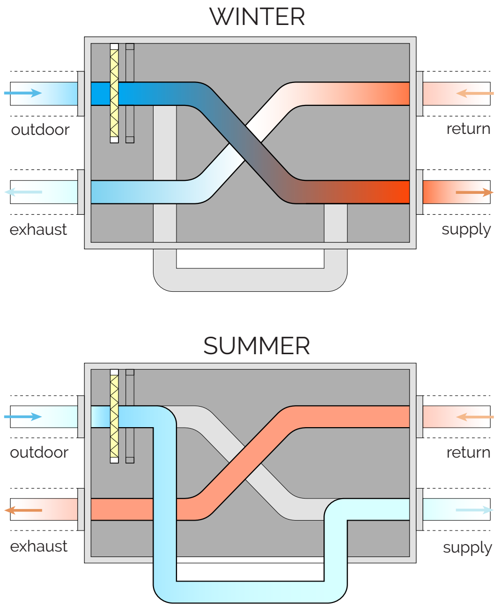
The results of a modeling exercise of a typical single-family house in Vancouver shows that natural ventilation and exterior shading have a more significant impact on cooling, than reducing the envelope performance, i.e. using a Step 3 envelope rather than Step 5.
(Data source: Morrison Hershfield)

Mechanical Ventilation

Semi-active ventilation solutions can assist natural ventilation and help reduce the size and use of cooling systems. Many high-performance houses utilize a Heat Recovery Ventilator (HRV) to capture heat before exhausting the air for ventilation to reduce heating loads. However, in summer there is no need for recovering the heat. Therefore, HRV systems commonly have a summer bypass option that allows bringing in filtered fresh air without using a heat recovery mechanism.

In milder conditions, an oversized HRV system can allow sufficient airflow for venting overnight without leaving windows open, which may be a safety or air-quality concern. However, the airflows from mechanical ventilation are typically an order of magnitude lower than natural ventilation and therefore cannot replace natural ventilation as an effective cooling strategy.

Unlike traditional AC systems, HRV systems do not require building openings to be closed to work effectively. If exterior noise and air quality permit, operable windows and HRV can be used in conjunction to enhance passive ventilation. Increasing air movement through supply or exhaust fans can also assist ventilation. This is especially necessary for spaces with a single-sided ventilation strategy.



In summer, HRV systems can be equipped with a core bypass to avoid heat exchange when outdoor air is cooler than indoor air, especially during summer nights to flush out the heat.
(Source: BC Housing Overheating Guide)

ADDITIONAL RESOURCES

Additional resources, guidelines, and manuals that complement the information provided in this technical primer.

Standards, Guidelines, and Toolkits:

Design Guide Supplemental on Overheating and Air Quality
published by BC Housing in collaboration with BC Hydro, the City of Vancouver, the City of New Westminster, and the Province of British Columbia.

Passive Design Toolkit
published by the City of Vancouver, this toolkit provides best practices for houses and larger buildings to incorporate passive design elements such as layout, orientation, insulation, landscaping, and ventilation.

CIBSE applications Manual AM10
developed by Carbon Trust and the Chartered Institution of Building Services Engineers, this document provides guidance on the design and application of natural ventilation in buildings.

Thermal Resilience Design Guide
developed by Daniels School of Architecture of the University of Toronto this guide provides solutions for enhancing the thermal resilience of buildings.

Passive House Planning Package
developed by the Passive House Institute, this package provides strategies for improving DHW insulation to mitigate overheating (section 29.5).


Credit: JSHOT - Building: Westbay Passive House

GLOSSARY

Key terms, definitions, and abbreviations used in this primer arranged alphabetically.

Air Source Heat Pump (ASHP)
A type of heat pump that works by extracting the heat from the outside air and transfer it into the building. This heat can be released directly into the air stream or through the water pipes, based on the heating distribution system.

Active and Passive Cooling
These are strategies used to keep the heat away from a building. Active cooling uses mechanical systems that use energy, such as fans or pumps. Whereas passive cooling transfers heat through the natural flow of heat without using any additional energy, like using shading or natural ventilation.

Air Conditioning System
An air conditioning is an active cooling system designed to stabilize and control the condition of the air in a given space. It controls the temperature, humidity, and purity of the air in a house by transferring the excess heat and moisture from the interior space to the outside space.

ASHRAE 55
It is an American National Standard that establishes the ranges of indoor environmental conditions to achieve acceptable thermal comfort for occupants of buildings.

CIBSE
It is the premier UK technical reference source for designers and installers of heating, ventilating and air conditioning services.

Domestic Hot Water (DHW)
The water used for everyday human needs like drinking, food preparation, sanitation, and personal hygiene. As they are mostly the water that is exposed to direct contact, it must not be hotter than 105 F.

G-value or Solar Heat Gain Coefficient (SHGC)
Solar Heat Gain Coefficient or G-value is a measure that shows how well the glazing blocks the solar heat. It is expressed in values between 0 and 1, with the lower values corresponding to a better heating restriction. High solar heat gain can be beneficial in winters as it reduces the need for heating, but causes overheating in summers.

Heat Pumps
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 and 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 this device helps reduce the heating load and save the energy required to bring the outside air to the ambient room temperature.

Passive House
An internationally recognized certification program, developed by an independent research institute based in Germany. The program is intended to result in buildings with extremely low space heating and cooling needs and consequently lower environmental impacts, as well as comfortable indoor temperature and air quality.

Passive House Planning Package (PHPP)
PHPP is an energy modeling tool specifically developed to design Passive House buildings and is based on a combination of several existing, proven and verified calculation methods that are compliant to the European standard for the thermal performance of buildings (EN 832).

Stack Effect
Stack effect is a natural phenomenon that causes hot air to rise and seek an escape out in a building due to its lower density. The rising of warm air results in reduced pressure at the base of the building, forcing cold air to infiltrate through openings and leakage in lower levels of the building.

Window-to-wall Ratio
Window-to-wall ratio is the measure of the percentage area of a building's exterior envelope that is made up of glazing, such as windows. In general, it is calculated as the ratio of the total window area to the total wall area of a building's façade.

NOTES

TECHNICAL PRIMER:
COOLING STRATEGIES FOR HOUSES IN LOWER MAINLAND, B.C.

Learn more at

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

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