# BC Energy Step Code
# Design Guide

July 2019

Version 1.1

BRITISH COLUMBIA

BC HOUSING

## About This Guide

The BC Energy Step Code Design Guide is published by BC Housing in collaboration with BC Hydro, the City of Vancouver, the City of New Westminster, and the Province of BC. This guide provides information on the key strategies and approaches to meeting the Energy Step Code in mid- and high-rise (Part 3) wood-frame and noncombustible residential buildings within British Columbia. However, it is also a good resource for larger or more complex low-rise (Part 9) wood-frame residential buildings and buildings with other occupancies. The guide is intended to provide a clear and easy-to-read resource for a range of actors in British Columbia, including local governments, architects, and developers.

While the strategies outlined in the guide are designed for buildings to comply with the Energy Step Code across the province, they are also applicable to those seeking compliance with the City of Vancouver's Zero Emissions Building Plan. Additional information on strategies of particular relevance to designers working in Vancouver is provided at key points throughout the guide, and in Supplement S1 (pg 46) and S2 (pg 47). Strategies to ensure designers address issues of overheating and indoor air quality are provided in Supplement S3 (pg 48).

## Disclaimer



## Acknowledgements

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## SECTION 01.

# Introduction to the BC Energy Step Code Design Guide



# 01 Introduction

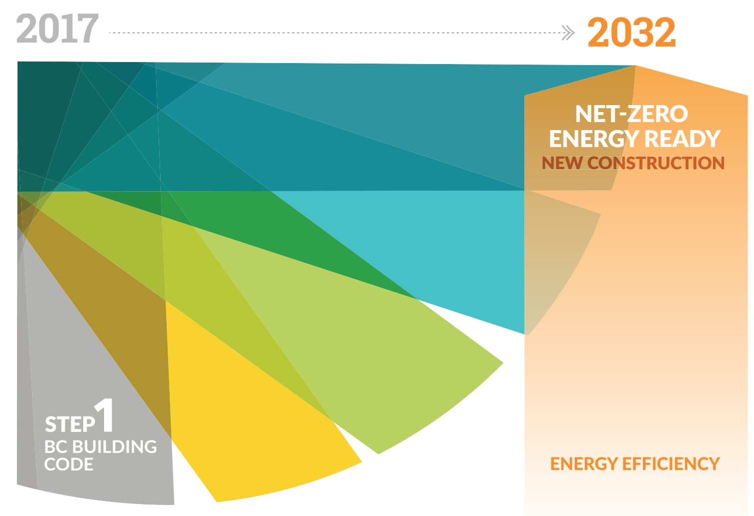
## What is the BC Energy Step Code?

In April 2017, the Province of British Columbia adopted the BC Energy Step Code as a series of amendments to the Building Act and the Local Government Act. Local governments may now use the standard, if they wish, to incentivize or require a level of energy efficiency in new construction that goes above and beyond the requirements of the BC Building Code. Builders may also adopt the standard voluntarily.

The standard consists of a series of steps, representing increasing levels of energy-efficiency performance. By adopting one or more steps of the standard, local governments and builders can increase building performance requirements in their communities.

Local governments and builders may apply the BC Energy Step Code to new residential construction across the province. They may also apply the standard to multi-unit and commercial buildings in the Lower Mainland and on southern Vancouver Island.

The Province of British Columbia has set a goal that all new buildings must reach a "net-zero energy ready" level of efficiency by 2032. The BC Energy Step Code serves as a policy pathway and technical roadmap to reach that target. Please visit **www.energystepcode.ca** to read about the standard and access presentations and additional resources.




## Additional References

The Energy Step Code Council, the Provincial Government, and third parties such as BC Housing have produced a series of publications and presentations to increase awareness and understanding of the BC Energy Step Code in local government and industry audiences. A few of these are listed below. For additional materials, visit www.energystepcode.ca

**Provincial Policy: Local Government Implementation of the BC Energy Step Code** (PDF 903KB)
Office of Housing and Construction Standards, Province of British Columbia
*April 2017*

**The Energy Step Code: A Best Practices Guide for Local Governments** (PDF 3.8MB)
Building and Safety Standards Branch, Province of British Columbia, with the Energy Step Code Council
*September 2017*

**Consumer Guide to High-Performance Homes** (PDF 540 KB)
BC Housing
*April 2016*

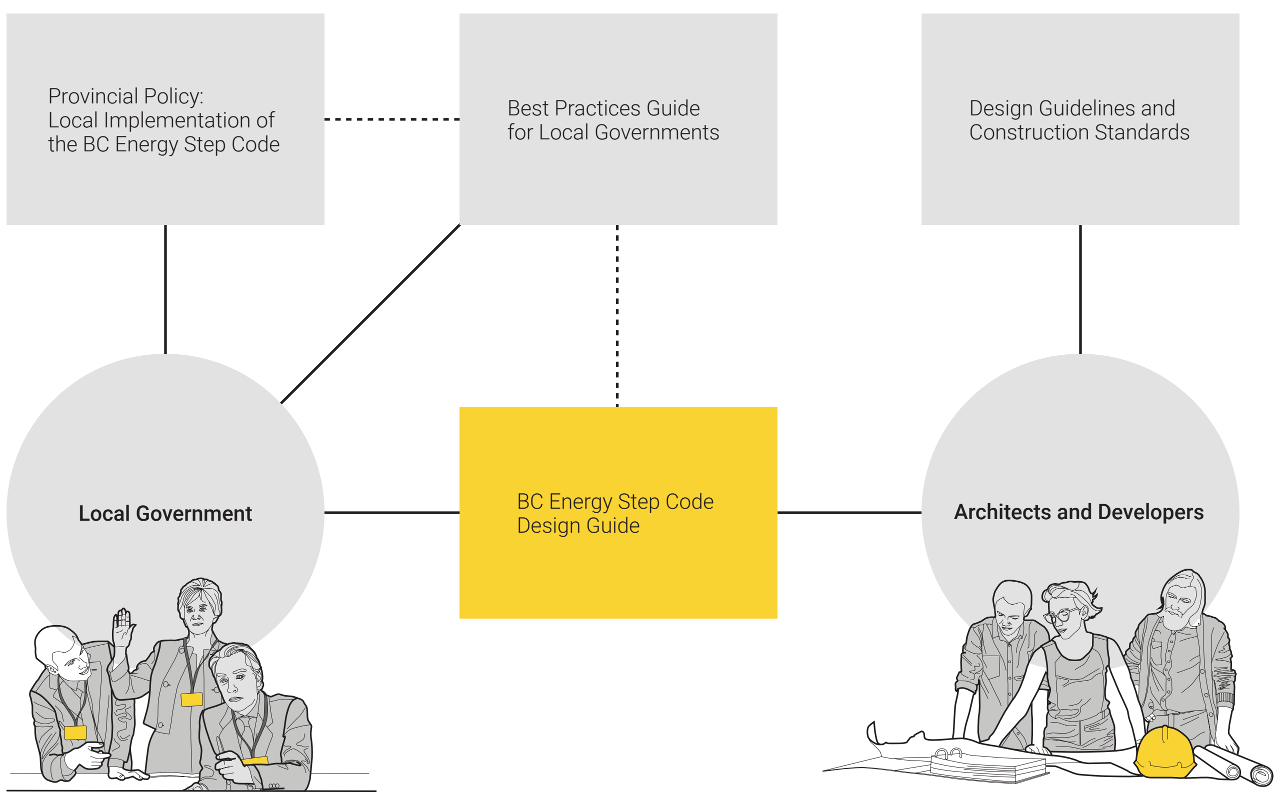
**BC Housing Design Guidelines and Construction Standards**
BC Housing 2014
*Revised July 2017 to accommodate the BC Energy Step Code*

**Guide to Low Thermal Energy Demand for Large Buildings**
BC Housing
*February 2018*

## Why do we need a design guide?

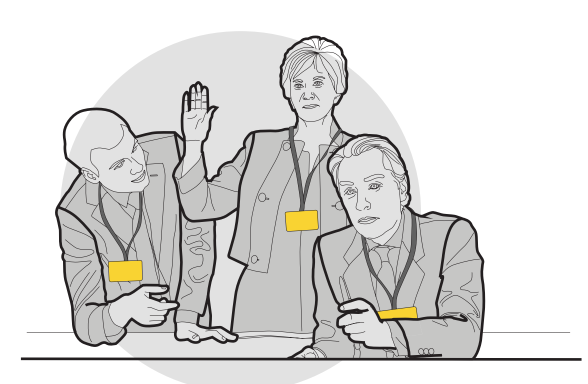
While increasing numbers of builders, developers, and architects are embracing high-performance construction practices, there is still considerable opportunity to grow awareness and capacity. The purpose of this guide is to provide an accessible resource to clearly illustrate a variety of techniques and strategies that industry can consider in meeting the BC Energy Step Code's performance requirements.

The guide will help local governments and industry understand the benefits and impacts of key design strategies necessary to achieve each step of the standard, including both mechanical and envelope strategies. It also offers a graphic explanation of more detailed implementation tactics related to heating, ventilation, and air-conditioning (HVAC) solutions and strategies.




## Who is the guide for?

This guide is a resource for local governments, architects, and developers interested in pursuing the BC Energy Step Code.



### LOCAL GOVERNMENT

British Columbia local governments, subject to the BC Building Code and covered by the Community Charter, may reference the BC Energy Step Code in their policies and bylaws.[1] Effective December 2017, Section 5 of the Building Act rendered all bylaws that referenced energy-performance programs other than the BC Energy Step Code to be unenforceable.

By adopting one or more steps of the standard, local governments will be able to improve the energy performance of the built environment in their communities, while contributing to occupant comfort, lowering utility bills, and reducing greenhouse gas (GHG) emissions. Local governments can choose to adopt any one or more steps of the standard, but should consider existing policies and market conditions in their communities when doing do.

Until 2020, the province is discouraging local governments from requiring Upper Steps on a community-wide basis, but Upper Steps may be used in connection with an incentive program. Higher steps of the BC Energy Step Code are expected to be adopted more widely as industry capacity increases and services and products for the design and construction of high-performance buildings become more readily available.

### ARCHITECTS AND DEVELOPERS

Industry may voluntarily adopt the BC Energy Step Code as an alternate compliance path to meeting the minimum performance requirements of the BC Building Code.

Many developers already voluntarily adopt advanced performance standards to meet the growing demand for high-performance buildings. The consistent approach of the BC Energy Step Code allows industry to gradually build capacity and skills in a coordinated and predictable manner. This will help developers control costs and minimize disruption.

[1] At the time of this guide's production, the City of Vancouver had announced that, subject to Council approval, it would allow builders to reference the BC Energy Step Code as an alternate performance pathway to demonstrate compliance with its Zero Emissions Building Plan. For more information on Vancouver's Zero Emissions Building Plan, please see **Supplement S**.

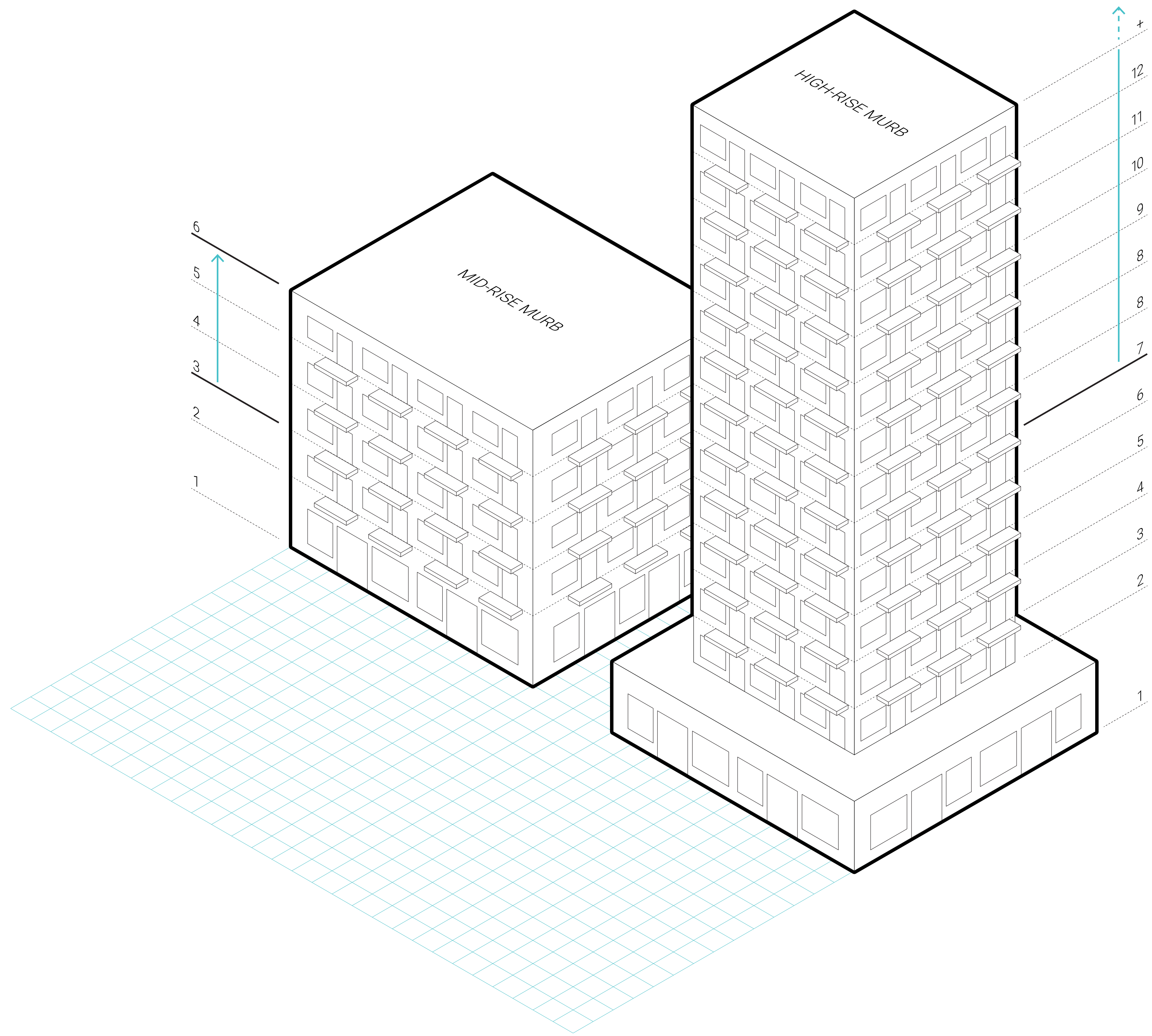
## What does the guide cover?

While the BC Energy Step Code applies to a number of Part 3 and Part 9 building types, this guide outlines key principles and strategies for meeting the Upper Steps of the BC Energy Step Code for two of B.C.'s primary Part 3 building types: High-Rise and Mid-Rise Multi-Unit Residential Buildings, or MURBs.

The principles, strategies, and technologies depicted in this guide are most relevant for construction in Climate Zones 4 and 5 (B.C.'s Lower Mainland, Vancouver Island, the southern Thompson-Okanagan/Kootenay region, and the southern coast), though several will also apply in higher Climate Zones. The guide is structured to take the reader from high-level strategies through a progression to greater levels of detail.

Several strategies included in the guide may be used or modified to meet the requirements of the City of Vancouver's Zero Emissions Building Plan. Callout boxes are used to indicate where the design strategies can be adapted to achieve the greenhouse gas emission reduction requirements in that plan. For more information on Vancouver's Zero Emissions Building Plan, please see Supplements S1 and S2.

In addition, Supplement S3 provides information on the strategies and approaches necessary to reduce the impacts of a warmer climate on mid- and high-rise residential buildings within British Columbia. Specifically, it provides building industry actors with an accessible source of information on the key means of addressing issues of overheating and indoor air quality.



## SECTION 02.

# How to Use this Guide

# 02 How to Use this Guide

This guide outlines key design concepts that will meet the requirements of the BC Energy Step Code as it applies to High-Rise and Mid-Rise MURBs. It is intended as a quick reference for developers, architects, and local governments.

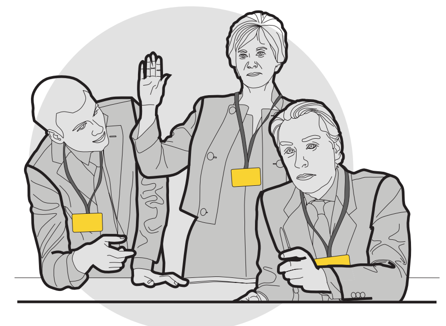
**GO TO SECTION 03 FOR:**
Overarching design principles necessary to meet BC Energy Step Code targets, and a diagram showing the importance of each design strategy in relation to the three key metrics of the BC Energy Step Code.

**GO TO SECTION 04 FOR:**
Detailed design strategies for High-Rise and Mid-Rise MURBs.

**GO TO SECTION 05 FOR:**
An overview of the benefits of energy efficient design.

**GO TO APPENDIX A FOR:**
A glossary of terms, and image sources.

**GO TO SUPPLEMENT S1-S3 FOR:**
Strategies to reduce greenhouse gas emissions, to comply with the City of Vancouver's Zero Emissions Building Plan, and to address issues of overheating and indoor air quality.



## A Resource for Local Governments

Local governments should use this guide in two general ways: to inform policy design and development, and to review specific development applications to ensure proponents are complying with performance requirements.

**Inform Policy Design**

**Elected officials, policy-makers, community planners, and energy planners** may wish to use this document to help establish guidelines for highly energy efficient urban form and development policies in official community plans and other documents. Local governments may wish to quickly adopt Lower Steps, while planning to adopt higher steps in the future. Consulting this and other BC Energy Step Code resources early will help inform policy development.

**Community and energy planners** should consult the guide when creating local area plans to determine how planned and proposed buildings will be impacted by the application of the BC Energy Step Code.

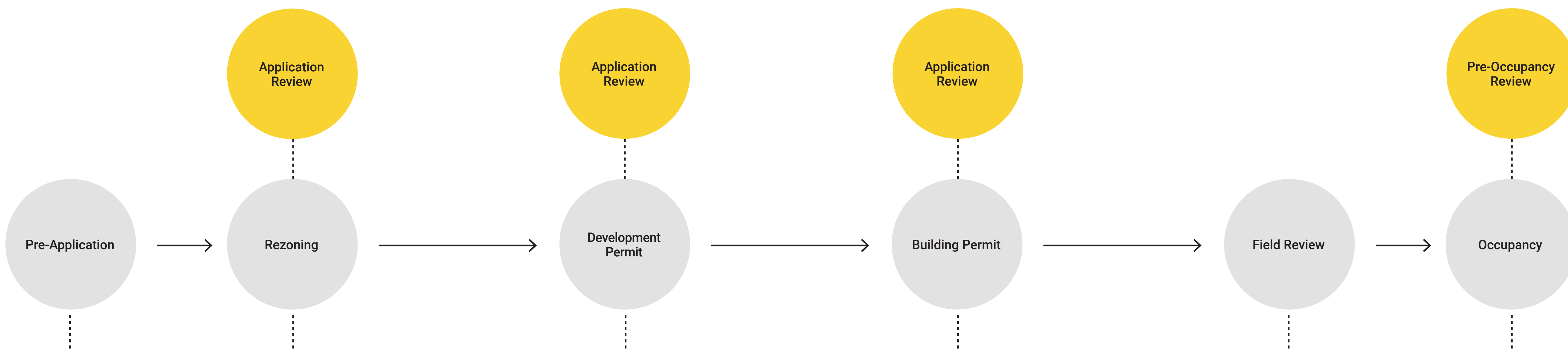
**Review Specific Development Applications**

**Area and energy planners** should consult this guide when reviewing rezoning and development applications, to ensure proponents have applied the principles and strategies necessary to meet BC Energy Step Code performance targets.

## A Resource for Architects and Developers

This Guide is designed to help architects and developers understand and use the key considerations and design strategies necessary to meet the BC Energy Step Code's performance targets. It offers clarity on the most cost-effective and straightforward strategies to reduce building energy demands and improve airtightness. As such, mechanical and envelope engineers may also find it helpful in their work.

While the guide provides some of the lowest cost strategies to meet the BC Energy Step Code, it is important to note that there are many ways of meeting the standard's performance targets. Practitioners can explore different design strategies, or **energy conservation measures**, for their ability to meet the TEDI, TEUI, and airtightness targets. These options should be considered early in the design process to ensure the final building complies with requirements.




**Developers** should review this guide while acquiring land and calculating a project's proforma analysis. It is important to begin to explore different possibilities regarding the overall massing, orientation, and unit density of a prospective project at this stage, as all have implications for energy performance.

Prior to submitting a rezoning application, **developers, architects, and engineers** should use this guide to consider the key design strategies that will reach a given performance step. While designs are rarely final at the rezoning stage, massing, orientation, and fenestration should be identified as early as possible, along with broad mechanical, ventilation, and envelope strategies. Local government staff and design panels may review applications to ensure the proponent has considered BC Energy Step Code requirements.

At the development permit stage, **designers** will be required to use energy modelling to confirm that the proposed development meets the relevant community's BC Energy Step Code performance targets, and that any concerns identified at the rezoning stage have been addressed.

Final project design documentation is required for the application of a building permit. By this stage, all design strategies will be final, and the required whole-building energy model will demonstrate that the proponent's chosen approaches will meet the performance targets.

Building officials will require **architects and engineers** to review the project while it is under construction, to ensure it substantially conforms with the requirements of the BC Energy Step Code.

Prior to issuing an occupancy permit, local government officials may check that letters of assurance have been completed, and that the coordinating registered professional has signed off on all design strategies needed to achieve the targeted step of the BC Energy Step Code. Developers must also ensure that a post-construction airtightness test is conducted, and that the results of the airtightness test are included in determining the final energy performance of the building.

## SECTION 03.

# Designing for the BC Energy Step Code



# 03.1 Primary Objective

Communities and developers can reduce the impact of new buildings on the built environment by embracing energy-reducing design techniques. Buildings currently account for approximately 22% of the energy consumed in the Province of British Columbia, and 12% of the greenhouse gas emissions released into the atmosphere. The BC Energy Step Code has been designed to create a stepped approach to reducing building energy consumption, while controlling costs and improving occupant comfort — particularly at the Upper Steps.

While there are countless possible combinations of energy conservation measures that can be used to reduce building energy consumption, the strategies and principles outlined below will yield significant results.

## BC ENERGY STEP CODE

### Primary Objective

Reducing the impact of the built environment through the use of thoughtful design techniques that minimize building energy consumption.

### Performance Metrics

The BC Energy Step Code requires buildings to achieve specific levels of performance in three key metrics:

- **Thermal Energy Demand Intensity (TEDI)**
- **Total Energy Use Intensity (TEUI)**
- **Airtightness**

### Key Strategies

Design strategies for achieving Step Code required performance targets in each of the three metrics.

| | |
|---|---|
| **Minimizing Heat Losses Through Simplified Massing** | **Reducing Thermal Bridging** |
| **Minimizing Heat Losses Through Orientation** | **Increasing Airtightness** |
| **Considering Unit Density** | **Using Compartmentalization** |
| **Optimizing Fenestration** | **Using Heat Recovery in Ventilation** |
| **Increasing Building R-Values** | **Separate Heating and Cooling from Ventilation** |

## VANCOUVER'S ZERO EMISSIONS BUILDING PLAN (ZEBP)

In addition to limits on heat loss and energy use, the City of Vancouver sets limits on greenhouse gases (GHG) to further target reductions in emissions.

### Primary Objective

Minimizing GHG emissions

### Performance Metric

- **Greenhouse Gas Intensity (GHGI)**

### Key Strategy

- **Select Low-Carbon Mechanical Systems (See Supplement S, pg 45.)**

# 03.2 Performance Metrics

The BC Energy Step Code specifies levels of performance in Thermal Energy Demand Intensity (TEDI), Total Energy Use Intensity (TEUI), and airtightness. (See the Glossary of Terms for an explanation of each.) The key principles for achieving good performance in each of the three metrics are outlined below.

## BC ENERGY STEP CODE

### TEDI

***Thermal Energy Demand Intensity*** is a measure of the total heating energy necessary to maintain a comfortable indoor temperature over the course of a year, measured and expressed in $kWh/m^2/year$. The metric considers both passive gains (e.g. incoming solar radiation, heat generated by indoor appliances) and losses (e.g. heat losses through the building envelope), as well as any energy needed to mechanically heat a building or warm incoming ventilation air.

To achieve a TEDI target, professionals must maximize gains and minimize losses as much as possible, and reduce reliance on mechanical systems.

**Strategies for achieving TEDI targets:**

- *Minimize heat loss*
- *Consider occupant and unit density*
- *Optimize fenestration*
- *Increase building R-values*
- *Reduce thermal bridging*
- *Increase airtightness*
- *Recover heat during ventilation*

### TEUI

***Total Energy Use Intensity*** is a measure of the total amount of energy a building uses over the course of a year, per unit of building area. The metric considers all energy used in a building, including plug loads (e.g. lighting, appliances) and process loads (e.g. elevators, mechanical systems, fans). Like TEDI, TEUI is measured and expressed in $kWh/m^2/year$.

**Strategies for achieving TEUI targets:**

- *Consider occupant and unit density*
- *Optimize fenestration*
- *Increase airtightness*
- *Recover heat during ventilation*
- *Separate heating and cooling from ventilation*

### Airtightness

In Part 3 buildings, professionals measure ***airtightness*** using the Normalized Air Leakage Rate, which tracks the rate at which air leaks through the envelope. The air leakage rate is measured per unit of envelope area and expressed as $L/s{\cdot}m^2$ at 75 Pascals pressure differential.

**Strategies for increasing airtightness include:**

- *Designing buildings with a more compact massing to reduce the number of corners*
- *Limiting building-envelope penetrations*
- *Paying careful attention to detailing at interfaces*
- *Ensuring strict adherence to construction practices*

## VANCOUVER'S ZEBP

### GHGI

The City of Vancouver has authority over its own building code, and has instituted its own step code-like provisions described in the Zero Emissions Building Plan. In addition to setting targets for TEUI and TEDI, the plan also sets thresholds for performance in ***greenhouse gas intensity (GHGI)***.

GHGI is a measure of the emissions intensity of a building's emissions, measured and expressed in tonnes or kilograms of carbon dioxide equivalent per unit area over the course of a year (kg $CO^2/m^2$/year).

For more information, go to Supplement S, pg 45.

# 03.3 Achieving the BC Energy Step Code

The strategies presented in this guide represent the lowest cost strategies to achieve Steps 2, 3, and 4 of the BC Energy Step Code in Climate Zone 4, as determined by the 2017 BC Step Code Metrics Study. However, this is only one set of strategies that can be used to achieve the performance targets in the BC Energy Step Code. There are many different possible combinations of measures that can be taken to achieve the same level of performance, depending on the nature and goals of the project. Designers should use energy models to explore the different trade-offs between strategies and identify the appropriate set of architectural, envelope, and mechanical strategies for their project.

This chart presents a summary of the kinds of measures required to meet each step of the BC Energy Step Code.

Higher Performance

## Step 1

Step 1 is often referred to as "enhanced compliance", because it simply requires builders to demonstrate that they have achieved the energy-efficiency requirements of the existing BC Building Code. In a Step 1 project, builders must supply officials with an energy model to demonstrate that their design will meet the code requirements. Upon substantial completion, a builder must also submit the results of an airtightness test. He or she would ideally do so before installing drywall or other interior surfaces, to allow opportunities to address leaks.

## Step 2

Builders can achieve Step 2 using conventional practices and widely available materials. However, they will need to improve the building's overall airtightness and use additional measures. For example, they should:

- Design for a lower overall window-to-wall ratio (e.g. 40% WWR)
- Require higher building R-values (e.g. minimum effective R-10 for walls and effective R-20 for roofs)
- Improve window performance (e.g. double- and triple-glazed windows with higher U-values)
- Improve heat-recovery efficiency (e.g. 60%)

## Step 3

To comply with the requirements of Step 3, designers will use many of the Step 2 strategies noted here. However, they will also begin to take a more integrated approach. To reach Step 3, they might also:

- Consider sealing off individual building units and uses from one another to improve airtightness, a practice known as compartmentalization
- Reduce thermal bridging

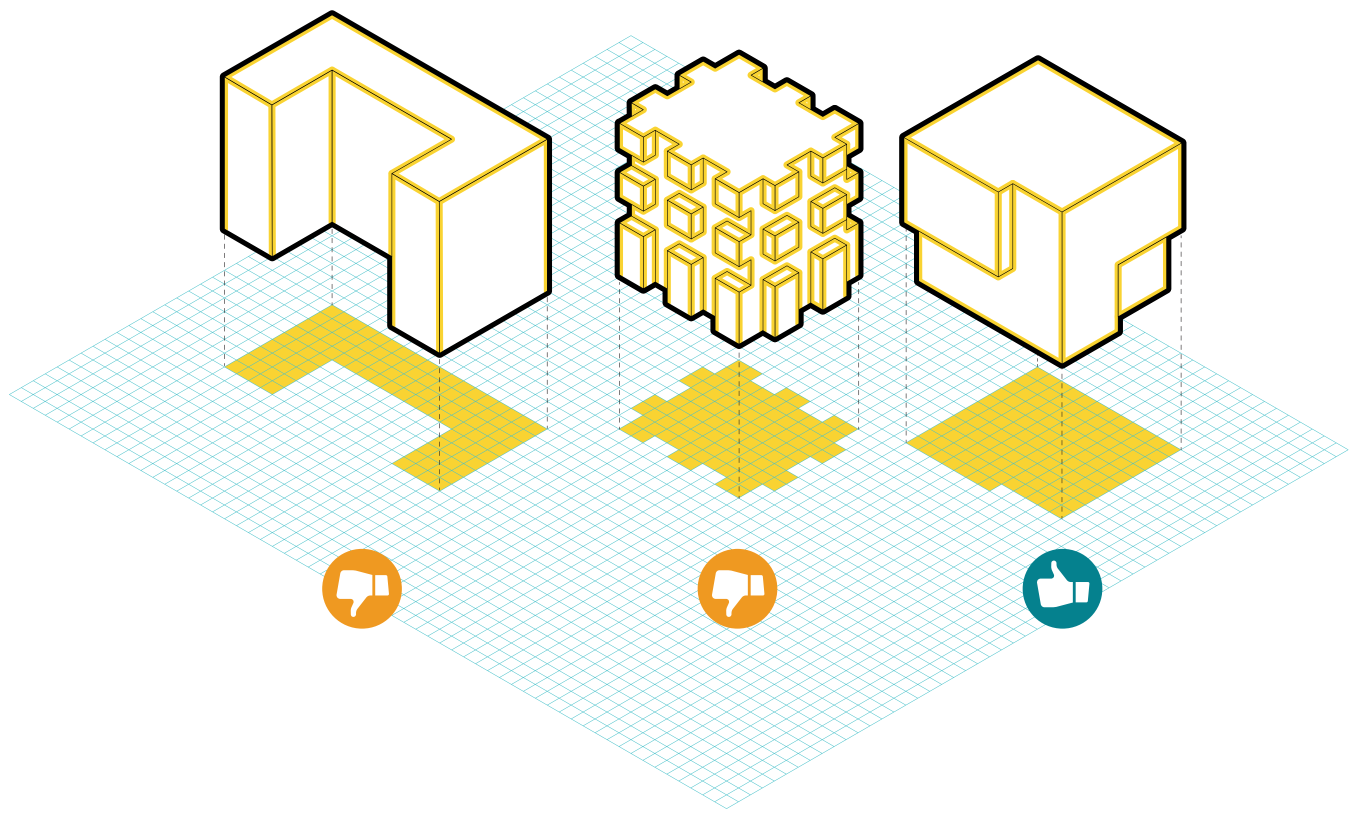
## Step 4

Designers wishing to achieve Step 4's more rigorous energy efficiency and airtightness requirements will need to reconsider multiple practices and systems. Although they can achieve this level of performance using wall systems applicable to the Lower Steps, they will want to consider the building envelope first. Designers should look to the strategies we suggest for Step 3 and also:

- Specify very high levels of heat recovery efficiency (e.g. at least 80%)
- Source triple-glazed windows with high performance frames and reduce frame elements
- Eliminate all significant thermal bridges

# 03.41 Minimize Heat Loss through Simplified Massing and Orientation

Two key factors that should be considered early in the design process are the proposed building's massing and its orientation. Massing refers to a building's overall shape, form, and size. Orientation refers to the alignment of a building's principal axis. (See page 16 for Orientation).



### Simpler Form

A building's massing can influence the achievement of TEDI performance targets: the more complex a building shape, the greater the number of opportunities for heat loss through the envelope. A building with several complex junctions and corners will lose far more heat through the envelope than a building that has been designed as a simple, solid form, such as a cube or rectangle. Compact buildings also reduce the total number of exterior walls — where heat is lost — as well as the number of ledges and other horizontal surfaces where accumulations of moisture can degrade the building envelope.

### Lower VFAR

Massing can also be thought of in terms of a building's vertical surface area to floor area ratio (VFAR). A lower VFAR decreases overall heat loss potential, because vertical surfaces (walls) tend to have lower R-values than horizontal ones (floors and roofs). Higher VFAR values are often a function of the building's floor plate size, as well as the level of articulation, or the complexity its overall form.

### Larger Floor Plate

In general, smaller and narrower floor plates make TEDI performance targets harder to achieve. Increasing a building's floor plate size and simplifying its external shape and form both help improve a building project's ability to meet the BC Energy Step Code targets.

**CASE STUDIES**

A High-Performance Building Need Not Be Boring

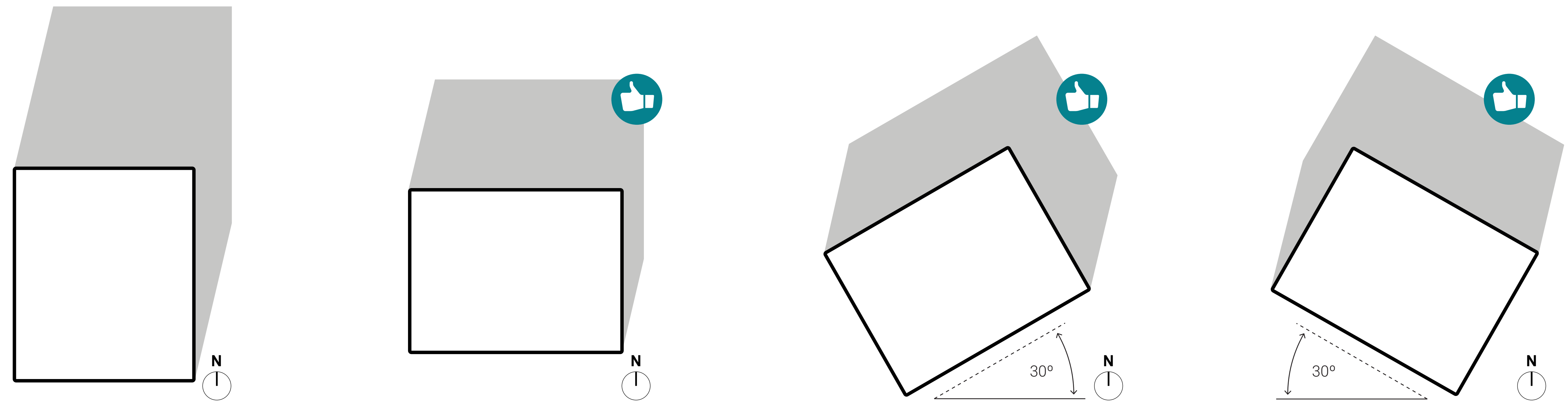
A building doesn't need a lot of bells and whistles to be attractive. Design professionals can use a wide variety of strategies — such as exterior colours or textures — to create visually interesting buildings that maintain a compact building form.

**Top** *The Spot, Vancouver, B.C.*
**Bottom** *Kiln Apartments, Portland, OR*

**KEY TAKEAWAY**

Reduce the complexity of the building facade, and increase the floor plate as much as possible to reduce the potential for heat loss through the envelope.

Most important metric(s) to consider TEDI Airtightness




Professionals who orient their buildings to maximize solar-gain potential from the south can reduce heating demands by as much as 30 to 40%. While this strategy does not minimize heat losses per se, it does take advantage of passive heat gains that can provide a benefit when reaching for a TEDI target.

### Take Advantage of Natural Light

Thoughtful building orientation can also help designers reach TEUI targets, by taking advantage of natural light to reduce lighting loads.

### Maximize Solar Gains

To maximize the potential for solar gains, designers should orient a proposed building's longest facade as close to due south as possible. Ideally, the south-facing facade should be within 30 degrees of due south. While many sites are constrained by existing adjacent buildings and street grids, opportunities may exist to orient upper floors to the south.

### Avoid Overheating

At the same time, designers taking advantage of solar gain must be careful to avoid overheating in the summer months, by specifying the use of thermally-broken external shading (see Exterior Shading callout).

**KEY TAKEAWAY**

Orient the longest facade of the building towards south as much as possible. Shade south-facing facades to mitigate the risk of overheating.

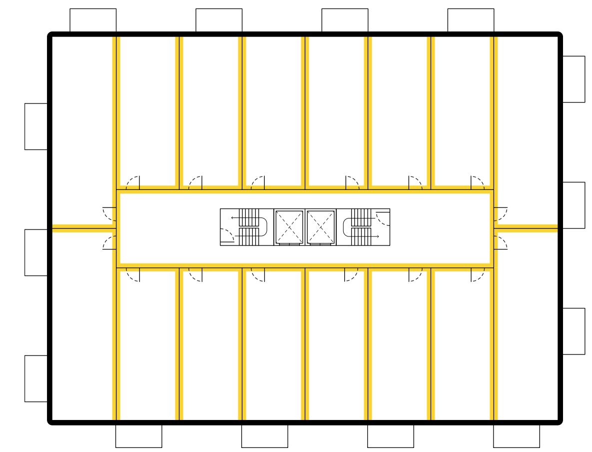
Most important metric(s) to consider TEDI TEUI

# 03.42 Consider Unit Density

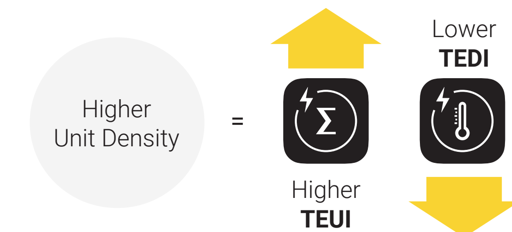
Occupant and unit density significantly influence a proposed building's TEDI and TEUI performance.

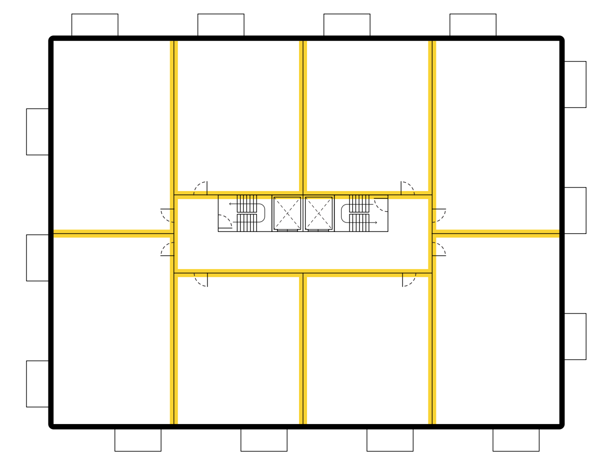
Higher occupant density can make it easier to achieve a TEDI target, while pushing a TEUI objective farther out of reach. This is because a building's occupants drive plug loads, as more people switch on more appliances, and turn on hot-water faucets. As such, the higher a building's occupancy, the more difficult it may be to achieve a specified TEUI. While this trend can be inhibited by poor ventilation, designers should nevertheless look for opportunities to reduce hot-water demand when planning high-occupancy buildings.

On the flip side, the higher a given building's occupancy, the greater the potential for passive internal heat gains. Those appliances and all that hot water — and even the warmth generated by human bodies — all help passively heat buildings. As such, in cooler months, higher occupancy can also reduce a building's heating requirements. Designers should therefore carefully consider expected occupant and unit densities when calculating TEDI and TEUI.

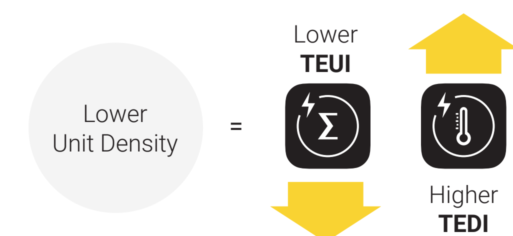


**Higher density buildings** will achieve TEDI targets more easily as a result of higher rates of passive heating, but can experience challenges in achieving TEUI targets.



**Lower density buildings** experience the opposite, and have greater ease in achieving TEUI due to a lower overall demand for energy.




**KEY TAKEAWAY**

Consider trade-offs between TEDI and TEUI carefully in building energy modelling.

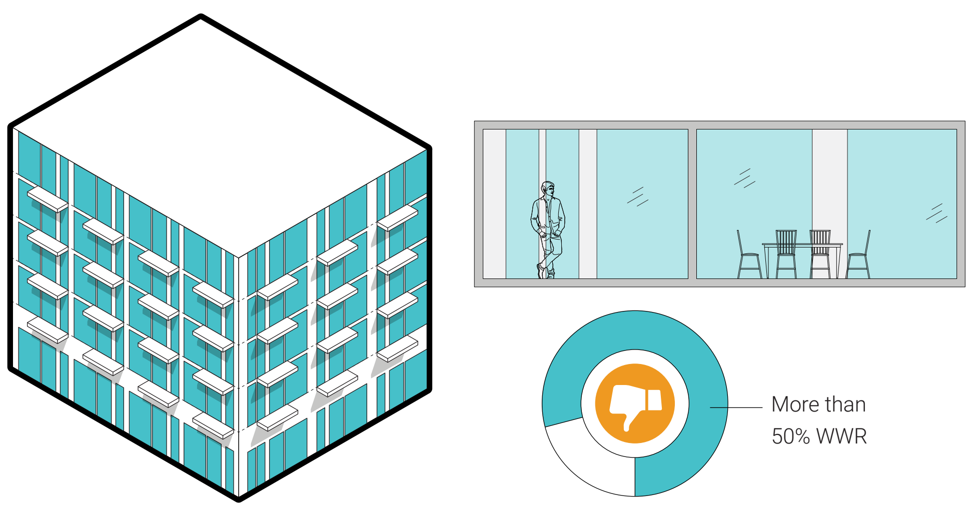
Most important metric(s) to consider TEDI TEUI

# 03.43 Optimize Fenestration

Fenestration refers to the number, size, and placement of windows on a building's facades. Size and placement are key factors when considering passive heat gains and daylighting.

## Window-to-Wall Ratio (WWR)

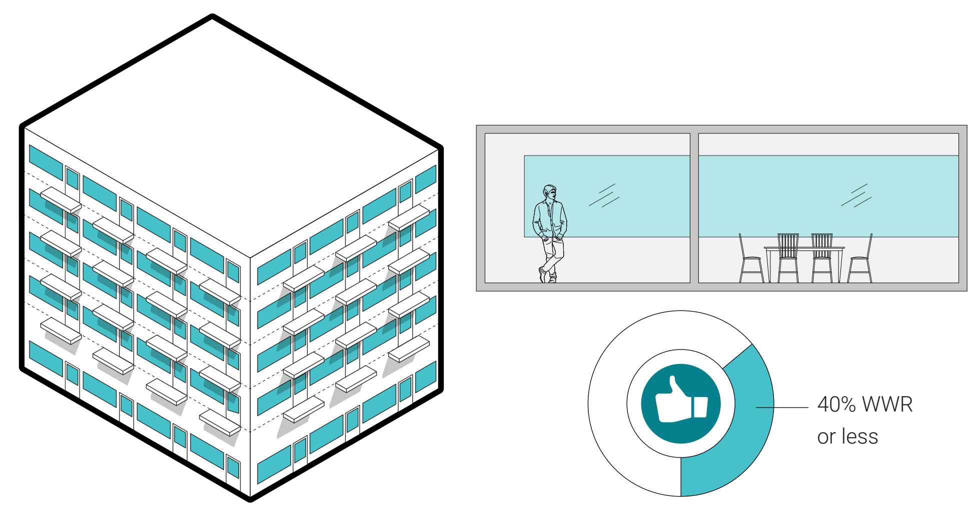
When compared with opaque walls, windows offer low thermal resistance. As such, a lower window-to-wall ratio (WWR) reduces heat gain and loss through the envelope by increasing the area of insulated wall. As a rule of thumb, designers working to comply with the Lower Steps of the BC Energy Step Code should target no more than a 50% WWR. Buildings intended to meet Upper Steps should target a WWR of less than 40%.




While many building designs emphasize much larger WWR (e.g. floor-to-ceiling windows), larger windows can provide harsh light at certain times of the day.

## Orientation and Site Specific Considerations

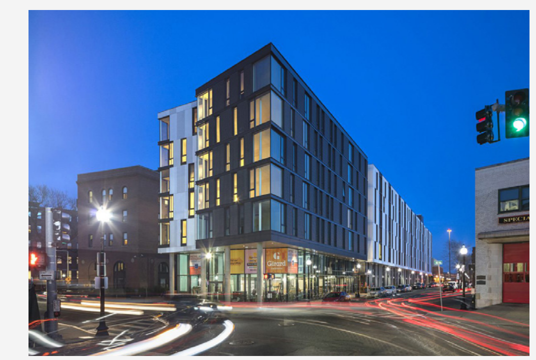
Designers should also consider the direction the building's windows will face, as well as site-specific considerations, such as shading from nearby buildings. Buildings with a high WWR on the southern elevation will maximize their solar gains in the cooler winter months when the sun is lower in the sky. As north-facing windows have the lowest potential for solar gains, WWR on north facades should be more modest if possible. Abundant glazing on south and west facades will support solar heat gains during the winter months.




Reducing the size of windows can actually help to improve occupants' comfort by reducing glare and providing a more comfortable indoor temperature, without requiring any additional indoor lighting or losing the potential for views.

Designers should specify lower window sills to sit 24 inches or more above the floor helps to reduce unnecessary solar radiation at foot-level, while still allowing light and views while occupants are sitting or standing.

**Top** *Cornerstone Apartments, Vancouver, B.C.*
**Middle** *Girard, 600 Harrison Ave, Boston, MA*
**Bottom** *Marquis Lofts, Portland, ME*



**KEY TAKEAWAY**

Target a 40% window-to-wall ratio (WWR)

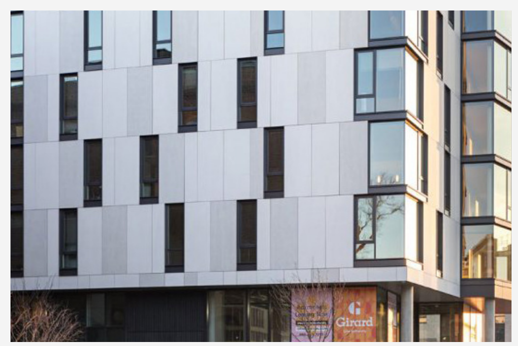
Most important metric(s) to consider TEDI

**CASE STUDIES**

## How to Cut the Rays When They Aren't Wanted

Exterior shading devices can be used to block unwanted solar gains and keep indoor temperatures comfortable in the summer months. These will become even more important as B.C.'s climate warms, and the number of days of extremely high temperatures we experience over the course of a summer rises. Designers can use solar shading devices such as louvres, overhangs, eaves, and balconies to improve occupant comfort, as well as programmable motorized shades placed on the exterior of a building. On lower floors, deciduous trees can provide shade in summer months.

In some cases, designers may also use horizontal shading devices as "light shelves" to direct light deeper into building interiors, reducing the need for artificial illumination.



**NORTH FACING**

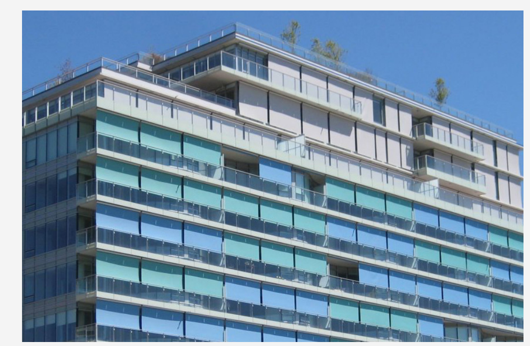
Shading devices aren't necessary on north-facing facades, but designers can reduce the WWR to reduce heat losses through the envelope.

**Reference** *Girard, 600 Harrison Ave, Boston, MA*

**EAST/WEST FACING**

Designers can use vertical fins to block incoming summer sun on western elevations.

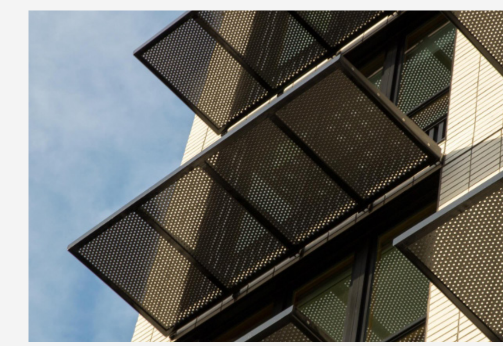
**Reference** *The Spot, Vancouver, B.C.*



**WEST FACING**

Programmable motorized shades can be placed on the outside of a building to shade interiors when necessary. Shades automatically extend or retract according to the amount of incoming solar radiation.

**Reference** *181 W 1st Ave, Vancouver, B.C.*



**SOUTH FACING**

Designers should place shading devices along a building's southern elevation to block incoming solar radiation in the summer, while welcoming solar gains from lower winter sunlight.

**Reference** *Muse Apartments, Portland, OR*

**KEY TAKEAWAY**

Use external shading devices to minimize unwanted solar gains.

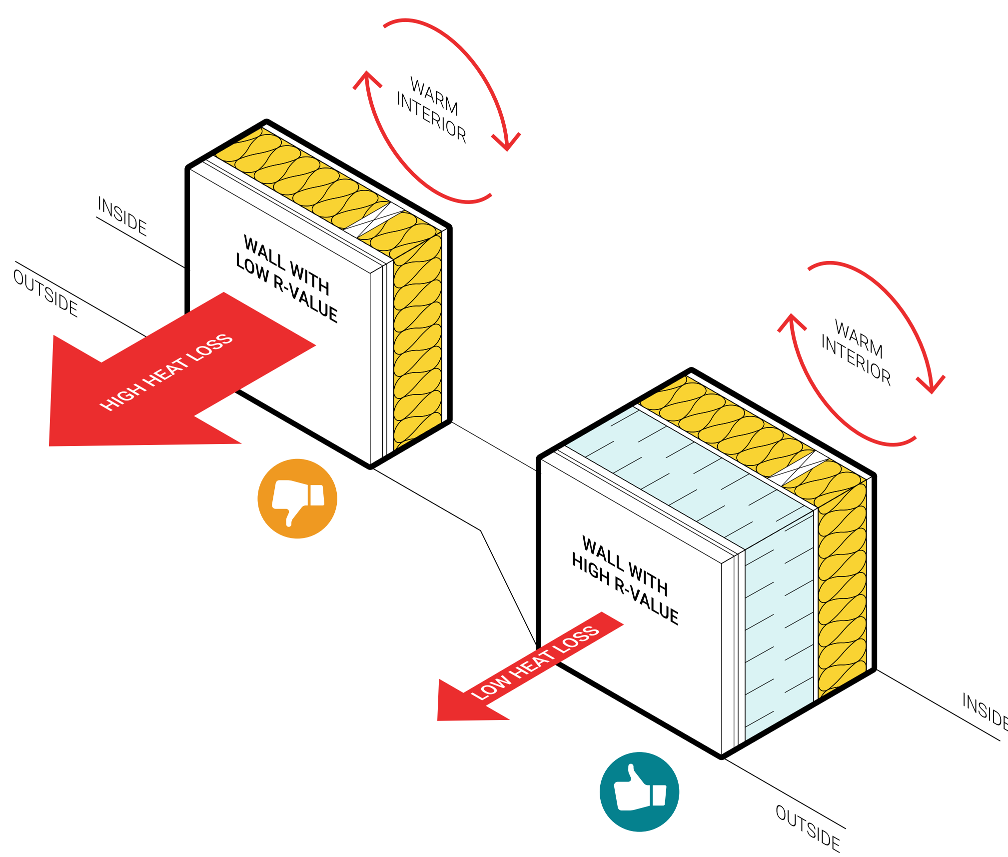
# 03.44 Increase Building R-Values

R-values indicate an envelope's thermal resistance, or its ability to prevent heat from moving from one side to the other. The higher the R-value, the better the envelope is in terms of its insulating effectiveness. By selecting building-envelope components with higher R-values, designers can improve a building's thermal performance and help reach TEDI targets. Higher R-values also help to improve occupant comfort by keeping building interiors warmer in the winter, and cooler in the summer.

R-values depend on many variables, including a given wall system's insulation type, thickness, and overall density. However, there are two different ways to measure and present a given material's R-value. Nominal R-values indicate the insulating effectiveness of the material itself, while effective R-values convey its performance in conjunction with framing members and/or other materials. Designers should carefully select envelope systems for their effective R-values, and to minimize or even eliminate thermal bridges.

As window areas (glazing) offer lower thermal resistance than opaque wall assemblies, designs that feature a lower WWR and high-performance windows will also improve overall envelope performance. Professionals typically evaluate window performance in terms of U-value — a measure of how well a given window allows heat to pass through. U-values are the inverse of R-values. As such, the lower the U-value, the better a window's performance.

In general, wall systems that are scalable with respect to their insulation allow greater flexibility in balancing glazing and wall performance throughout the design process. These primarily include wall systems that can easily accommodate more insulation without substantially changing their cost or form. When selecting a window system, designers should consider the composition and arrangement of framing elements. Low-conductivity frames and fewer framing elements can help to reduce the potential heat loss through the windows.




**CASE STUDIES**

Is everyone comfortable?

Higher performance wall and window systems improve a building's energy efficiency, but they can also greatly improve the comfort of its occupants by maintaining a more consistent and comfortable indoor temperature.

**Image** *Kiln Apartments suite, Portland, OR*

**KEY TAKEAWAY**

Select envelope systems with high effective R-values. Select windows with low U-values.

Most important metric(s) to consider TEDI

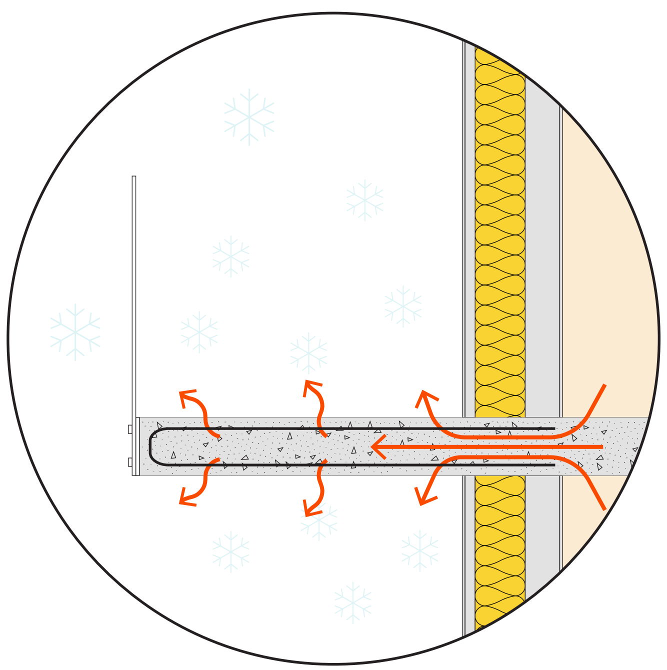
# 03.45 Reduce Thermal Bridging

A thermal bridge refers to an area in a building's envelope that interrupts the building's continuous insulation layer, causing heat to escape the interior of the building to the outside.

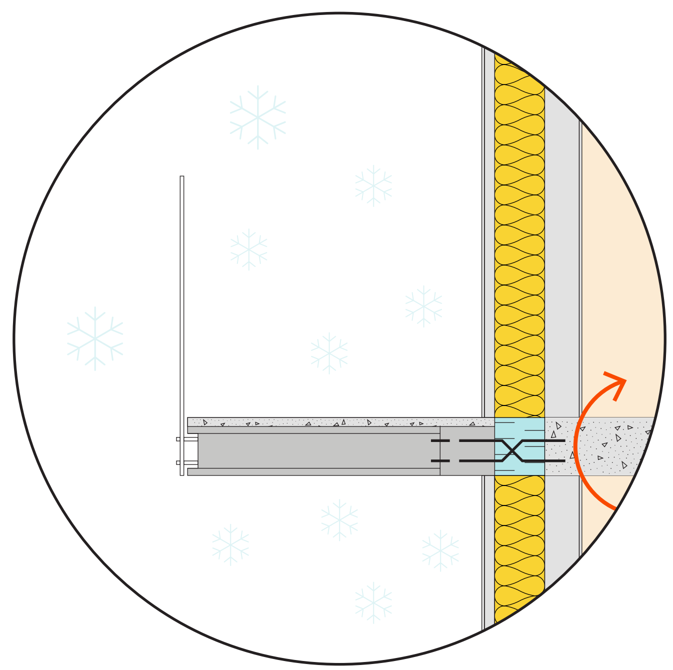
Examples of thermal bridges include concrete balconies and beams that run from the building's interior to exterior. To prevent excessive heat loss, designers should avoid or "break" these thermal bridges with insulating materials, or specify thermally broken building products.

Designers can mitigate thermal bridging by choosing a compact building design that reduces articulations and junctions. They should also require continuous insulation around floor edges, and position window frames in line with building insulation. Doing so will minimize heat loss through the frame-to-wall connection.

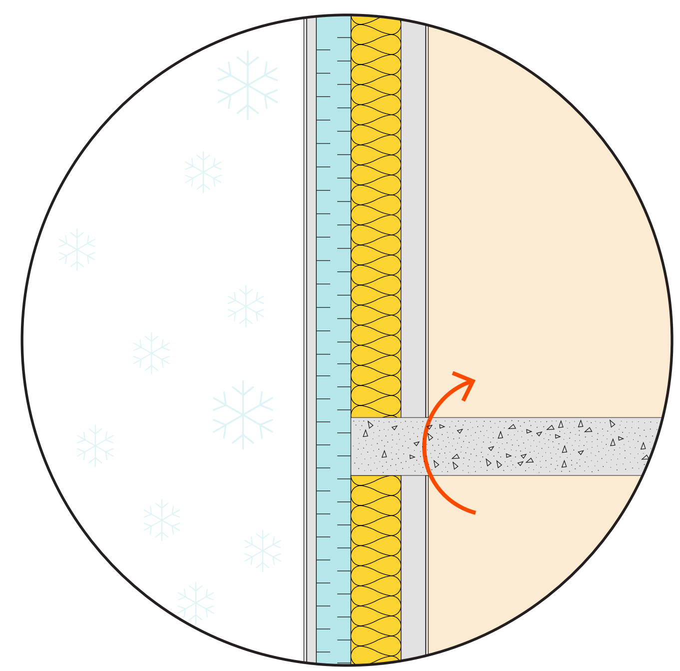
Professionals should avoid slabs that extend the floor plate beyond the heated building envelope, and choose thermally broken balconies in situations where balconies are required.



Balcony with high thermal bridging



Thermally broken balcony



Continuous insulation

**ADDITIONAL RESOURCES**

Software tools and resources such as **BC Hydro's Building Envelope Thermal Bridging Guide** are useful in identifying and mitigating thermal bridging.

**KEY TAKEAWAY**

Break all thermal bridges with insulating materials.

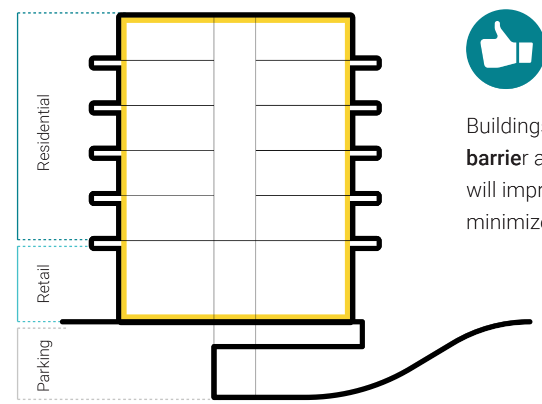
Most important metric(s) to consider TEDI

# 03.46 Increase Airtightness

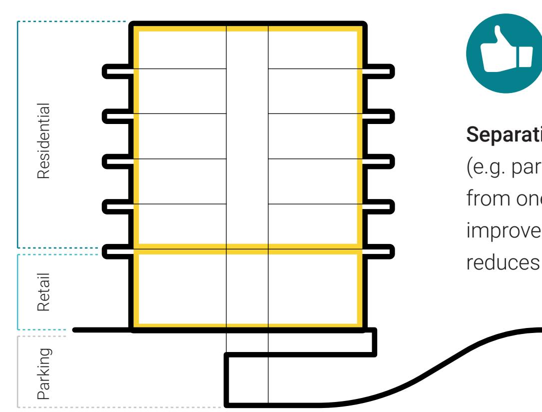
Buildings designed for a compact shape, form, and size not only improve thermal performance, but can improve airtightness as well. Complex forms with more corners have a greater overall potential for air leakage through the building envelope.

Designers should create an airtightness plan to detail the installation of a continuous air barrier, and clearly indicate it on section drawings.

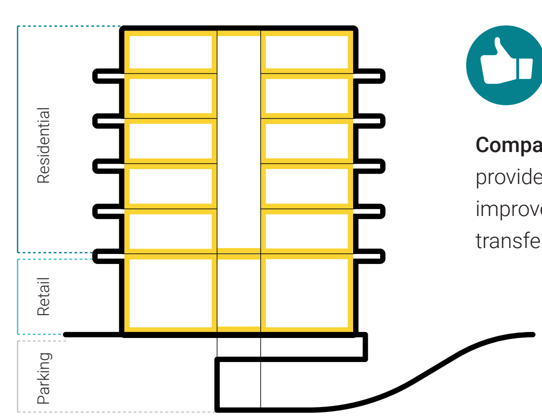
Designers might also consider a compartmentalization strategy to improve a proposed project's airtightness. **Compartmentalization** refers to the practice of isolating individual suites or units in a building from one another, such that they are individually ventilated. The approach minimizes transfer of air — and therefore smoke, smells, and contaminants — from adjacent units or spaces. It also helps to mitigate the "stack effect" in taller buildings.




Buildings with a **continuous air barrie**r around the entire facade will improve airtightness and minimize heat losses




**Separating building uses** (e.g. parking, retail, residential) from one another further improves airtightness and reduces the stack effect




**Compartmentalizing individual units** provides the highest level of airtightness and improve occupant comfort by reducing the transfer of noise and smells between units

**ADDITIONAL RESOURCES**

**The Illustrated Guide to Achieving Airtight Buildings**, published jointly by BC Housing, BC Hydro, and the City of Vancouver, offers additional resources on how to create effective air barriers.

**KEY TAKEAWAY**

Install a continuous air barrier to minimize heat losses through the building envelope. Seal off residential units from each other and from other building uses.

Most important metric(s) to consider Airtightness

# 03.47 Recover Heat During Ventilation

## Typical Ventilation

Historically, MURBs have been ventilated using a centralized pressurized corridor system, in which positively pressurized corridors on each floor force air into individual units through gaps under entrance doors. While it is still common in some areas, this approach has been found to be inefficient in effectively or evenly distributing air throughout the building. Leakage along the distribution system ductwork wastes large amounts of energy, and leads to inadequate ventilation across a building's units. As of 2012, the BCBC also began requiring the provision of ventilation to individual rooms within a unit, making this approach less feasible.

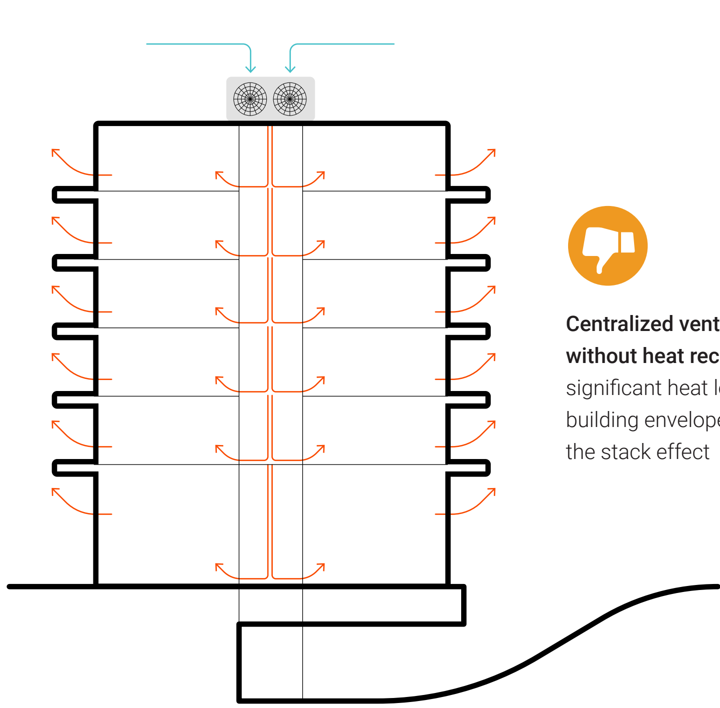
## Compartmentalized Ventilation

In contrast, the compartmentalization of unit ventilation helps to control the overall flow of air in a building, reducing overall energy demand and improving the health and comfort of unit occupants.

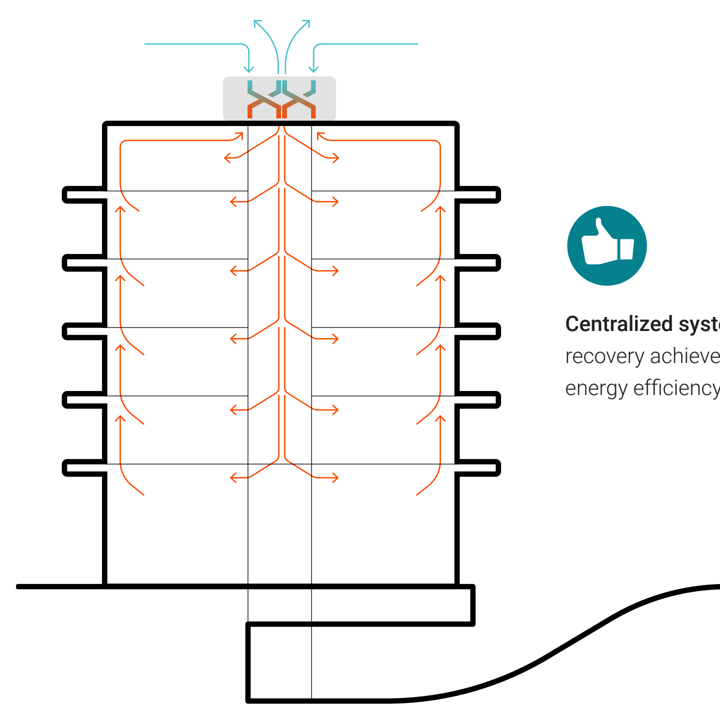
Designers working to meet the performance targets of the BC Energy Step Code should specify high-efficiency heat recovery ventilators (HRV) for either the whole building or at the suite level. Buildings will not likely achieve the Upper Steps of the code without some kind of highly efficient heat recovery.

## Heat Recovery

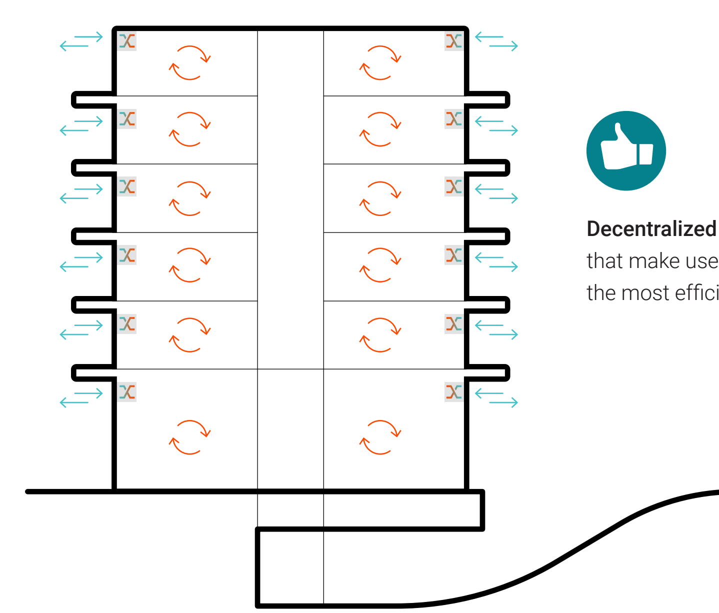
With HRVs, designers can limit centralized, conditioned ventilation to corridors and common areas only, reducing energy that is often wasted through redundant heating. These systems also provide a direct source of fresh air to individual suites, reducing the transfer of smoke, smells, and sounds between units and improving air quality. They minimize heat loss in ventilation, improving a building's overall TEDI and TEUI.



**Centralized ventilation systems without heat recovery** can lead to significant heat losses through the building envelope, and can increase the stack effect



**Centralized systems** that use heat recovery achieve higher levels of energy efficiency



**Decentralized ventilation systems** that make use of heat recovery are the most efficient

**KEY TAKEAWAY**

Use a heat recovery ventilation system at whole building or individual unit scales to reduce heat losses.

Most important metric(s) to consider TEDI

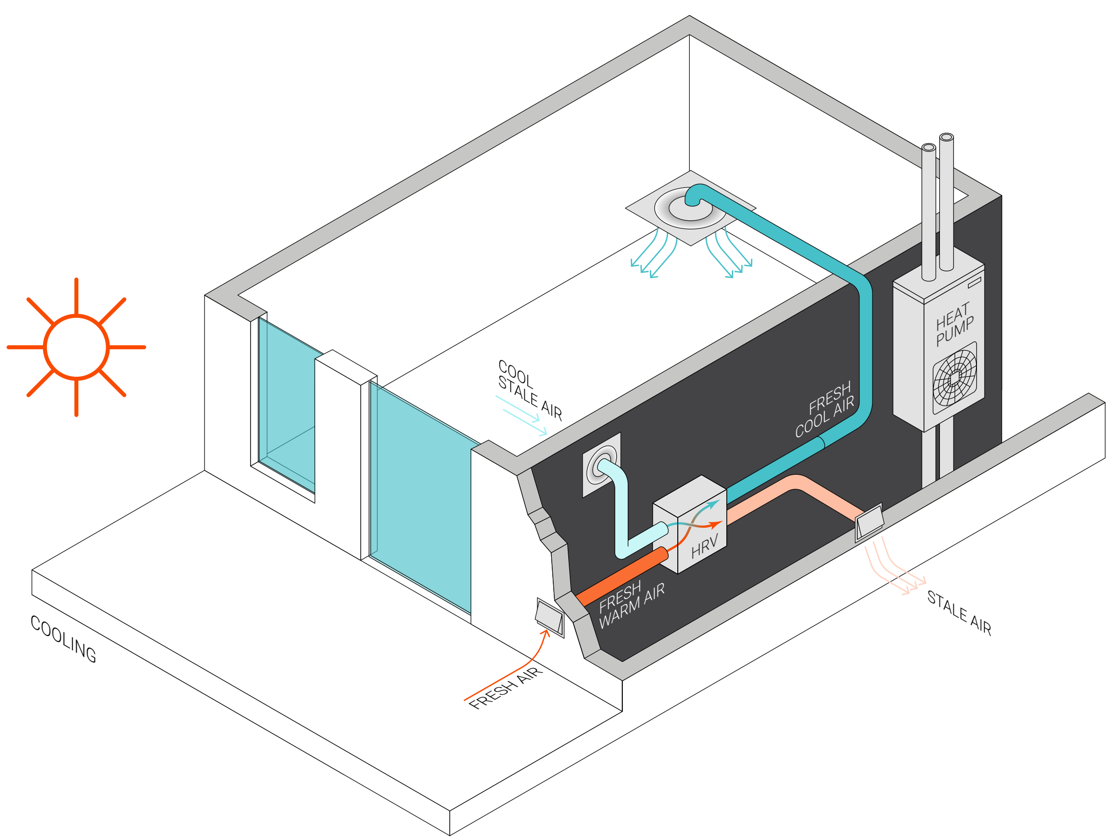
# 03.48 Separate Heating and Cooling from Ventilation

To achieve TEUI targets, designers should separate heating and cooling systems from ventilation systems. In addition to the ventilation strategies noted in Section 03.47, designers striving to achieve TEUI targets should consider high-efficiency mechanical systems. This separation allows for continuous ventilation, regardless of whether a suite requires heating.

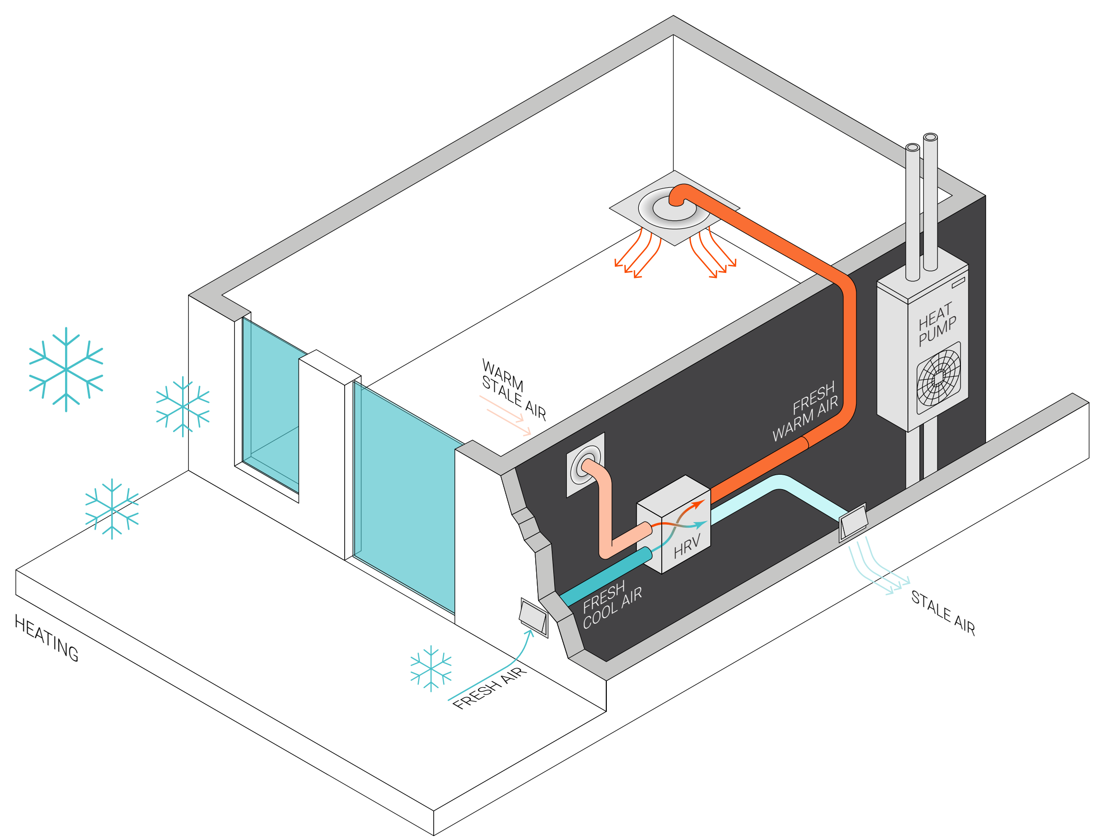
Of all mechanical space-conditioning systems, heat pumps generally do the most effective job of lowering TEUI scores. Options include geo-exchange, air-source, and variant refrigerant flow (VRF) systems. Systems that connect to district energy systems also tend to incorporate some type of heat pump.

Beyond improving a building's TEUI, heat pumps often offer the added benefit of providing occupants with air-conditioning in the summer months. However, prior to selecting mechanical systems, designers should take an envelope-first approach to reducing energy demand as much as possible.

Heat pump technologies are desirable in that they can also provide cooling in summer months




Heat pumps can efficiently provide heat to buildings in cooler months




### Selecting Low-Carbon Mechanical Systems for the City of Vancouver's Zero Emissions Building Plan (ZEBP)

The selection of mechanical strategies is of central importance to the achievement of GHGI performance targets in the City of Vancouver ZEBP. See Supplement S (page 45) for more details on the City of Vancouver's ZEBP.

**KEY TAKEAWAY**

Separate heating and cooling systems from ventilation systems

Most important metric(s) to consider TEDI

# 03.5 Summary of Key Strategies

While certain design strategies will help meet a single BC Energy Step Code performance target (e.g. TEDI), others will help accomplish all three. Practitioners should consider these core strategies — addressing building shape, orientation, and envelope, as well as mechanical and ventilation systems — early in the design process. Proponents must retain the services of an energy modeler at the design and permitting stages. To ensure overall compliance, designers should rely on hourly energy modelling tools.

## Diagram Description

The figure to the right shows the importance of each design strategy in relation to the three key metrics of the BC Energy Step Code (TEDI, TEUI, and airtightness). To explore the impact of different design decisions interactively, visit the **Building Pathfinder website**.

**LEGEND**

TEDI

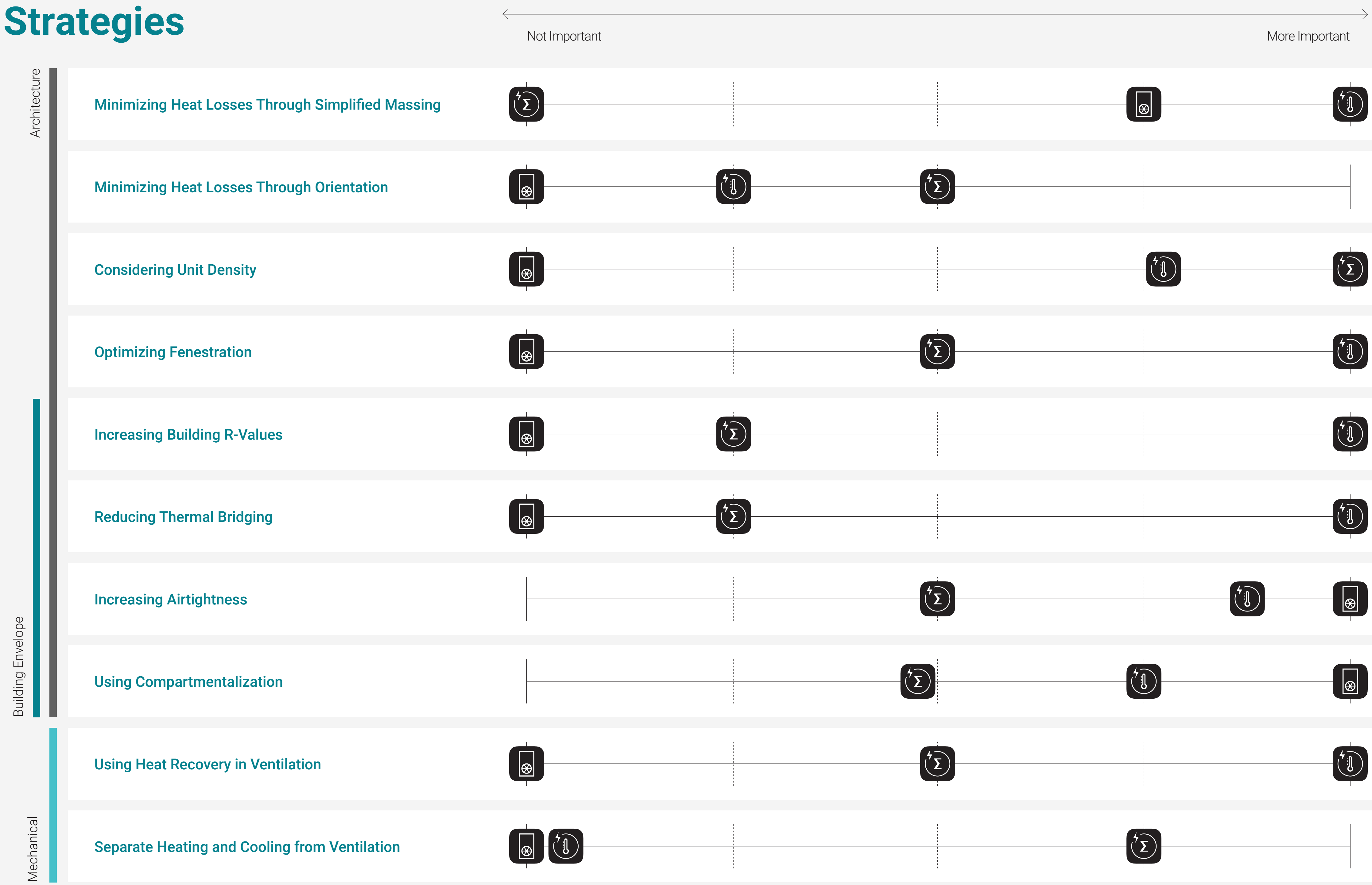
TEUI

Airtightness

Architecture

Building Envelope

Mechanical



## SECTION 04.

# Design Strategies for High-Rise and Mid-Rise MURBs

# 04.1 Introduction

This section presents details on the key design strategies necessary for designers of MURBs to meet the BC Energy Step Code.

## High-Rise MURB

In this guide, High-Rise MURB refers to multi-unit residential buildings of six storeys or higher, designed and built using concrete construction techniques. Such buildings often consist of one to two storeys of commercial space at grade, with up to several dozen setback storeys of residential units above. Exclusively residential high-rise MURBs often include common areas such a lobbies and shared-use facilities, such as gyms and common rooms, alongside or in addition to ground-level suites.

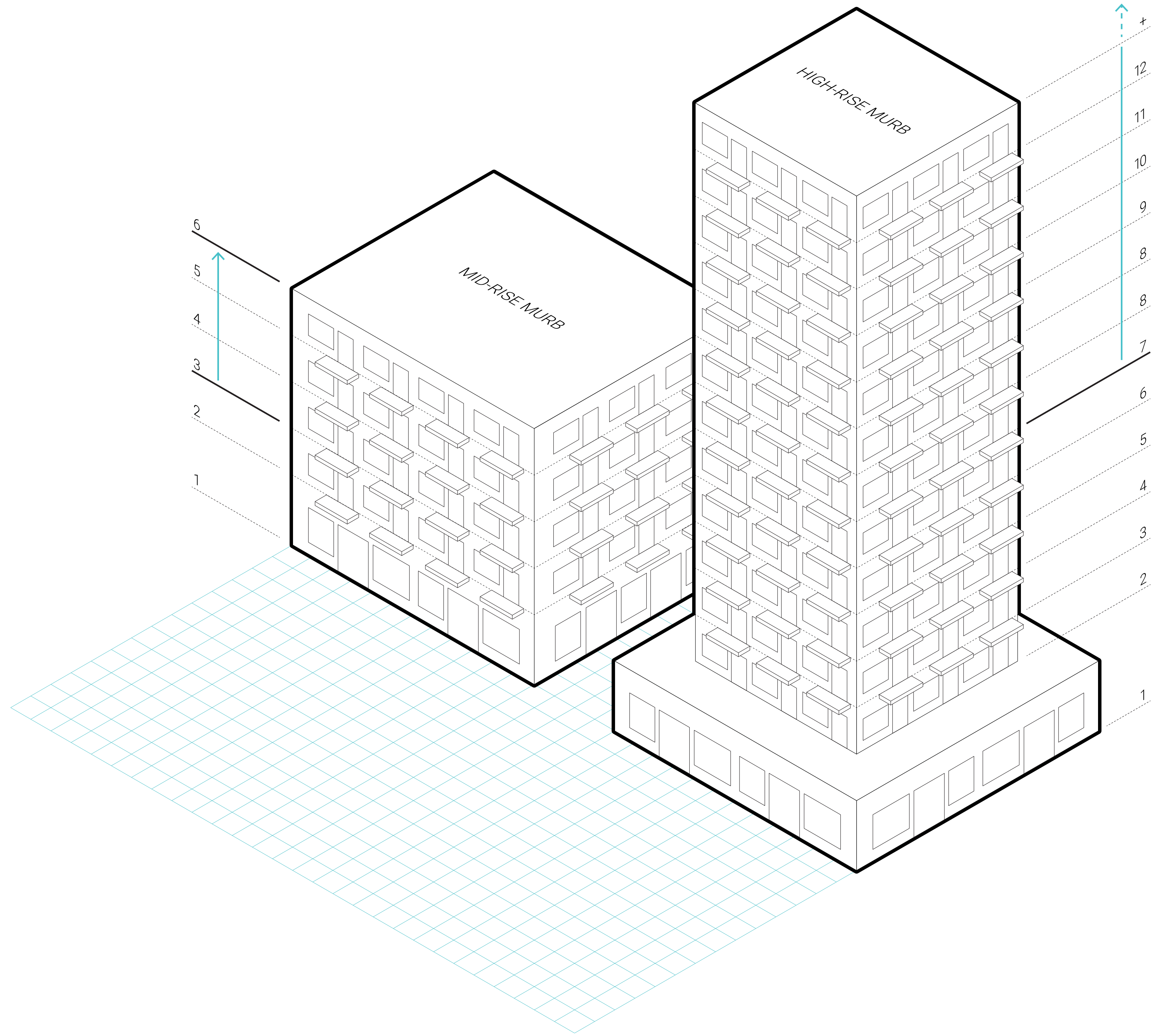
## Mid-Rise MURB

Mid-Rise MURB refers to multi-unit residential buildings of three to six storeys, and designed and built using wood-frame construction techniques. Mid-rise MURBs can be configured with a concrete first storey and wood construction above. While many mid-rise MURBs are purely residential, others can host small businesses in the first and second storeys.

## Key Design Strategies

The strategies presented in this section represent some of the lowest cost design solutions to meet TEDI, TEUI, and airtightness performance targets in the province's Lower Mainland (Climate Zone 4). However, it bears repeating that designers can turn to nearly endless combinations of energy conservation measures to meet BC Energy Step Code requirements. Site conditions, the owners' performance requirements, and many other factors impact a given design's potential to meet BC Energy Step Code requirements.

As such, designers should consider a variety of strategies to determine the best response to meet their specific needs. Hourly energy modelling tools will prove invaluable in doing so.



# 04.2a Building Massing: High-Rise MURB

The design of high-rise residential towers is often constrained by existing site conditions, including the size of the lot and its orientation with respect to the existing street grid. However, designers can take measures to improve a proposed building's ability to meet the BC Energy Step Code's TEDI targets.

## Lower VFAR

High-rise residential towers designed with a lower vertical surface area to floor area ratio (**VFAR**) have a lower overall potential for heat loss through the building envelope. Towers with smaller, narrower floor plates tend to lose more heat through the building envelope. In tower forms, any floor plate of 600m² (6,500ft²) or less can be considered to be a "smaller" floor plate. As cities often emphasize smaller floor plates to help maximize daylight to the street, building designers will need to strive for a balance between municipal requirements and a building's energy performance.

## Simpler Form

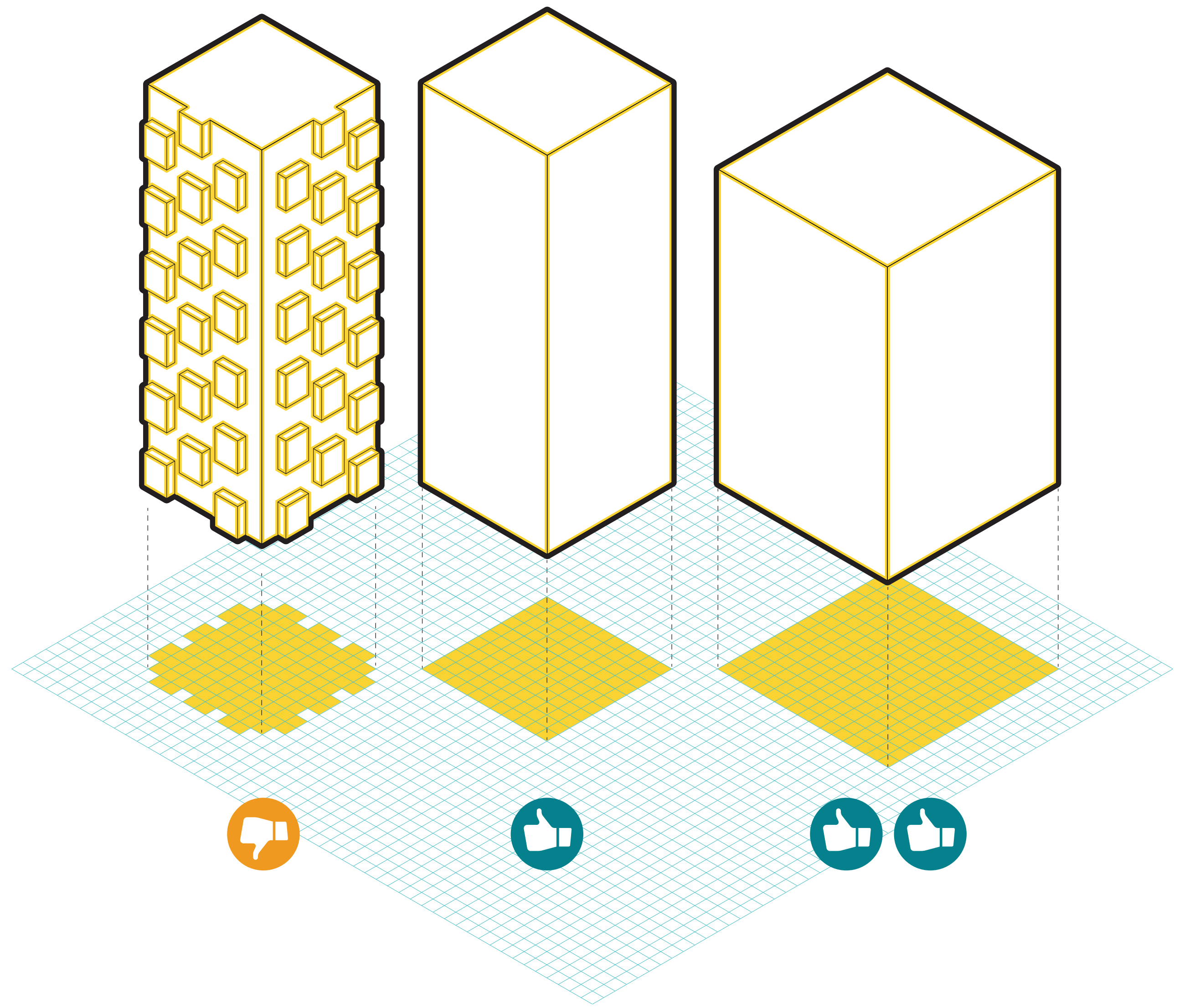
Heat loss through the building envelope is also influenced by the complexity of the building's shape, or **massing**. High-rise MURBs tend to have simpler forms than low- or mid-rise residential buildings. Nonetheless, designers should still work to minimize the number of junctions, indents, and intersections in the building envelope.

## Optimized Orientation

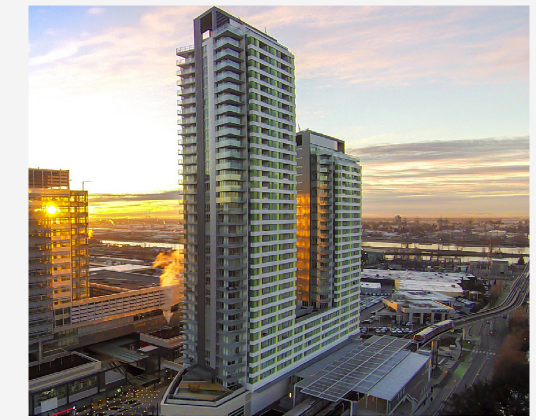
Finally, high-rise MURBs that are designed in such a way that incoming solar gains are maximized in the winter will reduce heating requirements in the wintertime, helping to achieve TEDI performance targets. The **orientation** of residential towers should allow the longest facade of the building to align with due south as much as possible, while ensuring precautions are taken to address the potential for overheating (see Fenestration and Shading). While orientation is often highly constrained by existing street grids and other considerations, high-rise MURB can be designed in such a way that the building's podium aligns with the grid, and the tower is oriented to align towards south.

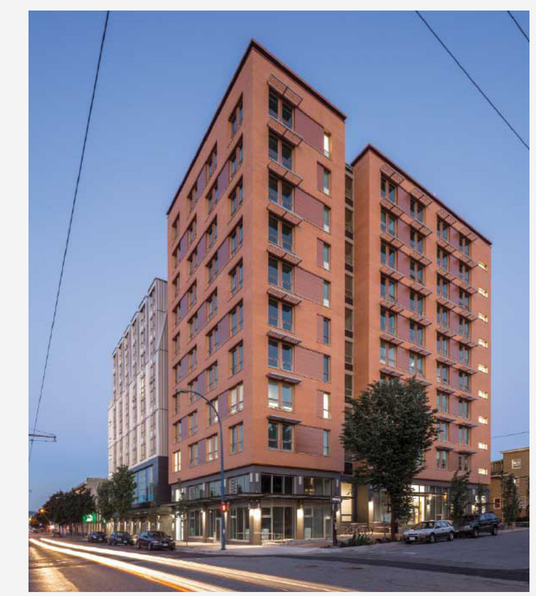
A building with several complex junctions and corners will lose far more heat through the envelope than a building that has been designed as a simple, solid form (e.g. cube, rectangle)

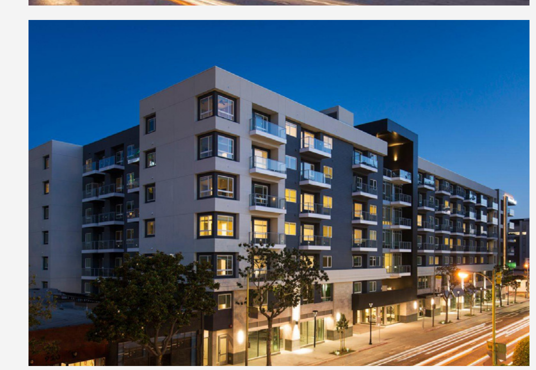
Complexity of shape and size of floor plate both impact Step Code targets



**Top** *Marine Gateway, Vancouver, B.C.*
**Middle** *Budzey Building, Vancouver, B.C.*
**Bottom** *Olympic by Windsor, Los Angeles, CA*



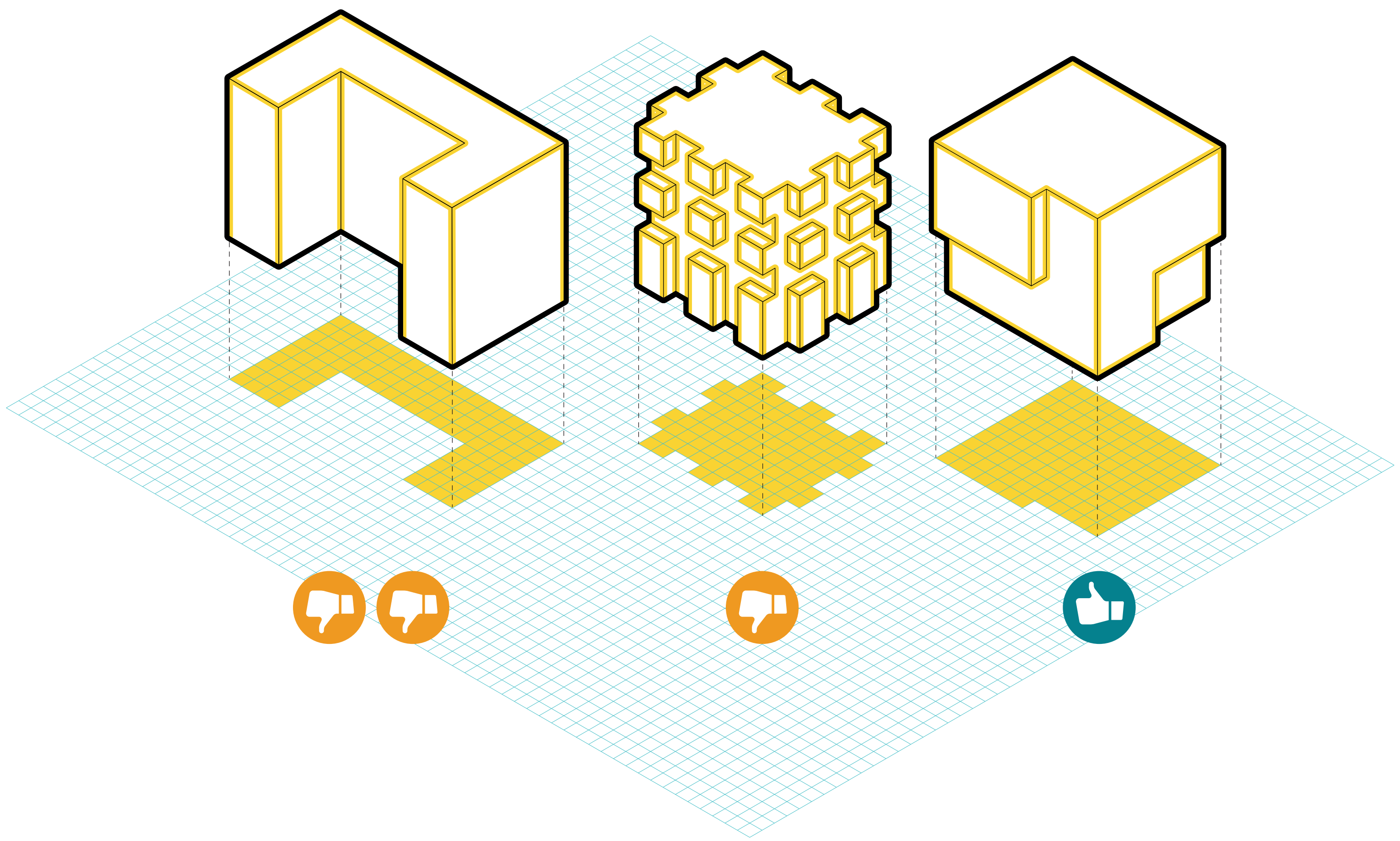




Most important metric(s) to consider TEDI Airtightness

# 04.2b Building Massing: Mid-Rise MURB

Mid-rise residential buildings are usually the most constrained by existing site conditions, setback requirements and lot size, and the existing street grid. However, designers can begin to consider the massing and proportions of the building's design early on to improve its ability to meet the BC Energy Step Code's TEDI targets.



### Simpler Form

The complexity of the building's shape, or massing, significantly influences heat loss through the building envelope. Traditionally, mid-rise MURB designers design multiple junctions and articulations in the envelope to enhance visual interest and/or assimilate the building into the urban landscape. However, the fewer such junctions, indents, and intersections, the easier time a designer will have reaching TEDI and airtightness targets. Designers should aim to reduce the overall complexity of the building's shape by replacing complex envelope designs with simpler, compact forms.

### Maximize Solar Gains

Mid-rise MURB designers should seek to maximize solar gains in the winter to reduce heating requirements; doing so will help achieve TEDI performance targets. This is often challenging given existing site conditions, but may be a consideration for upper floors. Designers must also be careful to avoid overheating.

**CASE STUDIES**

Compact Charisma

Building designers can make use of different colours and textures to enhance the visual interest of a building while keeping its form simple and compact.

**Top** *Cornerstone, Vancouver, B.C.*
**Bottom** *Kiln Apartments, Portland, OR*

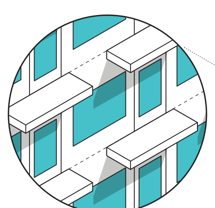
Most important metric(s) to consider TEDI Airtightness

# 04.3 Fenestration and Shading

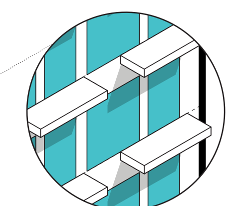
The size and placement of windows can influence a MURB's TEDI and TEUI performance. To reduce a building's TEDI, windows should be placed in such a way as to optimize incoming solar gains in the winter, and minimize solar gains in the summer. Careful placement of windows can also improve cross-ventilation, support daylighting, and reduce the need for artificial lighting, all lowering total energy demand.

Strategies to address these issues include increasing sill heights, and ensuring that operable windows are on multiple facades or walls wherever possible. Moving corridors and elevators to the north side of a building can also help to minimize areas that require glazing and daylight access.

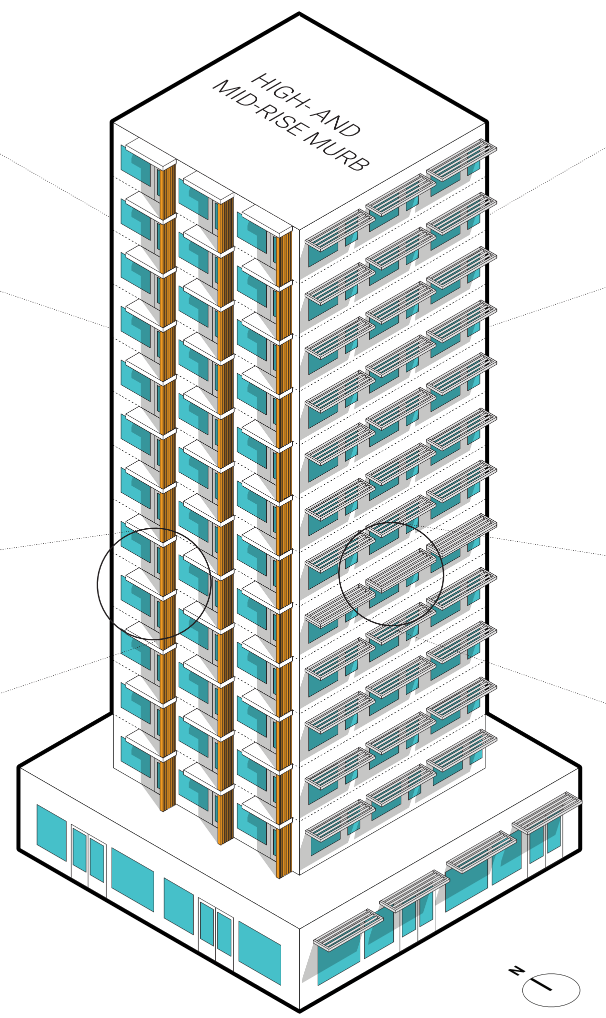
Designers can also consider existing adjacent buildings and trees in a shading strategy, so long as they recognize that neither strategy may be permanent. (Adjacent trees and buildings are subject to change!)

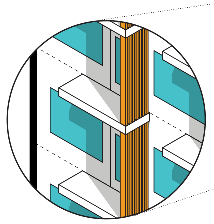


**NORTH FACING**
Minimize the WWR on north facades, to reduce winter heat losses.

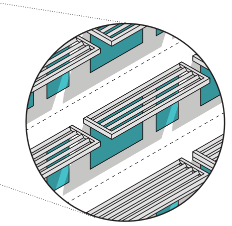


**EAST FACING**
Increase WWR on east facades, to increase daylighting potential and lower lighting loads. Shading on the east facade has minimal impact on TEUI, but can improve occupants' thermal comfort.

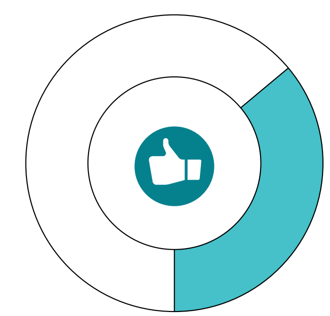


**WEST FACING**
Externally shade windows on south and west facades to prevent unwanted solar gains in summer.

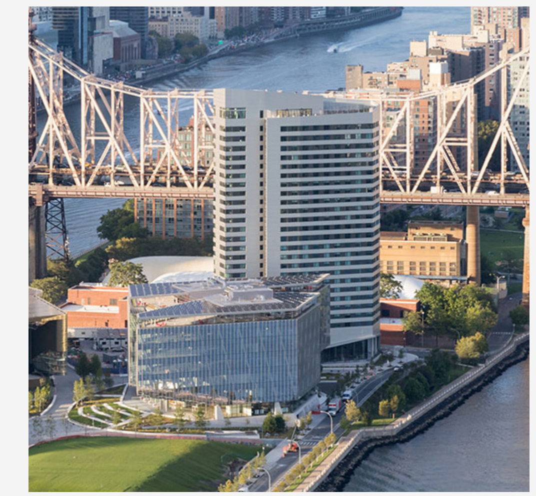


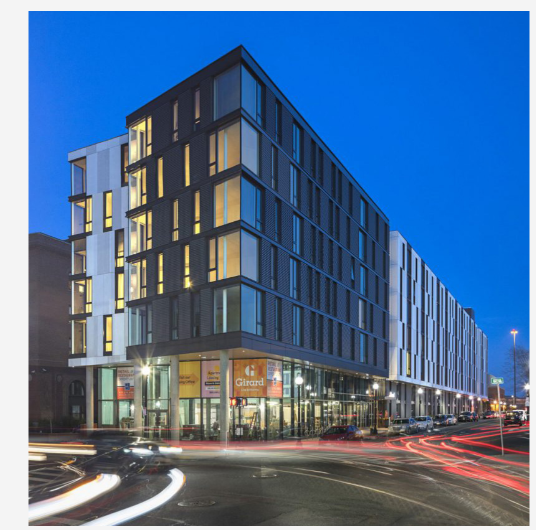
**SOUTH FACING**
Externally shade windows on south and west facades to prevent unwanted solar gains in summer.



**OVERALL WWR**
40% or less

**Top** *Cornell Tech Residential, NYC*
**Middle** *Girard, 600 Harrison Ave, Boston, MA*
**Bottom** *Cornerstone, Vancouver, B.C.*





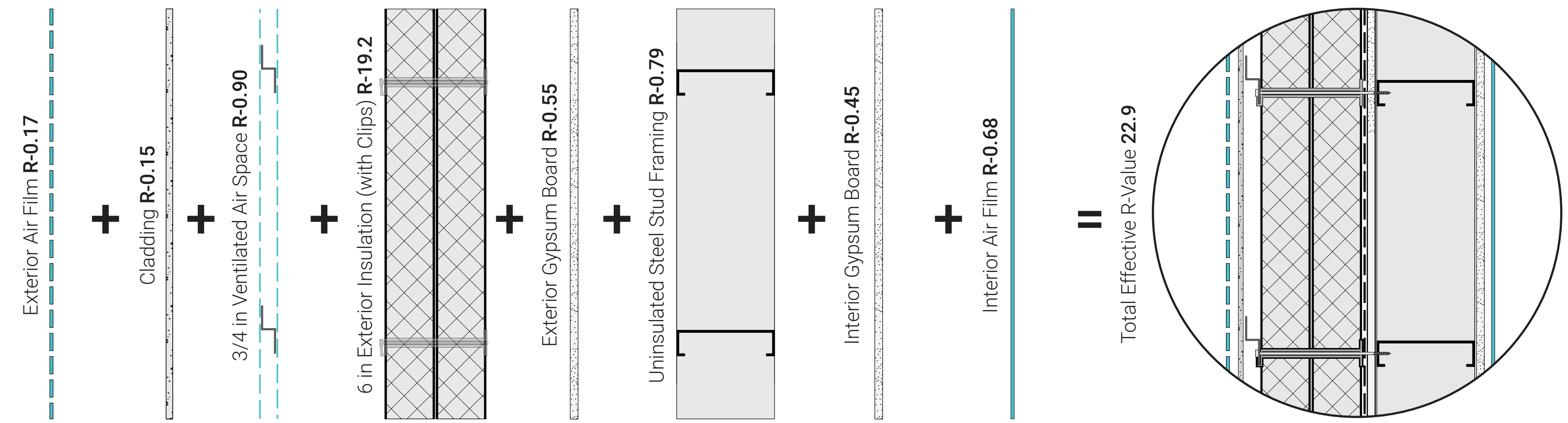
Most important metric(s) to consider TEDI

# 04.4a Wall R-Values: High-Rise MURB

To improve the ability to meet the TEDI performance targets for all steps of the BC Energy Step Code, designers should select wall systems with a minimum value of R-10 effective, and consider roof designs with a minimum value of R-20 effective.

Historically, window wall systems have not achieved high R-values and, as a result, do not typically achieve the higher levels of performance that steel stud and exterior insulation or concrete panel systems can achieve. That said, there are a small number of high-performance window wall systems that are currently on the market in B.C. that can be designed and installed to achieve insulation levels capable of achieving Steps 2 and 3.

Wall systems that exhibit the most favourable characteristics for achieving better building performance include concrete assemblies with exterior insulation, concrete sandwich panes, and steel-stud with exterior insulation wall systems.



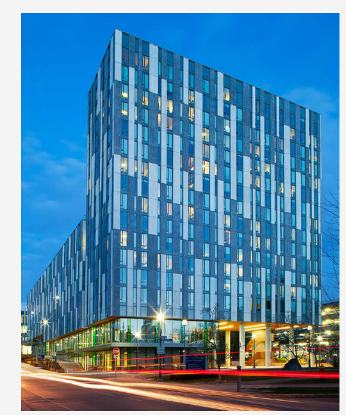

## Concrete Assemblies with Exterior Insulation

Cast-in-place concrete wall assemblies are common on high-rise MURBs. In this approach, cladding and exterior insulation is attached to the concrete wall with intermittent thermally efficient clips. A continuous layer of insulation around the entire envelope is necessary to achieve higher levels of thermal performance and minimize thermal bridging.

**Above**
*Terrace 459, Chicago, IL*

## Concrete Sandwich Panels

In this approach, insulation is sandwiched between two layers of pre-cast reinforced concrete panels. Sandwich panels offer higher levels of thermal performance than solid pre-cast panels, as the sandwiched layer provides for continuous insulation. They also achieve good levels of airtightness.



**Above**
*Ponderosa Commons, Vancouver, B.C.*

## Steel-Stud with Exterior Insulation

Steel stud wall assemblies are commonly used in High-Rise MURB construction. In this approach, cladding and exterior insulation is attached to the steel stud wall with intermittent thermally efficient clips. Steel stud walls can either be built on-site, or made as prefabricated panels off-site and lifted into place. A continuous layer of insulation around the entire envelope is necessary to achieve higher levels of thermal performance and minimize thermal bridging.

**Above**
*Mclaren House, Vancouver, B.C.*

**Fire Safety** All exterior wall assembly materials must be non-combustible.

Most important metric(s) to consider TEDI

# 04.4b Wall R-Values: Mid-Rise MURB

Mid-rise MURB designers can improve TEDI performance by selecting wall and roof systems that offer a minimum effective R-20 insulation value. Mid-rise MURBs are commonly constructed using either wood-frame or concrete wall assemblies. Wood-frame construction typically achieves higher thermal performance than concrete wall systems, because the thermal conductivity of wood is lower than that of concrete and steel. Mid-rise MURB designers seeking BC Energy Step Code compliance will want to consider four major wall approaches:

### Wood-Stud with Split Insulation

This conventional construction method achieves high thermal performance with standard 2x4 or 2x6 studs. Crews install insulation within the stud cavities, and also apply a continuous layer of rigid or semi-rigid insulation to the building's exterior.

### Deep Wood-Stud Assemblies

Designers can achieve higher thermal performance with deeper stud walls (e.g., 2x8, 2x10, 2x12, or I-joists), and/or double stud framing with an interior service wall. Contractors then fill these deeper stud cavities with mineral-fibre batt insulation, blown-in fibrous insulation, or spray-foam insulation.

### Steel-Stud with Exterior Insulation

Steel-stud wall assemblies are commonly used in MURB construction. In this approach, cladding and exterior insulation is attached to the steel stud wall with intermittent thermally efficient clips. Steel-stud walls can either be built on-site, or made as prefabricated panels off-site and lifted into place. A continuous layer of insulation around the entire envelope is necessary to achieve higher levels of thermal performance and minimize thermal bridging.

### Concrete Assemblies with Exterior Insulation

Exterior insulated concrete walls score well on durability and thermal performance. Designers choosing this option can minimize thermal bridging through the exterior insulation by carefully selecting cladding attachments and ensuring interface details are thermally improved.

**Above**
*Riverport Flats, Richmond, B.C.*


**Above**
*Orchards at Orenco, Portland, OR*

**Above**
*Richardson Apartments, Portland, OR*

**Above**
*Knickerbocker Commons Passive House, NY*

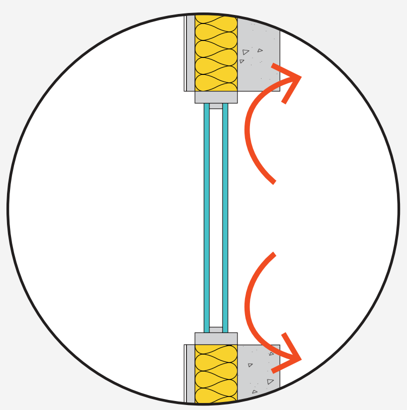
Most important metric(s) to consider TEDI

# 04.5 Window U-Values

The U-value of the glazing selected for use in building design will have a significant impact on the ability of the building to achieve the performance targets of the BC Energy Step Code. In general, energy modelling will reveal the level of window performance needed to meet a given step's TEDI target.

## Select the Right Windows:

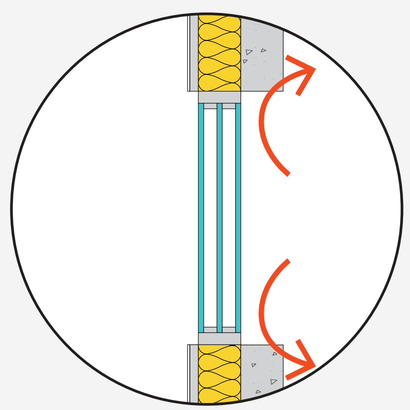
For Designers Targeting Step 2 or Step 3:
**Select Double Pane Windows**



**High-Rise MURBs**
Designers targeting Step 2 or Step 3 should consider the use of double pane windows with a **maximum U-value of USI-2.5.**

**Mid-Rise MURBs**
Designers targeting Step 2 or Step 3 should consider the use of double pane windows with a **maximum U-value of USI-2.5.**

For Designers Targeting Step 4:
**Select Triple Pane Windows**



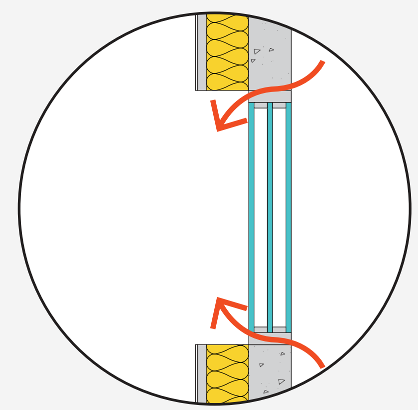
**High-Rise MURBs**
Designers aiming for Step 4 will want to investigate the use of triple pane windows with a **maximum U-value of USI-1.6.**

**Mid-Rise MURBs**
Designers aiming for Step 4 should consider the use of double or triple pane windows with a **maximum U-value of USI-2.0.**

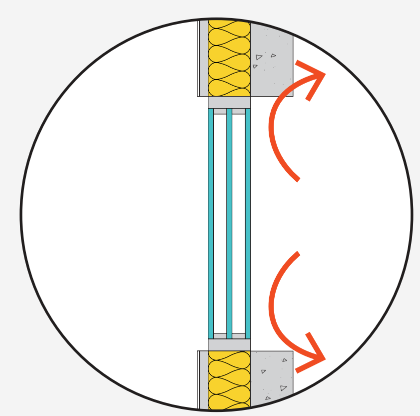
! In mid-rise MURBs, designers can also reduce thermal bridging by specifying window frame materials, such as vinyl or fibreglass, which offer lower thermal conductivity.

## Reduce the Number of Opportunities for Thermal Bridges to Occur:

**Align Windows with Insulation**

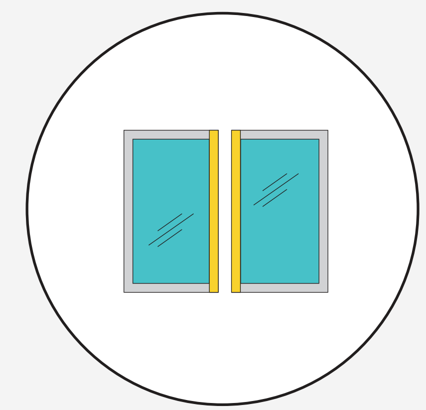


Windows frames that are out of line with the building's insulation layer increase the chances of heat loss through the envelope.

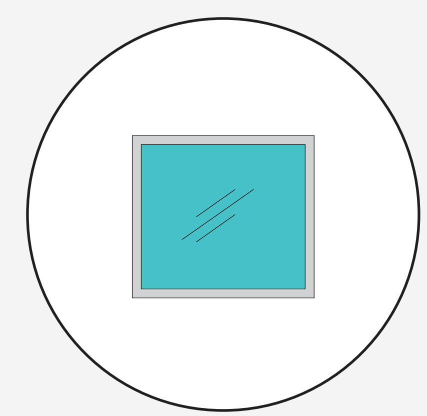


Place windows in line with the building's insulation layer to minimize heat losses.

**Reduce Framing Elements by Having Fewer, Larger Windows**



The greater the number of window framing elements, the greater the opportunities for thermal bridging.



Minimize the number of framing elements to reduce heat losses through the building envelope.

Wherever possible, window design should emphasize fewer, larger windows in lieu of a greater number of smaller windows.

Most important metric(s) to consider TEDI

# 04.6 Thermal Bridges

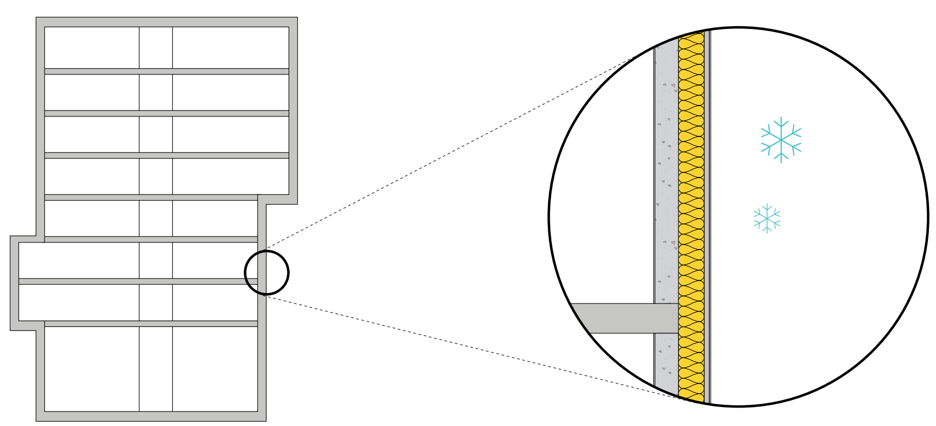
MURB designers will be required to identify and minimize instances of thermal bridging in building designs. This can be accomplished in three ways:

### Compact Massing

First, building massing should be as compact as possible in order to minimize the number of junctions and articulations in the building facade.

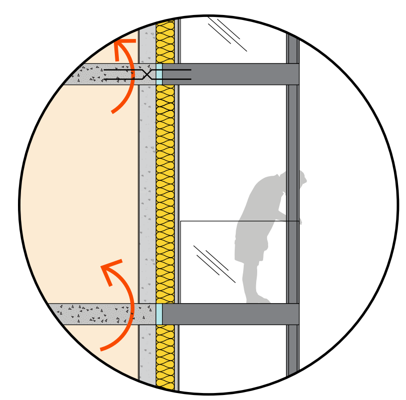
### Continuous Insulation

Second, continuous insulation should be placed across the entire building envelope to create a barrier between structural materials and the building exterior.

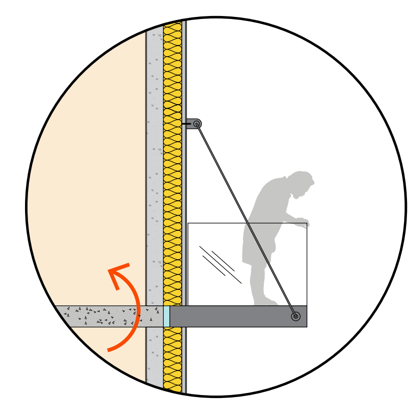


### Mounted Balconies

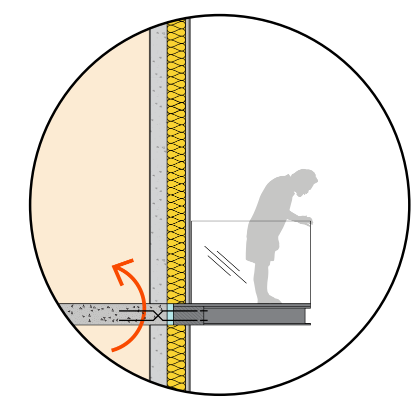
Third, building designs that cantilever floor slabs to form balconies without a thermal break should be avoided. Instead, designers should mount balconies so that they do not create thermal bridges. New methods of mounting balconies are becoming more available, and include:



**Exterior supported balconies** (or self-supporting balconies) are supported from below. This allows the size of the tie-backs that connect the balcony to the building to be minimized, reducing thermal bridging.



**Exterior hung balconies** (or suspended balconies) are attached to the building by tension cables. These allows for continuous insulation across the building envelope.



**Thermally-broken balconies** use lower-conductivity materials (such as stainless steel) to attach the balcony to the building, reducing heat losses through the envelope.

Mid-rise MURBs that make use of wood-frame construction methods will have less of an issue with thermal bridging, because wood materials exhibit lower thermal conductivity overall. However, the key strategies for reducing incidences of thermal bridging are the same as those used for high-rise MURBs.

Most important metric(s) to consider TEDI

# 04.7 Airtightness

Designers should target a level of airtightness corresponding to the required step of the BC Energy Step Code.

## Minimum Requirements

While there are no prescriptive airtightness targets associated with any of the Steps for Part 3 buildings, designers should use the airtightness value recommended in the **City of Vancouver Energy Modelling Guidelines**, as referenced by the BC Building Code, in the initial energy modelling. The value represents a target air leakage rate of **2.0 L/s m² at 75 Pascals and translates to a design infiltration rate of approximately 0.00025 m³/s m².** On-site testing is required to determine the as-built building airtightness, and the energy model must be updated. If the tested values differ from the initial airtightness value assumed, it may impact the building's ability to achieve Step Code performance targets.

Findings reported in the 2017 BC Step Code Metrics Research report have shown that targeting a higher level of airtightness is one of the most cost effective energy conservation measures. This translates into a design infiltration rate of 0.0001 m³/s m².

## Step 4 Requirements

**Designers seeking to comply with Step 4 should target an airtightness level on par with that permitted by the Passive House standard. This requirement varies with building geometry, but translates into a design infiltration rate close to 0.00001 m³/s m².**

Compact building massing and a high-quality building envelope are two key design strategies that contribute to an improved level of airtightness. Designers should plan air barriers that will remain intact through minor repairs or occupant upgrades. For example, a resident hanging a picture on a wall should not be able to puncture an air barrier.

## Compartmentalization

**Designers seeking to meet the improved airtightness requirements of the Upper Steps should consider compartmentalization.** MURB designers can significantly improve airtightness by sealing off and separating each individual unit.

**Top** *Kiln Apartments, Portland OR*
**Bottom** *100 Pike, Seattle, WA*

**Below** *Cornell Tech Residential, NYC*

Most important metric(s) to consider Airtightness

# 04.8 Ventilation Systems

Ventilation is important to the achievement of BC Energy Step Code performance targets. Designers must plan to route direct ducting into each room within a dwelling unit. The conventional approach of simply providing exhaust ventilation in bathroom and kitchen areas will not meet BC Energy Step Code requirements. Similarly, corridor-pressurization ventilation strategies will not likely meet the standard's performance targets.

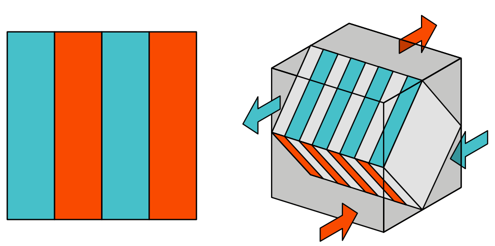
Designers targeting any level of the BC Energy Step Code are advised to use heat recovery ventilation (HRV), because it significantly reduces heat losses by recovering the heat energy from ventilation air before it is expelled from the building. Designers seeking to achieve Upper Steps should consider higher efficiency HRV systems. A minimum of 60% HRV efficiency should be considered for designs targeting Steps 2 and 3, while those aiming for Step 4 should seek minimum efficiencies of 80%.

The efficiency of an HRV is determined by the efficiency of the ventilation equipment, and the quality of its installation. A wide range of high efficiency HRV systems exist for larger buildings, including those that use thermal wheels.

For more compact residential applications, designers should investigate three forms of high-efficiency HRV technology:

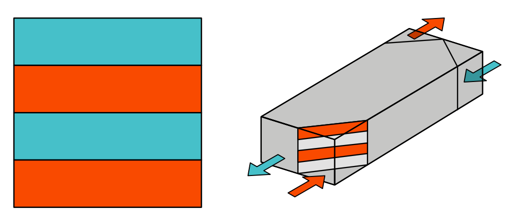
### Vertical Flat Panel HRV

These represent some of the least costly HRV systems



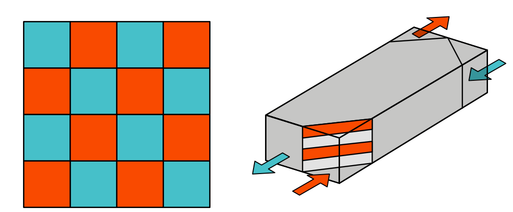
### Horizontal Flat Panel HRV

These can be more expensive than vertical flat panel systems, but achieve higher levels of performance



### Cellular HRV

Although these are not yet widely available and can be even more costly, they offer the highest available performance



**DESIGNERS TARGETING STEP 3**
Both the vertical and horizontal flat panel systems will achieve performance targets.

**DESIGNERS TARGETING STEP 4**
Designs using only a cellular-based technology will achieve the required levels of efficiency.

! The size of the HRV's core also has an influence on the level of the system's efficiency. Larger cores tend to achieve higher efficiencies.

! In high humidity environments, Energy Recovery Ventilation (ERV) Systems can be used in place of HRV systems. See **BC Housing's Heat Recovery Ventilation Guide for Multi-Unit Residential Buildings** for more details.

As noted, an HRV's design and installation impacts its effectiveness. Designers should be careful to avoid short circuiting and circuitous routing:

**SHORT CIRCUITING** refers to a design in which ventilation air enters and leaves a space or duct before it has a chance to mix well enough with room air to adequately dilute pollutants and replace stale air. In MURB construction, short circuiting occurs as a result of the placement of the ventilation supply too close to the ventilation exhaust.

**CIRCUITOUS ROUTING** occurs when too many corners and complex runs are placed within the duct work. This requires an increase in fan power to properly ventilate a space, which in turn reduces the overall effectiveness of the ventilation design. Direct duct routes make the most of fan power and improves the overall efficiency of the system.

While these two issues are some of the most problematic when designing ventilation systems, other issues such as improper sizing or excessively long duct runs can present problems. Designers should carefully review the ventilation design with the project's mechanical designer and contractor. All ducts should be insulated to improve the overall efficiency of the system. It is also recommended that special attention be paid to the location where the ducting meets the envelope to prevent thermal bridging.

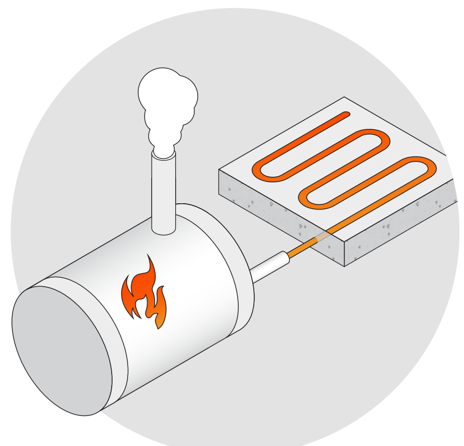
Most important metric(s) to consider TEDI

# 04.9 Mechanical Systems

Mechanical systems for MURBs can take four major forms:

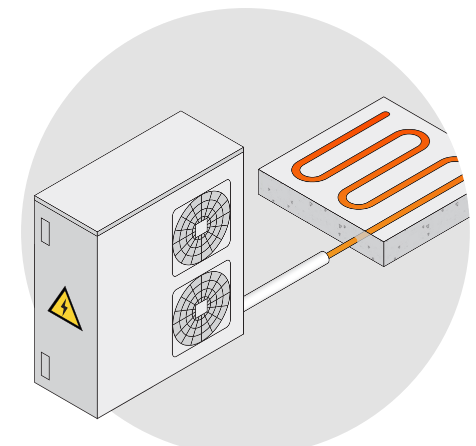
### Hydronic* Delivery Using Natural Gas

These systems use a central natural gas boiler to heat and provide domestic hot water to units. They are generally among the lowest cost systems to install and operate, because they reliably handle large loads using relatively low-cost natural gas. While other systems may require some redundancy, boilers typically do not.



### Hydronic* Delivery Using Electricity

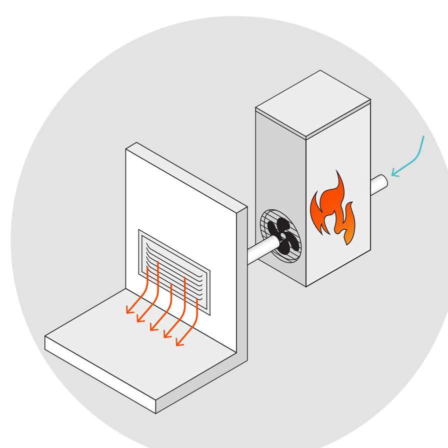
These systems use some form of heat pump to generate heat, including air-source, geo-exchange, and most district energy systems. They tend to be the most efficient of the available options. They also provide cooling, making them popular with occupants. Heat pump systems will struggle to deliver heating to large buildings when outdoor temperatures are below freezing.



* "Hydronic" refers to the practice of using a water-based medium to distribute heat throughout a building. Hydronic systems can use either radiators, in-floor systems, and in some cases, in-ceiling systems.

### Forced Air

Forced air systems driven by a two or four-pipe fan coil are also used to heat and cool MURB units. Mechanical engineers must combine these systems with either a centralized or suite-level heat recovery ventilation system to achieve the desired level of efficiency. However, designers should note that suite-level heat recovery requires more ducting space and can therefore be challenging in buildings with low floor-to-ceiling heights.

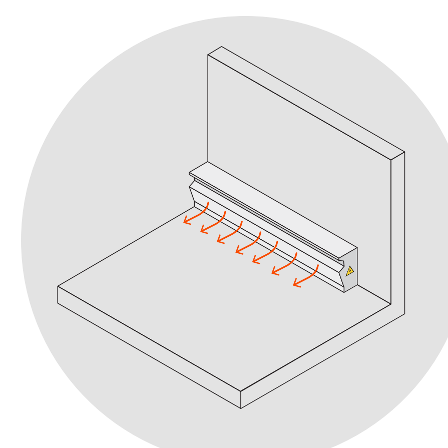


### Electric Baseboards

Electric baseboard heaters are often the cheapest and most flexible systems to install. Given the low carbon intensity of electricity in most parts of British Columbia, they are also very climate-friendly to use.

The current cost differential between electricity and natural gas can make these systems more expensive to operate. They are typically not used for common areas, and require an additional solution to heat domestic hot water.

Given their higher operating costs, baseboards work best in buildings that have low heating demands.



### Preventing Overheating in High-Rise MURBs

If not considered carefully, the use of highly efficient building envelopes can be at risk of overheating in the summer months.

To prevent the risk of overheating, designs should consider specifying:

- *Electrically powered mechanical cooling systems*
- *Shading devices on southern and western elevations*
- *Natural ventilation and cooling strategies, such as operable windows*

### Need to Comply with the City of Vancouver's Zero Emissions Building Plan?

Hydronic delivery and electric baseboard systems are low-carbon mechanical systems that will also conform to the City of Vancouver's Zero Emissions Building Plan, as natural gas based systems typically yield the highest carbon intensity. However, gas-based systems can be selected where designers pursue a higher step than they are required to under the Plan.

Most important metric(s) to consider TEDI

# 04.10a The High-Performance High-Rise MURB Checklist

### Massing and Orientation

Focus on simple, compact forms that minimize the number of junctions and articulations. Wherever possible, target a low VFAR to reduce envelope heat loss.

### Unit Density

Higher occupant and unit densities (i.e. buildings with many small one-bedroom and/or bachelor units) make TEDI targets easier to achieve, but make TEUI targets more difficult. Consider these trade-offs early in the design process.

### Fenestration and Shading

Aim for an overall WWR of 40%. Use thermally broken external shading devices on south and west facades to reduce risk of summer overheating.

### Wall and Window Systems

Select wall systems with a minimum effective R-10 insulation value; for roof systems, look for those rated to a minimum effective R-20. To meet the performance requirements of the Upper Steps, designers will need to specify triple-pane, high performance windows.

### Thermal Bridges

Specify continuous insulation to minimize envelope heat loss, and thermally broken balconies.

### Airtightness

Create an airtightness plan to detail the installation of a continuous air barrier, and clearly indicate it on section drawings. Consider sealing off building uses and units from one another, an approach known as compartmentalization.

### Heat Recovery

Use heat-recovery strategies to improve system efficiency and occupant comfort. Carefully configure HRV systems and ensure they are properly installed and provide fresh air to all rooms.

### Mechanical Systems

Specify highly energy efficient mechanical systems. Consider using electricity-based systems that reduce greenhouse gas emissions when designing for a zero emissions building.

# 04.10b The High-Performance Mid-Rise MURB Checklist

- [ ] **Massing and Orientation**

  Focus on simple, compact forms that minimize the number of junctions and articulations. Where site conditions support, designers should attempt to maximize solar gains to reduce wintertime heating requirements.

- [ ] **Unit Density**

  Higher occupant and unit densities (i.e. buildings with many small one-bedroom and/or bachelor units) make TEDI targets easier to achieve, but make TEUI targets more difficult. Consider these trade-offs early in the design process.

- [ ] **Fenestration and Shading**

  Aim for an overall WWR of 40%. Use thermally broken external shading devices on south and west facades to reduce risk of summer overheating.

- [ ] **Wall and Window Systems**

  Select wall and roof systems with a minimum effective R-20 insulation value. Specify double- or triple-paned windows to meet the BC Energy Step Code performance targets. Units should use minimal framing elements wherever possible, and utilize low-conductivity framing materials such as vinyl and fibreglass.

- [ ] **Thermal Bridges**

  Specify continuous insulation to minimize envelope heat loss, and thermally broken balconies.

- [ ] **Airtightness**

  Create an airtightness plan to detail the installation of a continuous air barrier, and clearly indicate it on section drawings. Consider sealing off building uses and units from one another, an approach known as compartmentalization.

- [ ] **Heat Recovery**

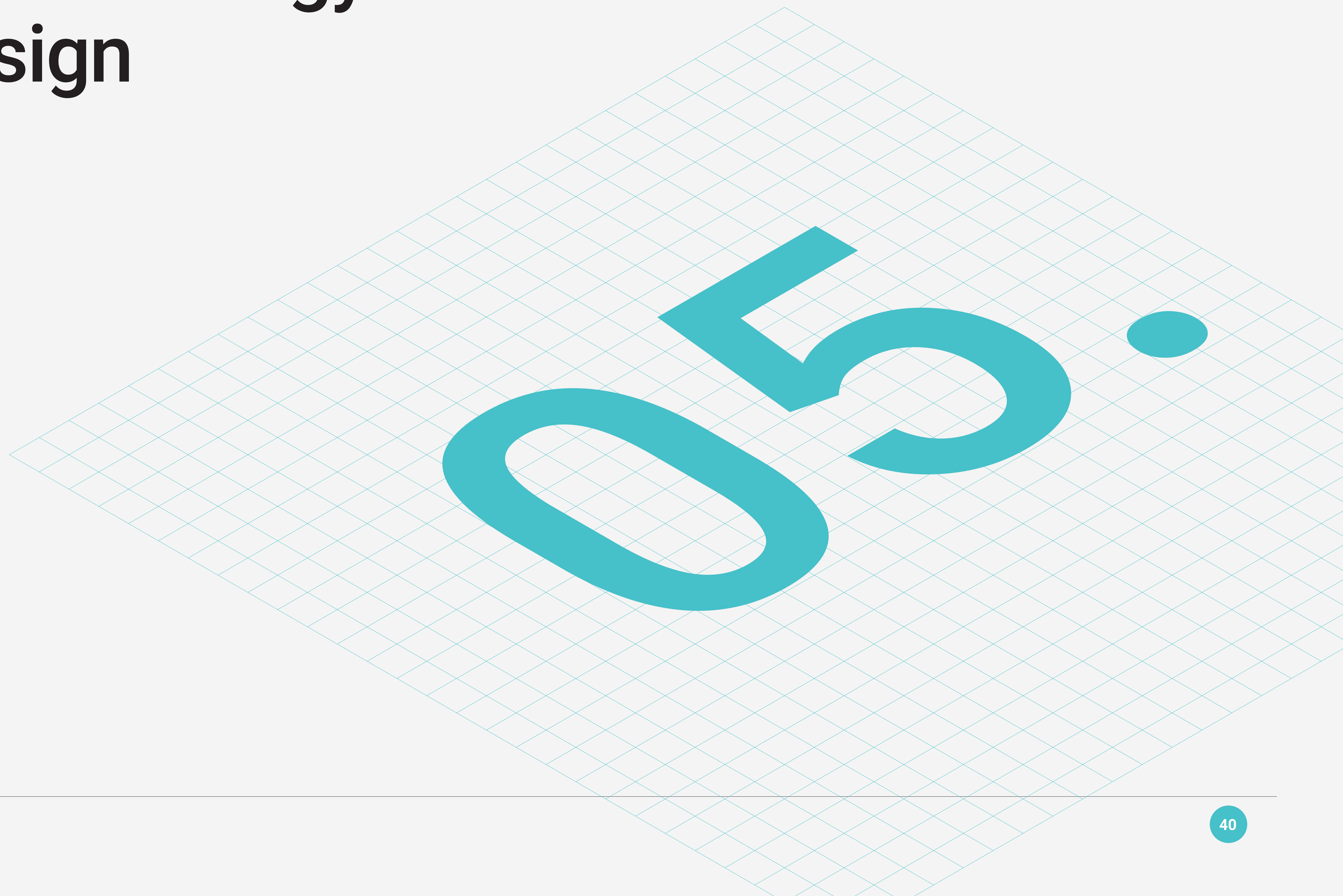
  Use heat-recovery strategies to improve system efficiency and occupant comfort. Carefully configure HRV systems and ensure they are properly installed and provide fresh air to all rooms.

- [ ] **Mechanical Systems**

  Specify highly energy efficient mechanical systems. Consider using electricity-based systems that reduce greenhouse gas emissions when designing for a zero emissions building.

SECTION 05.

# The Benefits of Energy Efficient Design



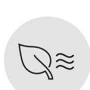
# 05.0 The Benefits of Energy Efficient Design

### Improve Health and Comfort

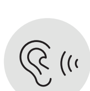
The strategies outlined in this guide can yield healthier and more comfortable buildings.

**HIGH-PERFORMANCE BUILDINGS:**

Eliminate transfer of smells, fumes, and smoke between units by sealing them off from one another.



Improve occupant health by supplying abundant fresh air and removing stale air.



Reduce noise from other units and the outside via thicker, better insulated walls.

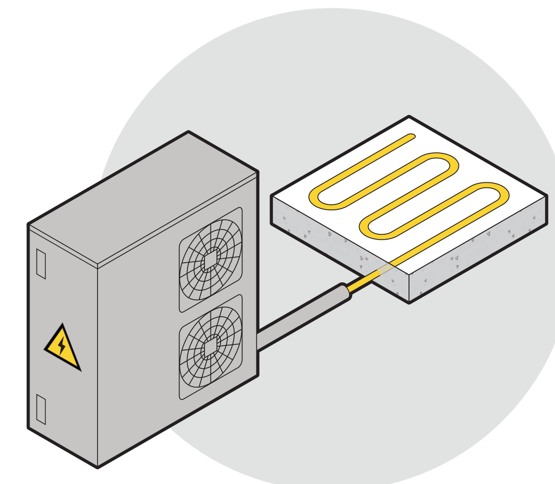
Improve comfort by reducing heat loss through the envelope.

### Reduce Costs

High-performance buildings help owners and occupants save money by lowering the amount of energy needed to provide a comfortable indoor temperature. They do so through improved insulation levels and more efficient mechanical systems. Buildings with thicker, higher-quality envelopes also tend to last longer, which lessens the need for costly repairs and upgrades over time.

### Provide Consistency to the Industry

The standard provides a clear set of steps and a shared "language" on energy efficiency between local governments. It serves as a clear roadmap to 2032, when all new construction must be built to a net-zero-energy-ready level of performance. Its staggered approach gives the industry the time it needs to upgrade skills, adopt new techniques, and identify new products and suppliers.



### Achieve Better Performance with Today's Technologies

The strategies outlined in this guide draw on technologies and practice that are already used across B.C. From building envelope systems to mechanical strategies, high-performance buildings can be achieved using familiar products.

### Reduce Greenhouse Gas Emissions

Although the BC Energy Step Code does not explicitly target greenhouse gas emissions by reducing energy demand, it will lower emissions in jurisdictions where natural gas is used for heat. Buildings that rely on electrical systems such as air-source heat pumps will help reduce carbon emissions, contributing to the province's overall climate goals.

# Appendix



# A1 Glossary of Terms

**AIR-SOURCE HEAT PUMP** A highly energy efficient heat pump-based system that uses low-grade heat from the ambient air and uses it as a source of heat to condition building interiors.

**AIRTIGHTNESS** The measure of an envelope's resistance to the leakage of air in or out of a building.

**ARTICULATION** An approach to building design that uses joints between different sections of a building's form such that they stand out individually. Highly articulated buildings have several transition points that create opportunities for thermal bridging to occur.

**BCBC** British Columbia Building Code

**BUILDING ENVELOPE (ENCLOSURE)** The elements that make up the outer shell of a building that separate indoor from outdoor spaces. A building's envelope prevents or controls the entry of heat, water, air, noise, and light from entering or leaving.

**BUILDING FORM** See massing.

**CLIMATE ZONE** A region of the country defined by its average temperature (based on heating degree days) and moisture. Climate zones in British Columbia range from Climate Zone 4 in Vancouver to Climate Zone 8 in the far north.

**COMPACT FORM** A building form that is characterized by a low surface-to-volume ratio.

**COMPARTMENTALIZATION** The isolation of individual suites or units in a building from one another such that they are individually ventilated.

**CONDUCTIVITY** A measure of a material's ability to conduct heat.

**COOLING DEGREE DAYS** The total number of days per year that the average outdoor temperature is above a certain threshold as to require cooling.

**CONDITIONED SPACE** Any space within a building in which the temperature is controlled to limit variation in response to the exterior ambient temperature by the provision, either directly or indirectly, of heating or cooling over substantial portions of the year.

**DAYLIGHTING** The practice of placing windows or other openings in the building envelope to allow the use of natural light and reduce the need for artificial lighting.

**EFFECTIVE R-VALUE** A measure of an envelope's thermal resistance, considering the effectiveness of the insulation when it is used in combination with other building materials, such as framing members.

**ENERGY EFFICIENCY** A measure of the effectiveness of energy use. A building with high energy efficiency requires less energy to perform the same tasks (e.g. heating, cooling, ventilation, etc.) as a building with lower energy efficiency.

**ENERGY PLANNER** In this guide, a broad category of energy-related local government positions, including energy managers, energy advisors, community energy managers, sustainability coordinators, and sustainability planners.

**ENERGY RECOVERY VENTILATION (ERV)** A ventilation device that captures the energy from stale air as it leaves a building and uses the warmth to temper or pre-heat incoming fresh supply air before circulating it to occupants. It also captures some of the humidity in the air to help temper indoor climates — in summer, humidity is removed from incoming air prior to being injected into a building; in the winter, the reverse process occurs.

**ENVELOPE** See building envelope.

**FACADE** The exterior face of a building.

**FENESTRATION** The placement or arrangement of windows on a building, including their general size and number.

**GEOEXCHANGE** A heat pump-based heating and cooling system that uses low-grade heat stored in the ground to condition interior building spaces.

**GEOMETRIC THERMAL BRIDGE** A thermal bridge that occurs where two planes meet, such as at a corner.

**GREENHOUSE GAS INTENSITY (GHGI)** A measure of the emissions intensity of a building's emissions, measured and expressed in tonnes or kilograms of carbon dioxide equivalent per square metre per year ($CO_2e/m^2/year$).

**GLAZING** Windows on a building.

**HEATING DEGREE DAYS** The total number of days per year that the average outdoor temperature is below a certain threshold as to require heating.

**HEAT RECOVERY VENTILATOR (HRV)** A ventilation device that captures heat from stale exhaust air as it leaves a building and uses the warmth to temper or pre-heat incoming fresh supply air before circulating it to occupants.

**HIGH-RISE MURB** A multi-unit residential building of six storeys or higher, and designed and built using concrete construction techniques.

**HYDRONIC** The practice of using a water-based medium to distribute heat throughout a building. Hydronic systems can use either radiators, in-floor systems, and in some cases, in-ceiling systems.

**HVAC** Heating, Ventilation, and Air-Conditioning, (usually refers to equipment).

**MASSING** A building's general shape and size.

**MURB** Multi-Unit Residential Building

**NATURAL VENTILATION** The process of intentionally exchanging air in a building to replace stale air with fresh air from the building exterior, using non-mechanical means such as stack effect, cross ventilation, design elements, and operable windows.

**PART 3 BUILDING** A building over three storeys in height or over 600 square metres in footprint. Part 3 also includes some buildings of three storeys or less in height or under 600 square metres in area that are of a specific use. This includes larger buildings intended for residential, commercial or medium-to-low hazard industrial activities, as well as buildings intended for public gatherings, residential care, detention, or high-hazard industrial activities.

**PART 9 BUILDING** A building three storeys and under in height and with a footprint of 600 square metres or less. Part 9 buildings include small buildings intended for residential, commercial or residential, commercial or medium-to-low hazard industrial activities.

**R-VALUE** The capacity of an insulating material to resist heat flow, or its ability to prevent heat from moving from one side to the other. The higher the R-value, the greater the material's insulating properties. R-values can be expressed in $h \cdot ft^2 \cdot °F/Btu$ (RSI units $K \cdot m^2/W$). U-value is the inverse of R-value.

**SOLAR HEAT GAIN** The increase in thermal energy in a building as it absorbs incoming solar radiation.

**STACK EFFECT** A phenomenon that occurs in taller buildings, this pressure differential between the interior and exterior drives the movement of interior air. In cooler months, it often creates positive pressure, which forces warmer air out of the enclosure at the upper portions of walls and the building, and draws cooler air into lower portions.

**THERMAL ENERGY DEMAND INTENSITY (TEDI)** A measure of the total heating energy necessary to maintain a comfortable indoor temperature over the course of a year, expressed in kilowatt hours per square metre per year ($kWh/m^2/year$).

**TOTAL ENERGY USE INTENSITY (TEUI)** A measure of the total amount of energy used by a building over the course of a year, per unit of building area, measured and expressed in kilowatt hours per square metre per year ($kWh/m^2/year$). TEUI encompasses all energy used in a building, including plug loads (e.g. lighting, appliances) and process loads (e.g. elevators, mechanical systems, and fans).

**THERMAL BRIDGING** The transfer of heat through materials and structures that interrupt the building's continuous insulation layer, causing heat to escape the interior of the building to the outside air. Thermal bridges lower overall building energy efficiency.

**THERMAL BREAK** The placement of a material of low conductivity (such as insulation) to prevent the transfer of heat through a building envelope.

**U-VALUE** A measure of how well a building element conducts heat. The lower the U-value, the greater the material's insulating properties. U-values are expressed in SI units of $W/(m^2K)$ and U.S. units of $BTU/(hr\ °F\ ft^2)$. U value is the inverse of R value.

**VENTILATION** The process of introducing fresh air to replace stale air in a building by mechanical or natural means.

**VFAR** A building's vertical surface area to floor area ratio. A building's VFAR influences a building's heating energy use, as buildings in B.C. lose the most heat through their vertical surface areas.

**VFR** Variable Refrigerant Flow, or a highly energy efficient refrigerant-based heating and cooling technology.

**WWR** Window-to-wall ratio, or the percentage of a building's facade that is made up of glazing.

# A2 Image Sources

**PAGE 15**
*The Spot, Vancouver, B.C.*
**Source** http://www.tcpm.ca/wp/portfolio/the-spot-at-12th-and-cambie/

*Kiln Apartments, Portland, OR*
**Source** http://kilnpdx.com/

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*Cornerstone Apartments, Vancouver, B.C.*
**Source** http://www.cornerarch.com/passive-house/

*Girard, 600 Harrison Ave, Boston, MA*
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*Marquis Lofts, Portland, ME*
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*Marine Gateway, Vancouver, B.C.*
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*Cornell Tech Residential, NYC*
**Source** https://www.burohappold.com/projects/the-house-at-cornell-tech/

*Girard, 600 Harrison Ave, Boston, MA*
**Source** http://www.sabmagazine.com/blog/2016/06/08/2016-regional-quebec-winner/

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*Terrace 459, Chicago, IL*
**Source** http://www.holstenchicago.com/communities/terrace459.html

*Ponderosa Commons, Vancouver, B.C.*
**Source** http://www.garibaldiglass.com/items/ubc-ponderosa-commons/

*Mclaren House, Vancouver, B.C.*
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*Riverport Flats, Richmond, B.C.*
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*Orchards at Orenco, Portland, OR*
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*Richardson Apartments, Portland, OR*
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*Knickerbocker Commons Passive House, NY*
**Source** http://blog.eima.com/eifs-in-the-spotlight-knickerbocker-commons/

**PAGE 34**
*Exterior supported balconies*
**Source** http://www.wright-ryan.com/blog/portfolio/marquis-lofts/

*Exterior hung balconies*
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*Thermally-broken balconies*
**Source** https://kirhammond.files.wordpress.com/2015/05/balcony-photo-for-schock.jpg

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*Kiln Apartments, Portland, OR*
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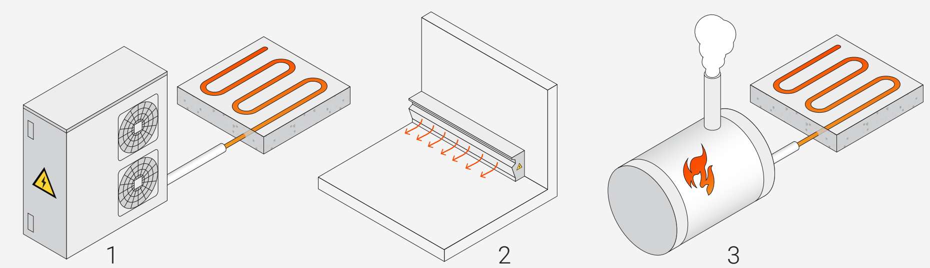
*100 Pike, Seattle, WA*
**Source** http://www.cascadebuilt.com/project/thirteenandpike/

*Cornell Tech Residential, NYC*
**Source** https://www.burohappold.com/projects/the-house-at-cornell-tech/

# Supplement



# S1 Complying with the City of Vancouver's Zero Emissions Building Plan




Hydronic delivery (diagram 1) and electric baseboard (diagram 2) systems are low-carbon mechanical systems that will conform to the City of Vancouver's Zero Emissions Building Plan. However, gas-based systems (diagram 3) can be selected where designers pursue a higher step than they are required to under the Plan.

## Reducing GHG Emissions

The City of Vancouver has authority over its own building code, and has instituted its own step code-like provisions described in the Zero Emissions Building Plan (ZEBP). In addition to setting targets for TEUI and TEDI, the ZEBP sets thresholds for performance in greenhouse gas intensity (GHGI). GHGI is a measure of the emissions intensity of a building's emissions, measured and expressed in tonnes or kilograms of carbon dioxide equivalent per unit area over the course of a year (kg $CO^2/m^2$/year).

## Selecting a Low-Carbon Mechanical System

The addition of a GHGI threshold requires building designers to consider not only the quantity of energy that a building will demand, but the source of that energy. As such, the selection of mechanical strategies is of central importance to the achievement of GHGI performance targets in the City of Vancouver's ZEBP. One of the easiest ways to achieve the GHGI targets in the ZEBP is to select a mechanical system that runs on the low-carbon electricity available in British Columbia. Heat pumps and electric resistance (e.g. baseboards) heating systems are readily available systems that can provide heat cost effectively, while reducing emissions. In some cases, buildings can also connect to a low-carbon district energy system.

Conversely, the selection of mechanical strategies that rely on energy sources with higher carbon intensities will render the achievement of GHGI targets more difficult. Due to their higher emissions intensity, designs that incorporate natural gas-based systems may not be able to meet the City of Vancouver's GHGI targets. While natural gas can still be used when necessary (e.g. for hot water heating), designers looking to lower GHGI should try to minimize the combustion of natural gas in the building wherever possible.

## Reducing Global Warming

In addition to GHGI, designers should also consider assessing the global warming potential (GWP) of any refrigerants that may be used, as reporting the GWP of refrigerants is a requirement of the City of Vancouver's Green Buildings Policy for Rezoning.

# S2 Summary of Key Strategies: Vancouver's Zero Emissions Building Plan

The design strategies necessary to met the Step Code (p. 25) are also applicable to designers seeking compliance with the City of Vancouver's Zero Emission Building Plan (ZEBP).

While certain design strategies will help meet a single performance target (e.g. TEDI), others will help accomplish a number of different targets, including GHGI. Practitioners should consider these core strategies — addressing building shape, orientation, and envelope, as well as mechanical and ventilation systems — early in the design process. Proponents must retain the services of an energy modeler at the design and permitting stages. To ensure overall compliance, designers should rely on hourly energy modelling tools.

## Diagram Description

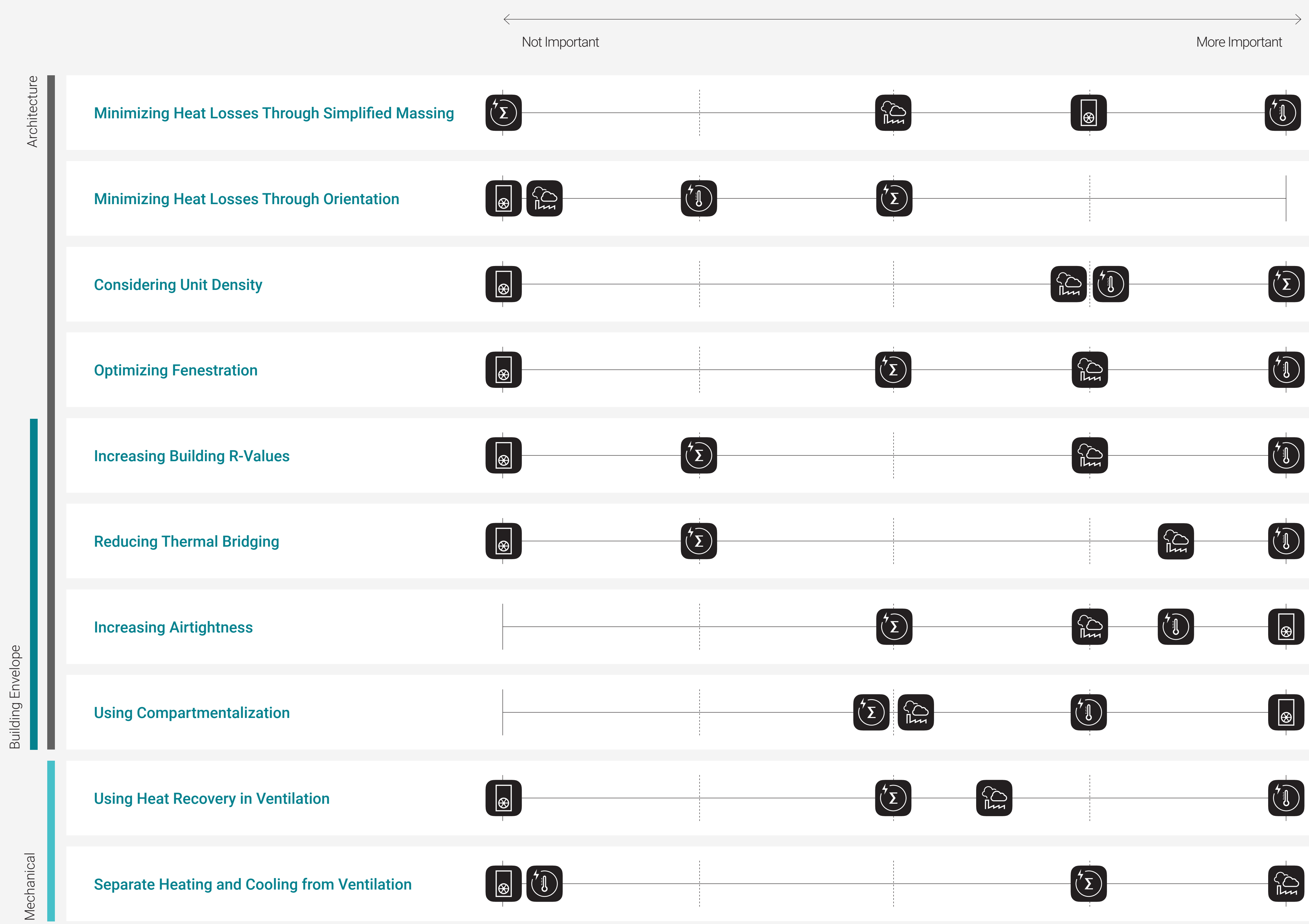
The figure to the right shows the importance of each design strategy in relation to the three key metrics of the BC Energy Step Code (TEDI, TEUI, and airtightness), as well as for their emissions reduction potential (GHGI) under the ZEBP.

The impact of each design strategy on GHGI depicted here assumes the use of a natural gas-based system. To explore the impact of different design decisions interactively, visit the **Building Pathfinder website**.

**LEGEND**

- TEDI
- TEUI
- Airtightness
- GHGI

- Architecture
- Building Envelope
- Mechanical



## SECTION S3-01.

# Introduction

# S3-01 Introduction

Buildings play a key role in preventing the adverse effects of climate change by employing design strategies to both reduce greenhouse gas (GHG) emissions and adapt to current and projected impacts.

To help reduce emissions from buildings, the Province of British Columbia has taken a number of actions. Under the umbrella of the CleanBC program, one such action is the release of the BC Energy Step Code, which sets energy performance requirements for new buildings as a means of reducing their energy use and emissions.

At the same time, the Province is projected to experience significant changes in climate over the next several decades, which will have considerable impacts on building performance. Preparing for Change: British Columbia's Adaptation Strategy, projects overall temperature increases of between 1.3 and 2.7°C by the year 2050, as well as heavier rains, longer dry spells, more heat waves and more severe wildfire events.[1] Such impacts can pose serious risks to British Columbia's buildings and the safety, well-being, and financial investments of their owners and occupants. Indeed, the average temperature across the province has already increased by 1.4°C over the last hundred years, with impacts on the built environment already occurring in different regions.[1]

Buildings can be designed to increase their resilience to these changes and in doing so, increase both their quality and overall value. Buildings constructed today should be designed in such a way that the comfort and safety of their occupants is ensured for the lifetime of the building. This is especially important as current building codes and standards are reflective of historical experiences – that is, they are based on past climatic conditions, and don't necessarily consider the impacts of a warmer world on the health, comfort, and safety of building occupants. Looking to future conditions is an increasingly important part of building design across all regions of the province.

[1] https://www2.gov.bc.ca/gov/content/environment/climate-change/adaptation/impacts

## Additional References

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**BC Building Code – Appendix C**
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**Update on Extreme Heat and Maximum Indoor Temperature Standard for Multi-unit Residential Buildings**
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## The Purpose of the Design Guide Supplement

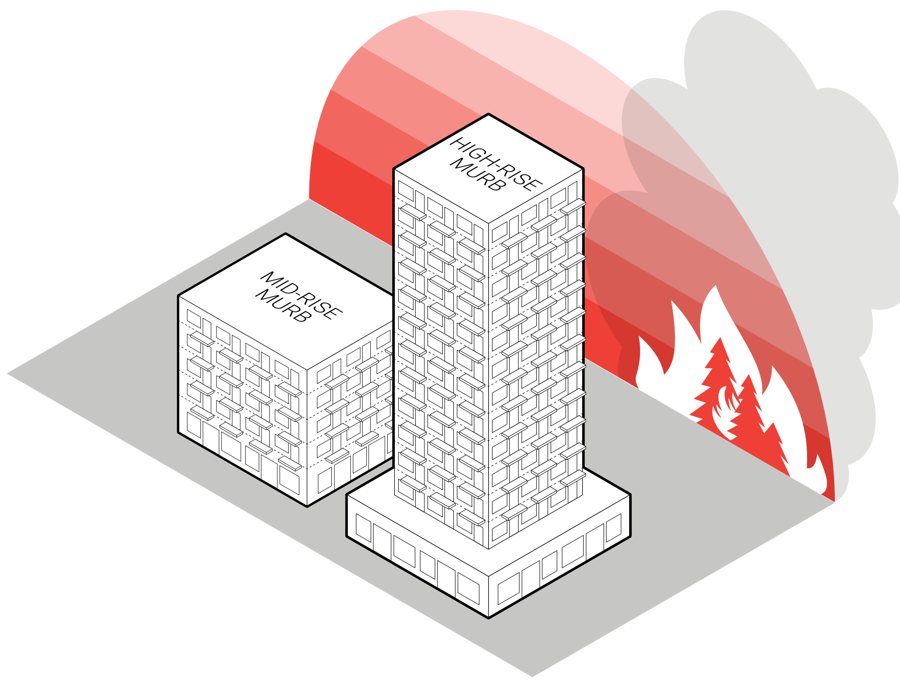
While potential climate change impacts on the built environment range by region and precise project location, this resource presents a set of design principles, strategies and practices intended to reduce the risk of two significant climate-related issues:

**1**

**Overheating**
due to higher average temperature and increases in extreme temperature events (such as heat waves)

**2**

**Indoor air quality issues**
due to an increase in wildfire events (as well as more localized sources of air pollutants)

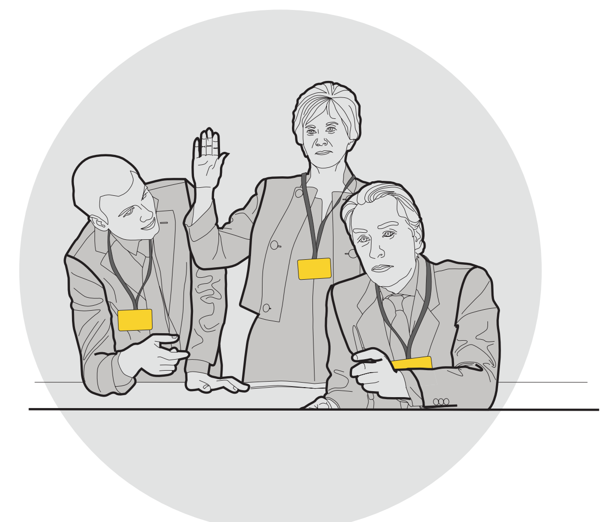



The information is intended primarily for Part 3 High-Rise and Mid-Rise Multi-Unit Residential Buildings (MURB) in British Columbia, and is most relevant for buildings constructed in Climate Zones 4 and 5. However, several of the strategies will also be useful and applicable to projects located in higher climate zones and to Part 9 MURB. While the information contained in this guide is relevant mainly to new buildings, many strategies can also be applied to renovations of existing buildings.

For those pursuing the BC Energy Step Code, the supplement is intended to complement the rest of the BC Energy Step Code Design Guide and should be referenced alongside it. However, the guide will serve as a useful resource for those working outside of British Columbia as well.

## Who Is This For?

This guide is a resource for local governments and design teams interested in pursuing the BC Energy Step Code.



### LOCAL GOVERNMENTS

Planners, urban designers, and other members of local government staff can play a role in supporting resilient buildings by encouraging the submission of applications that indicate how climate change adaptation strategies have been incorporated into building design. Local governments can use this guide as a means of understanding and promoting resilient building strategies.

### DESIGN TEAMS

Developers, architects, mechanical and building envelope engineers, and energy modellers all have a role to play in the design of safe, comfortable, and resilient buildings. Design teams that explore strategies to improve building resilience early on in the design process can more successfully identify ways to harness efficiencies and reduce overall costs. Teams should use this resource in conjunction with the rest of the BC Energy Step Code Design Guide to explore different design strategies for their potential to simultaneously improve energy efficiency, reduce GHG emissions, and improve overall building resilience.

## SECTION S3-02.

# Risk and Resilience in Building Design



## Resilience in Building Design

The idea of **resilience** refers to the ability of a system (such as a building) to anticipate, absorb, accommodate, or recover from the effects of an event or stress in a timely and efficient manner. The way in which a building adapts to an event (e.g. air quality advisory) or ongoing stress (e.g. elevated summer temperatures) depends on a number of factors, including its location, design, operations, and maintenance.

In general, a **resilient building** is one that is able to:

1. **Maintain critical operations and functions** in the face of either an acute shock or chronic stress, and return to normal operations in a fast and efficient manner, in order to maintain healthy, liveable spaces for its occupants.

2. **Improve the overall health and well-being** of its occupants through its design and operation.

## Key Terms

**PASSIVE SURVIVABILITY** is the extent of a building's ability to maintain healthy, liveable conditions in the event of extended loss of power or water, or in the event of extraordinary heat waves, storms or other extreme events.

**SHOCK** is an acute natural or human-made event or phenomenon threatening major loss of life, damage to assets and a building or community's ability to function and provide basic services (e.g. heat wave, wildfire).

**STRESS** is a chronic (i.e. ongoing or cyclical) natural or human-made event or phenomenon that renders a building or community less able to function and provide basic services (e.g. increased temperatures).

**THERMAL RESILIENCE** is the ability of a building to achieve thermal comfort in the event of power outages by improving weatherization and insulation, increasing air circulation, reducing solar gains through windows, increasing natural ventilation, and minimizing internal heat gains.

**VULNERABLE POPULATIONS** are groups and communities at a higher risk for poor health as a result of the barriers they experience to social, economic, political and environmental resources, as well as limitations due to illness or disability. These include children, pregnant women, elderly people, people with low incomes, and people who are ill or immunocompromised.

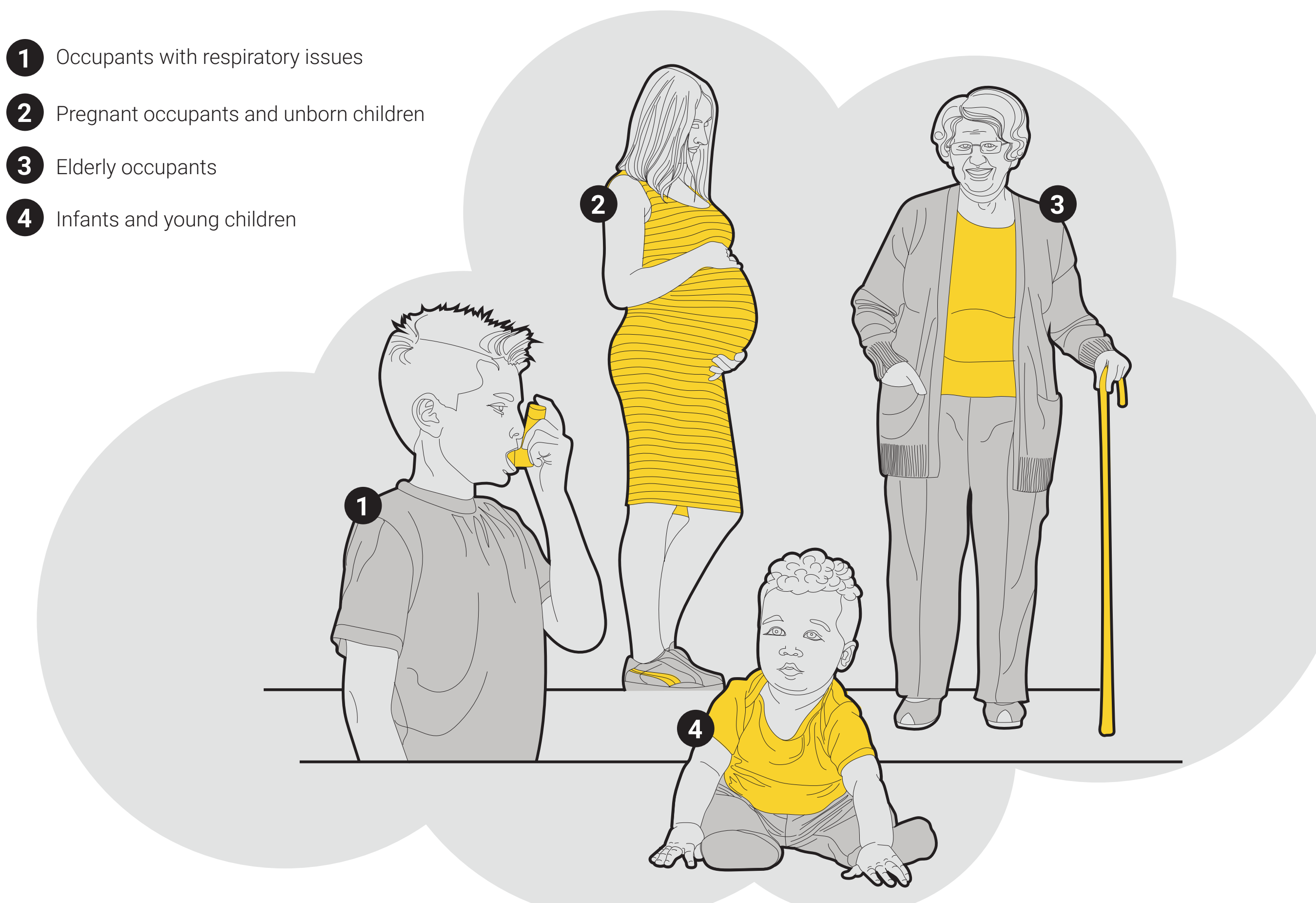
## Designing for Comfort and Safety

Designing for the most vulnerable occupants of a building can be a way to ensure that all occupants remain comfortable and healthy. This approach should be used by carefully considering the building's expected occupancy, and identifying strategies that benefit all occupants.

Resilient building design involves the need to maintain overall health and well-being of all building occupants. Designed, constructed, and managed thoughtfully, a resilient building can actually improve its core functions over the business-as-usual, and offer a safer, more comfortable alternative for both its occupants and the broader community.

For example, a highly resilient building can act as a refuge centre for a block or neighbourhood during extreme events by providing access to communal spaces with power, cooling, and good ventilation. Such centres can provide important resources during a range of extreme events, from heat waves to extreme storms and earthquakes.

1. Occupants with respiratory issues
2. Pregnant occupants and unborn children
3. Elderly occupants
4. Infants and young children



# 02.1 What is Overheating?

Overheating occurs when a space becomes too warm for its occupants. Prolonged or dangerously high temperatures can cause health risks, such as heat stress, heatstroke, increased morbidity or even mortality, particularly in vulnerable populations. Indeed, exposure to indoor temperatures above 26°C has been associated with increased premature mortality and emergency medical services calls[2,3].

### Overheating vs. Thermal Comfort

Related to the concept of overheating is **thermal comfort**, which is achieved when an occupant is satisfied with the temperature in a particular space. Individuals' experience of thermal comfort is complex, highly subjective and can depend on:

1. **Individual characteristics** (e.g. age, metabolic rate, size, overall health, preference)
2. **Behavioural factors** (e.g. whether a person is at rest, sitting, walking, or exercising)
3. **Cultural norms** (e.g. type of attire worn)
4. **Physical considerations** (e.g. air and radiant temperatures, air speed and relative humidity)

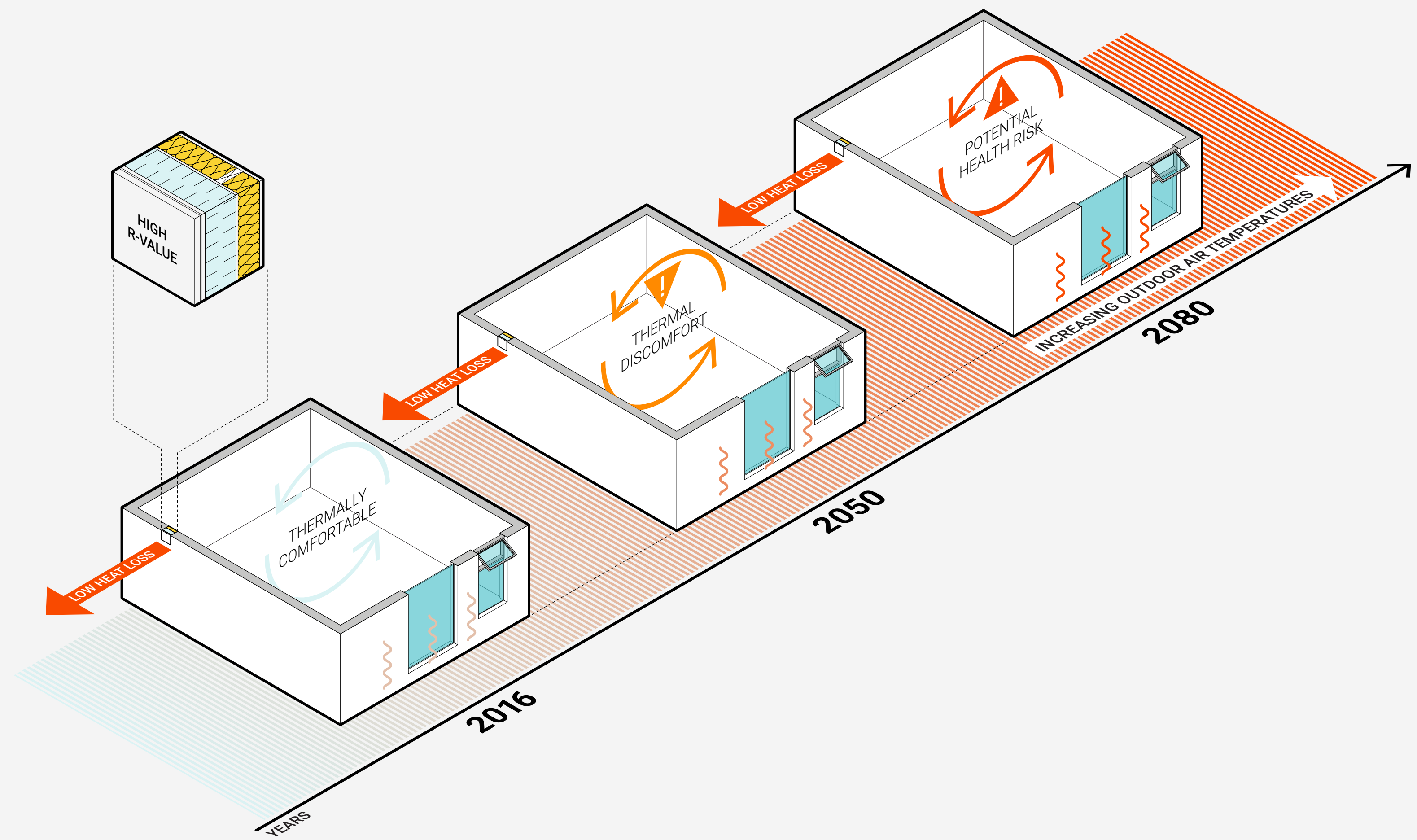
### Designing for Thermal Comfort

While experiences of thermal comfort can vary, ASHRAE Standard 55 – Thermal Environmental Conditions for Human Occupancy is a research-based standard that outlines specific methodologies to predict and measure occupant thermal comfort for healthy adults.

ASHRAE Standard 55 generally recommends occupied spaces to be designed to stay below 24-25°C (dry bulb) in the winter and 27-28°C (dry bulb) in the summer to prevent overheating. However, this can vary based on the intended use of the space, as well as other factors. For example, young children may not be able to cope with higher temperatures.

While it may not pose health risks for everyone, the experience of thermal discomfort can impact quality of life.

For instance, occupants may not be able to use building spaces as they were designed to (e.g. a bedroom may be too warm to sleep in). Occupants may leave a building altogether if it becomes uncomfortably hot, interrupting their ability to live and work normally.




### Comfort Today Can Be Discomfort Tomorrow

In 2009, British Columbia experienced a heat wave that contributed to an additional 110 overheating-related deaths per week[4].

Globally, the five hottest years have all occurred since that year[5], and even warmer temperatures are anticipated in the future.

As temperatures continue to increase, so too will the likelihood and magnitude of overheating in our buildings. Spaces that are designed to be comfortable today are likely to become uncomfortable under future climate conditions if care isn't taken to consider increasing temperatures. Energy efficient buildings can be especially at risk of overheating, as higher performance building envelopes can retain more heat in the summer.

Overall, designers will need to provide an adequate source of cooling using both passive and active building strategies to maintain the comfort and livability of our buildings.

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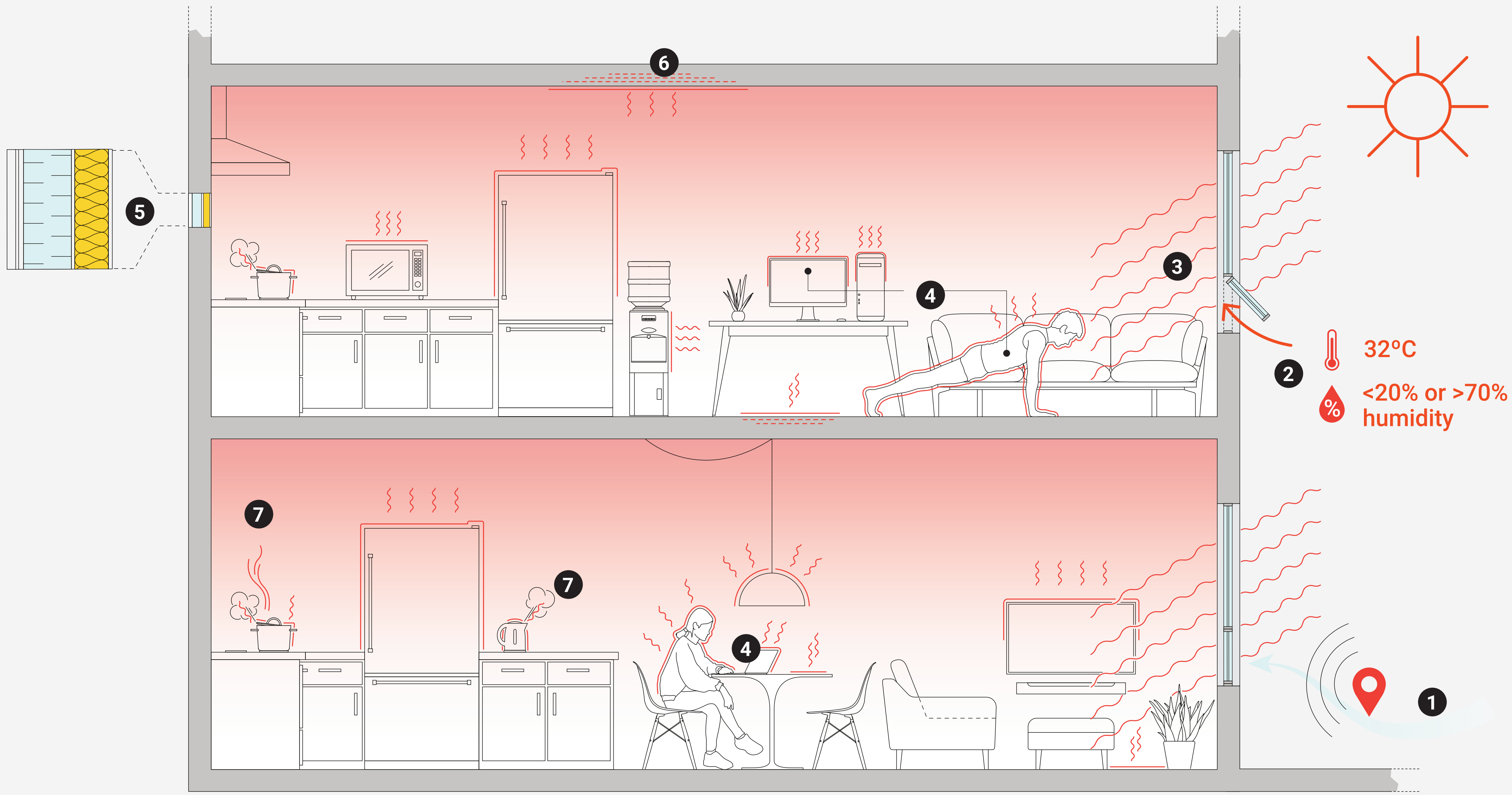
## Factors Involved in Overheating

Overheating can be caused by a combination of physical, behavioural and climatic factors.




1. **Contextual or situational factors** that prevent occupants from opening their windows (e.g. noise, pollution, poor outdoor air quality)
2. **High external temperatures** and/or extreme humidity levels
3. **Internal heat gains** via incoming solar radiation through the building glazing
4. **Internal heat gains** from lighting, equipment, occupants and occupant activities
5. **High wall and roof insulation** and/or building airtightness that retain internal heat gains
6. **Absorption of heat** by the buildings structure that create high surface temperatures
7. **Lack of adequate ventilation** that could assist in cooling

## Limiting Overheating

Both the BC Energy Step Code (BCESC) and the City of Vancouver Zero Emissions Building Plan (ZEBP) set limits for overheating.

For spaces that do not use any mechanical cooling, temperatures cannot exceed "80% acceptability limits" for more than **200 hours** during the summer months. The 80% acceptability limit is a specific temperature during the summer months at which overheating can be a concern, which varies depending on the building's location. This limit is calculated using a methodology defined in ASHRAE Standard 55. A full definition can be found in the City of Vancouver Energy Modelling Guidelines v2.0. It is important to note that buildings that house vulnerable populations have a lower limit of **20 hours**, but owners and project teams may target a lower number to limit the risk of overheating for project type.

For spaces that make use of mechanical cooling, design teams must demonstrate that each space will experience less than 100 "unmet cooling hours" per year. Unmet cooling hours occur when a cooling system is unable to achieve the desired indoor temperature. A full definition of unmet cooling hours can be found in NECB 2015 – Section 8.4.1.2 Determination of Compliance.

## International Guidance

The Chartered Institution of Building Services Engineers (CIBSE, similar to ASHRAE in the United Kingdom) provides tools to reduce the risk of overheating through Technical Memoranda TM52 and TM59. These set a 3% limit on the number of hours that a space's indoor temperature can exceed the threshold comfort temperature by 1°C or more during the occupied hours of a typical non-heating season. Overheating limits are also set for the severity of overheating on a given day (i.e. the number of hours), as well as an absolute maximum daily temperature for each room. For example, **bedrooms cannot exceed an operative temperature of 26°C for >1% annual night-time hours, between the hours of 22:00 and 07:00.**

# 02.2 What is Indoor Air Quality?

Indoor air quality is an important determinant of the health of building occupants and is affected by both indoor and outdoor factors.

## BC Air Quality Projections

Climate change projections for BC include an increase in the number of wildfire smoke events. This smoke contains a mixture of fine particulate matter, carbon monoxide, nitrogen oxides, volatile organic compounds, and heavy metals. Studies also predict increased levels of ozone in the summer months. While ozone in the stratosphere plays a beneficial role in offering protection from the sun's ultraviolet rays, ozone near the ground contributes to the formation or urban smog and is harmful to breathe.

Exposure to air contaminants have been linked to several short- and long-term health effects, including:

- *Fatigue*
- *Headaches*
- *Eye/nose/throat irritation*
- *Impaired cognitive function/decline*
- *Respiratory diseases*
- *Cardiovascular disease*
- *Diabetes and obesity*
- *Cancer*

## Air Quality Standards

The BC Building Code (BCBC) recognizes that outdoor air may not always be of an acceptable quality for ventilating buildings unless certain particles and gases are first removed or reduced. Code requirements for indoor air quality are outlined in the BCBC and ASHRAE 62.1, and set minimum ventilation requirements to maintain $CO_2$ concentrations below a certain threshold.

Developers interested in pursuing higher air quality standards can find examples in the Leadership in Energy and Environmental Design (LEED) standard and the WELL Building Standard™, both of which define thresholds for various pollutants. These standards require verification to demonstrate compliance with their set thresholds, and assess the effectiveness of ventilation systems to verify that a sufficient level of ventilation is provided.

## Factors Involved in Poor Indoor Air Quality

**1**

**Indoor sources of contaminants** include cleaning products, off-gassing from building materials and furnishings, cooking, and parkade exhaust, among others. High noise levels outside may also force occupants to close their windows, increasing the risk of poor indoor air quality.

- COOKING
- CLEANING PRODUCTS
- MATERIAL OFF-GASSING

**2**

**Outdoor sources of contaminants** that vary depending on local context, and include traffic, industry, construction, and hazmat emergencies involving flammable or poisonous substances.

- TRAFFIC
- INDUSTRY
- CONSTRUCTION
- HAZMAT EMERGENCIES
- NOISE

**3**

**Outdoor sources of contaminants** that affect entire regions, including urban smog due to increased ground-level ozone, and wildfire smoke events that will increase in frequency and severity with climate change.

- WILDFIRE

# 02.3 A Balancing Act

Design strategies that minimize overheating and indoor air quality issues can impact a building's chances of achieving the targets of either the BC Energy Step Code and/or the City of Vancouver's Zero Emissions Building Plan. It is therefore important to understand the relationship between these targets.

### Total Energy Use Intensity (TEUI)

Passive cooling strategies, such as operable windows, help to reduce a building's TEUI. However, they can be unsuitable under conditions of poor exterior air quality, as they let in unfiltered air. Using mechanical cooling to keep a space comfortable in the summer can help to prevent poor outdoor air quality from entering the building, especially when some degree of filtration is added.

### Airtightness (AT)

Improved airtightness leads to better TEDI performance and reduces the risk of indoor air quality issues from outdoor sources. A more airtight building envelope is highly effective in reducing winter heat loss. However, a less airtight building will not help to dissipate summer heat, making airtightness an important consideration for all building designs.

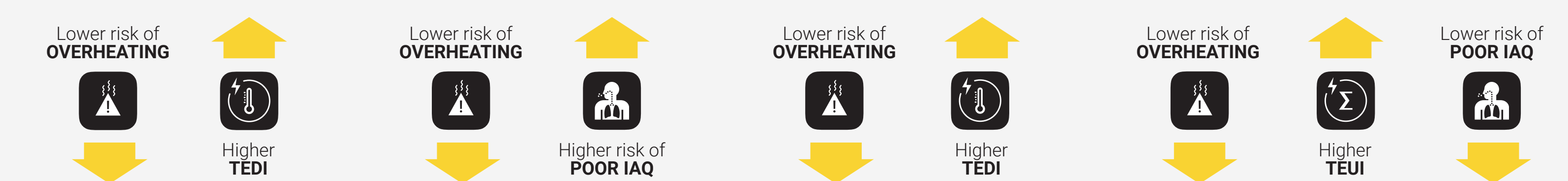
### Thermal Energy Demand Intensity (TEDI)

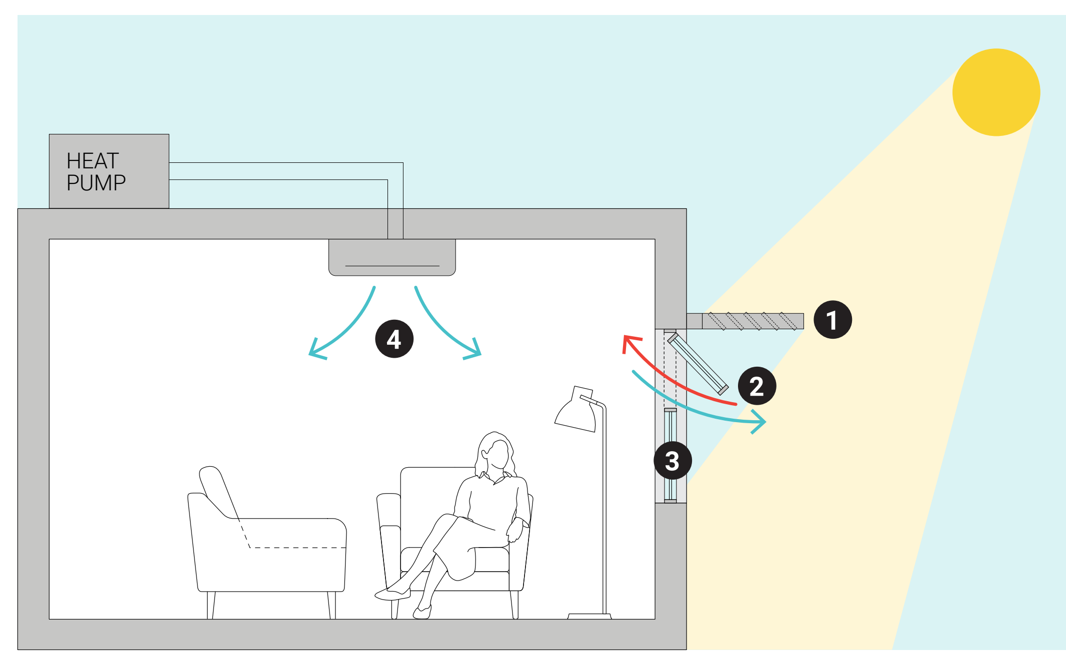
A high-performance building envelope will lead to better TEDI performance and can slow the movement of summer heat into the building. However, it can also lead to overheating issues when internal gains are trapped inside during the summer months. Passive cooling strategies designed to reduce overheating can also result in an increase in a building's overall TEDI in the winter by reducing passive solar gains.

### City of Vancouver ZEBP Greenhouse Gas Intensity (GHGI)

Depending on the system that is used, mechanical cooling can increase both the TEUI and the GHGI of a building. Using heat pumps for both heating and cooling can reduce a building's GHG emissions when compared to a natural gas-based or lower-efficiency electric heating system.

1. **Exterior shading** can be an effective strategy for reducing risk of overheating. However, it can also block desired passive solar heating in winter if not carefully designed, increasing TEDI.
2. **Operable windows** allow occupants to passively cool their space. In some situations, this unfiltered air may have an adverse effect on indoor air quality.
3. **Low solar heat gain glazing** can reduce the risk of overheating. As with shading, however, this may also block desired passive solar heating in winter, increasing TEDI.
4. **Mechanical cooling** can eliminate any overheating issues, but at the expense of increased energy use, increasing TEUI. This can also help with indoor environmental quality since it can allow the occupant to keep windows closed, keeping both noise and contaminated outdoor air out.




**THE RIGHT TOOLS FOR THE JOB**

Proper evaluation of strategies such as exterior shading and operable windows can be complex and require the use of powerful simulation tools. Ensure your team has the right tools to provide good quality information for making decisions.

**KEY TAKEAWAY**

Consider the impacts of design strategies used to achieve energy efficiency or emissions reductions on occupants' thermal comfort and indoor air quality.

## SECTION S3-03.

# Modelling for a Future Climate

# 03.0 Modelling for a Future Climate

One of the key ways that design teams can explore a building's potential for overheating is by using an energy model.

Energy models are used to assess the impact of a building's design on occupants' comfort by simulating building performance using different assumptions, including assumptions around the weather. However, standard approaches to energy modelling use weather files that are based on 30 years of historical data – in other words, the climate of the past. Since the climate has continued to warm and change, these weather files are unable to accurately represent current conditions, let alone future conditions.

Adopting an approach to energy modelling that takes future climate conditions into account can help design teams and owners make decisions today that will last the life of the building. This is particularly important given that occupants will be using these buildings for the next 50 years, if not more.

## 03.1 Understanding Weather Data

To model for a future climate, energy modellers need future climatic data. These data come in different formats, and often have different intended uses.

**Energy Simulation Weather Files** are used in energy models to help simulate the performance of a building over the course of a year.

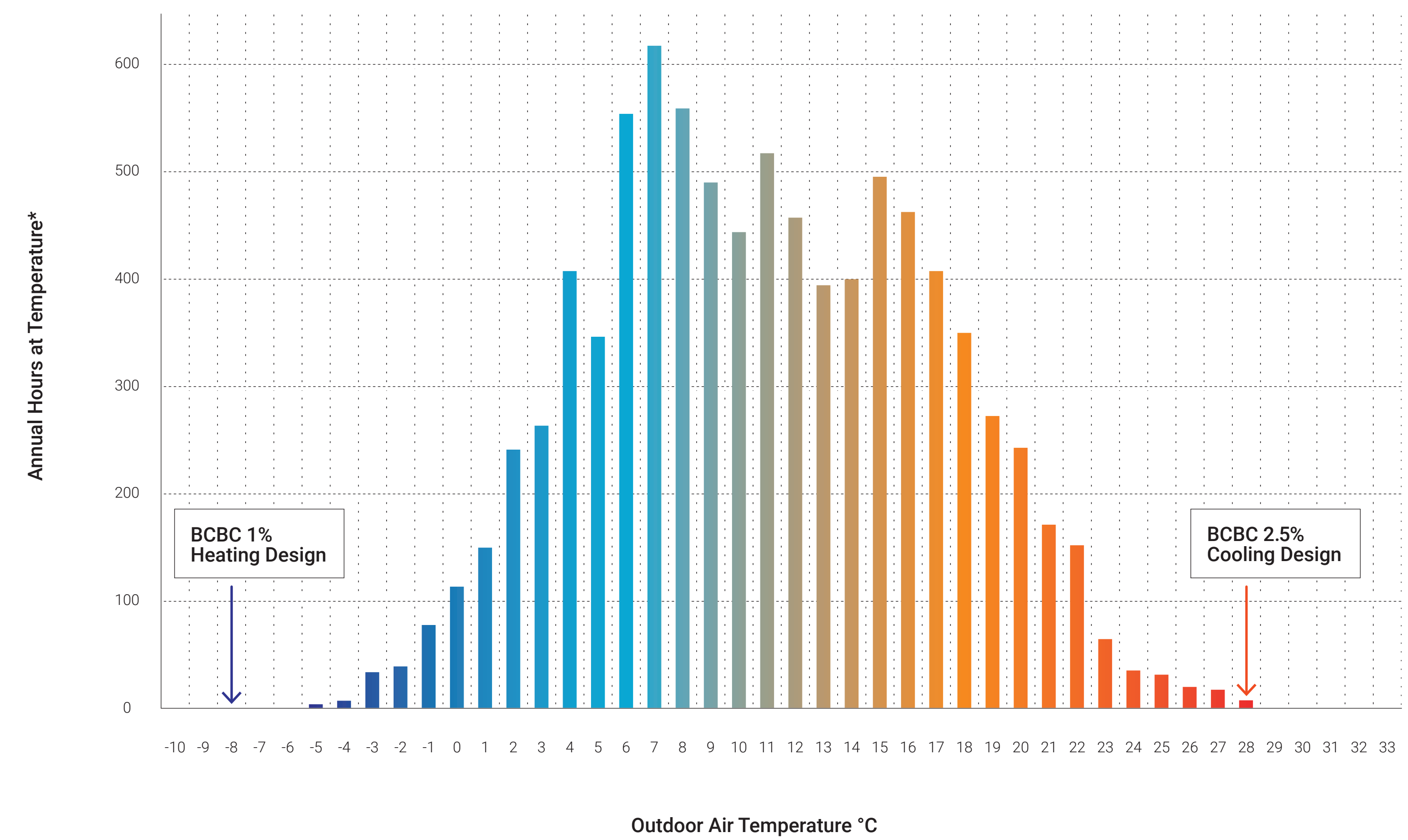
Canadian Weather Year for Energy Calculation (CWEC) files are used to represent a "typical" year of weather data. These files are generated by Environment Canada for a specific location based on 30 years of historical weather data using the most typical results for each month of the year. The original CWEC files used data from 1959 to 1989, but were updated in 2016 to reflect 1984 through 2014.

**Design Data** represent peak conditions for a location and are used for sizing mechanical heating and cooling equipment. These data are provided in the National Building Code, BC Building Code and Vancouver Building Bylaw.

Design data use near-worst case winter and summer temperatures, which are based on weather observations collected from 1981 to 2006 by the Atmospheric Environment Service at Environment Canada.

- *For summer, mechanical cooling systems are typically designed to the July 2.5% temperature – in other words, only 2.5% hours per year are expected to increase above this temperature.*
- *For winter, heating equipment is typically designed to the January 1% temperature – in other words, only 1% hours per year are expected to go below this temperature.*

A Common Example of Weather File Used in Energy Simulation




* Typical Number of Hours Based on 30 Years of Historical Weather Data (1984 -2014) Published in CWEC 2016.

An energy simulation weather file will contain temperature data for all 8760 hours of the year for a given location, while design data only represent the hottest and coldest conditions for mechanical equipment sizing.

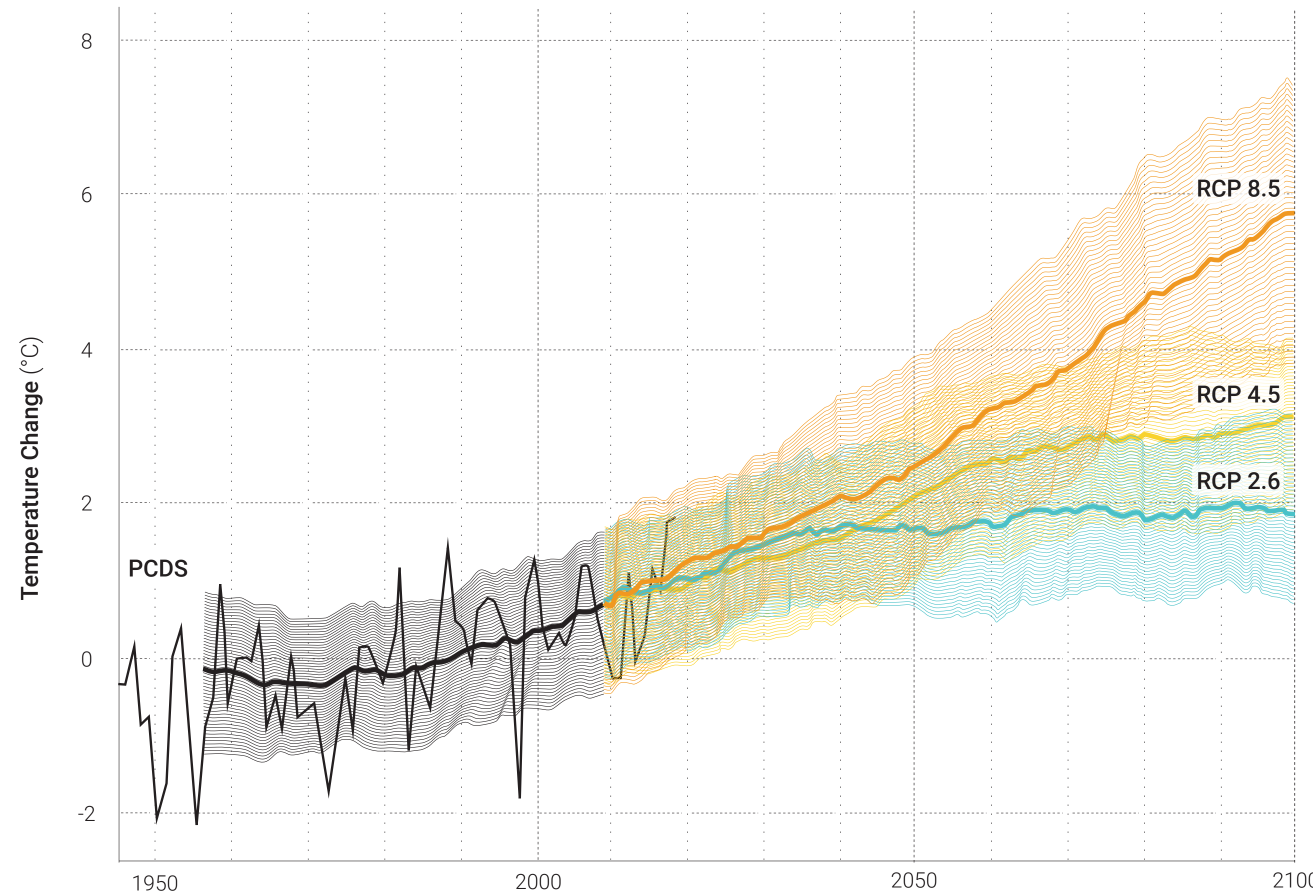
# 03.2 Performing a Future Climate Analysis

Design teams can conduct future climate analysis using available data on future weather projections and climate scenarios. Running multiple time periods and climate scenarios can help to give owners and design teams a better understanding of the potential impact of different design decisions.

**Weather file projections** are most often developed for the 2020s, 2050s and 2080s.

**Climate scenarios** are usually presented using three possible futures, or "Representative Concentration Pathways" that indicate the degree of climate change severity that we are likely to experience:

- *The **Best-Case Scenario (RCP 2.6)** assumes that we will drastically reduce our GHG emissions and begin to remove existing GHGs from the atmosphere.*
- *The **Stabilization Scenario (RCP 4.5)** assumes that all countries will undertake measures to mitigate emissions simultaneously and effectively.*
- *The **Worst-Case Scenario (RCP 8.5)** assumes that we will experience high population growth and relatively slow income growth with modest rates of technological change and energy intensity improvements.*




Adapted from Figure SPM.7a from "Summary for Policymakers" by Climate Change 2013: The Physical Science Basis. Lighter colour bands represent the range of potential temperature increases within a single scenario.

### Sources of Future Weather Files

**CLIMATEDATA.CA**

Launched by the Government of Canada in July 2019, this site allows users to search for climate data by location, view interactive climate data maps with detailed time series graphs, and download datasets.

**WEATHERSHIFT.COM**

This site provides simple future weather projections for major Canadian cities and allows weather files to be uploaded and translated into future scenarios for a fee.

**PACIFIC CLIMATE IMPACTS CONSORTIUM**

PCIC is a leading organization researching climate change and its impact to Canada's western regions. Their website provides access to a variety of practical tools and sources of climate information.

**KEY TAKEAWAY**

Even with ongoing efforts to reduce our carbon emissions, changes in climate to 2050 are guaranteed due to the inertia in the climate system. At a minimum, building designers should consider a 2050 climate scenario of RCP 8.5. Even if the climate begins to stabilize before 2050, this will improve resilience for the lifespan of the building.

## Case Study: A Future Climate Analysis for a Mixed-Use Residential Building

A climate weather analysis was completed on a mixed-use residential and clinic facility in Vancouver to better understand the design strategies a specific project might need to reduce overheating. The analysis compared the risk of overheating using CWEC 2016 data to the risk that might occur in 2050.

The study explored operable windows as a way of reducing the total number of overheating hours. Under a CWEC 2016 climate, the model showed that operable windows reduce overheating hours from 2271 to 29, making them a good passive cooling strategy.

However, the warmer temperatures of the 2050s make operable windows far less effective, pushing overheating hours above the BC Energy Step Code's allowable limit of 200 hours for the general population, and 20 hours for vulnerable populations. The results of this study show that additional strategies are necessary to cool the building.

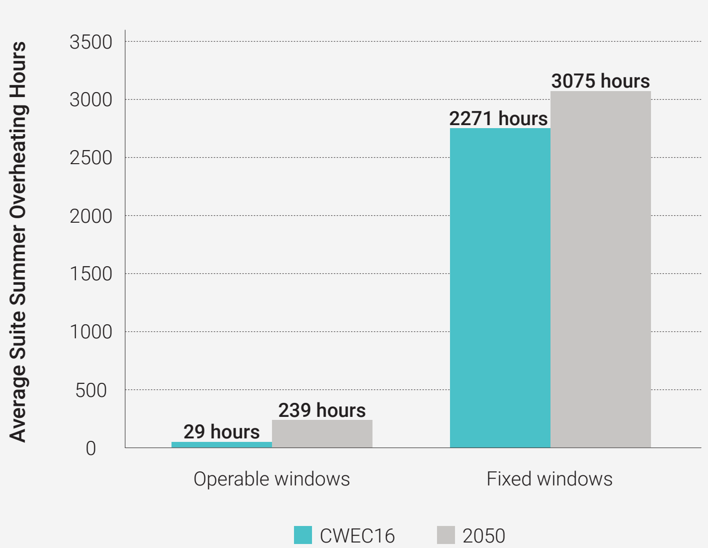
To explore additional methods of passively cooling the building, a second analysis explored the effectiveness of shading for the hottest rooms in the building.

The study found that for these rooms, peak indoor temperatures can coincide with peak outdoor temperatures, and not the peak intensity of incoming solar gains. As such, adding shading will not be sufficient in preventing overheating. As peak outdoor summer temperatures in the 2050s near 34°C, indoor temperatures in these suites will exceed the target indoor temperature of 28°C set by ASHRAE 55.

The results of these modelling exercises show that adding some form of mechanical cooling will be necessary to avoid overheating in the 2050s.

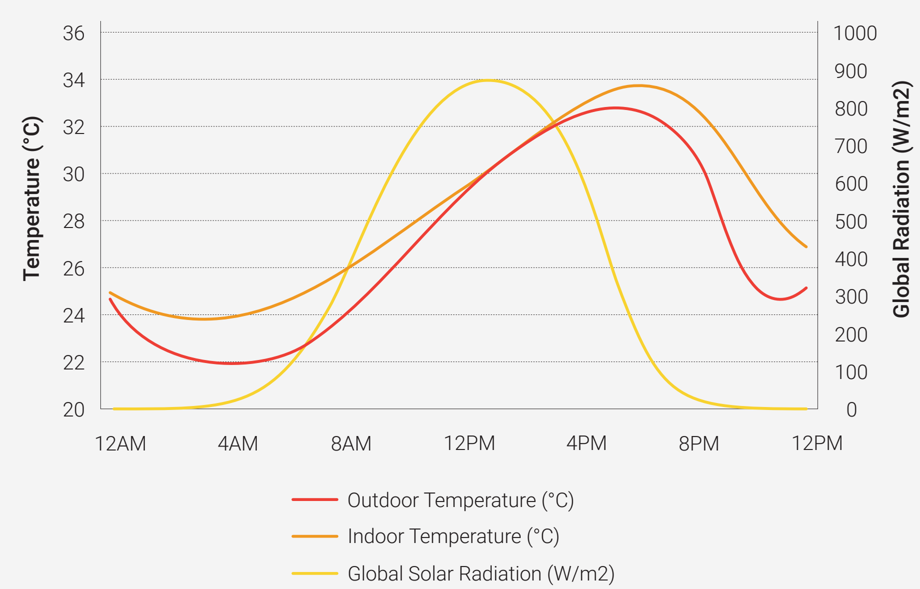
However, the addition of mechanical cooling in this analysis cause a spike in the building's Total Energy Use Intensity (TEUI). This means that the project's design team will have to incorporate additional energy saving features in order to meet both its TEUI and overheating targets.

**Average Suite Summer Overheating Hours**
**Operable versus Fixed Windows**



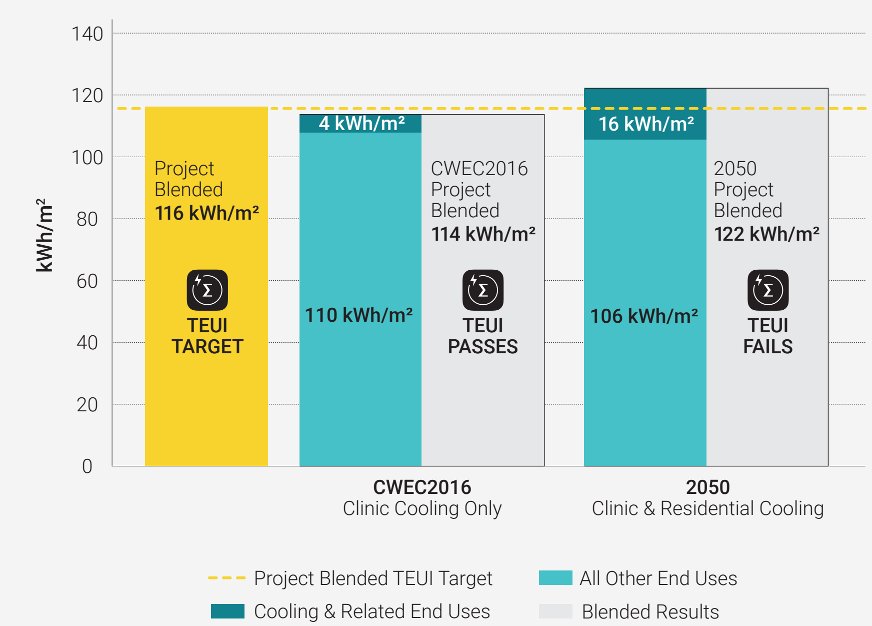

**METRIC:** BCESC Overheating Hours
**PROJECT TARGET:** < 200 hours, per BCESC
**CWEC 2016 RESULT:** 29 hours
**2050 RESULT:** 239 hours

**Level 6 SW Corner Suite Indoor and Outdoor Temperature**
**and Solar Radiation; July 23, 2050s**




**METRIC:** Peak Temperature in Southwest Suite
**PROJECT TARGET:** < 28°C, per ASHRAE 55
**2050S RESULT:** 34°C

**Energy End Use Intensiy Breakdown**
**Highlighting Cooling and Heat Rejection**




**METRIC:** BCESC TEUI
**PROJECT TARGET:** 116 kWh/m2
**2016 RESULT (NO COOLING):** 114 kWh/m2
**2050 RESULT (WITH COOLING):** 122 kWh/m2

## SECTION 04.

# Key Design Strategies

# 04.0 Key Design Strategies

This section presents details on the key design strategies necessary to mitigate air quality and overheating issues in MURB.

## High-Rise MURB

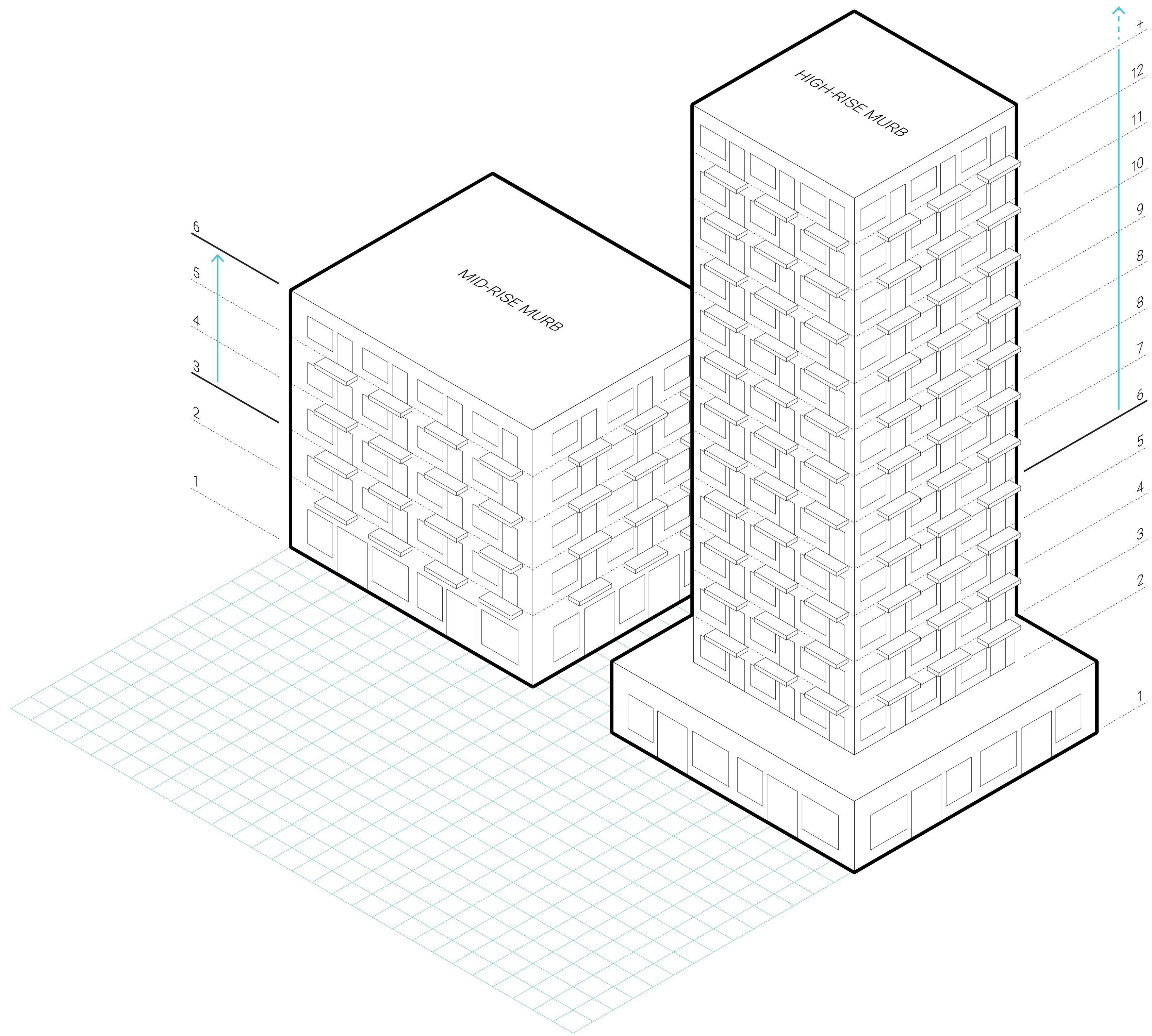
In this guide, High-Rise MURB refers to multi-unit residential buildings of six storeys or higher, often designed and built using concrete construction techniques. Such buildings usually consist of one to two storeys of commercial space at grade, with up to several dozen setback storeys of residential units above. Exclusively residential high-rise MURBs often include common areas (e.g. lobbies) and shared-use facilities (e.g. gyms and common rooms), alongside or in addition to ground-level suites.

## Mid-Rise MURB

Mid-Rise MURB refers to multi-unit residential buildings of three to six storeys, and designed and built using wood-frame construction techniques. Mid-rise MURBs can be configured with a concrete first storey and wood construction above. Mid-rise MURBs can be residential only, or else host small businesses in the first and second storeys.

## Key Design Strategies

The strategies presented in this section represent some of the most effective strategies to reduce the risk of indoor air quality and overheating issues that can be applied in BC's Climate Zones 4 and 5. Lower Mainland (Climate Zone 4). However, site conditions, the owners' performance requirements, and many other factors will affect what strategies are most appropriate for a given project. As such, designers should consider a variety of strategies to determine the best response to meet their specific needs.



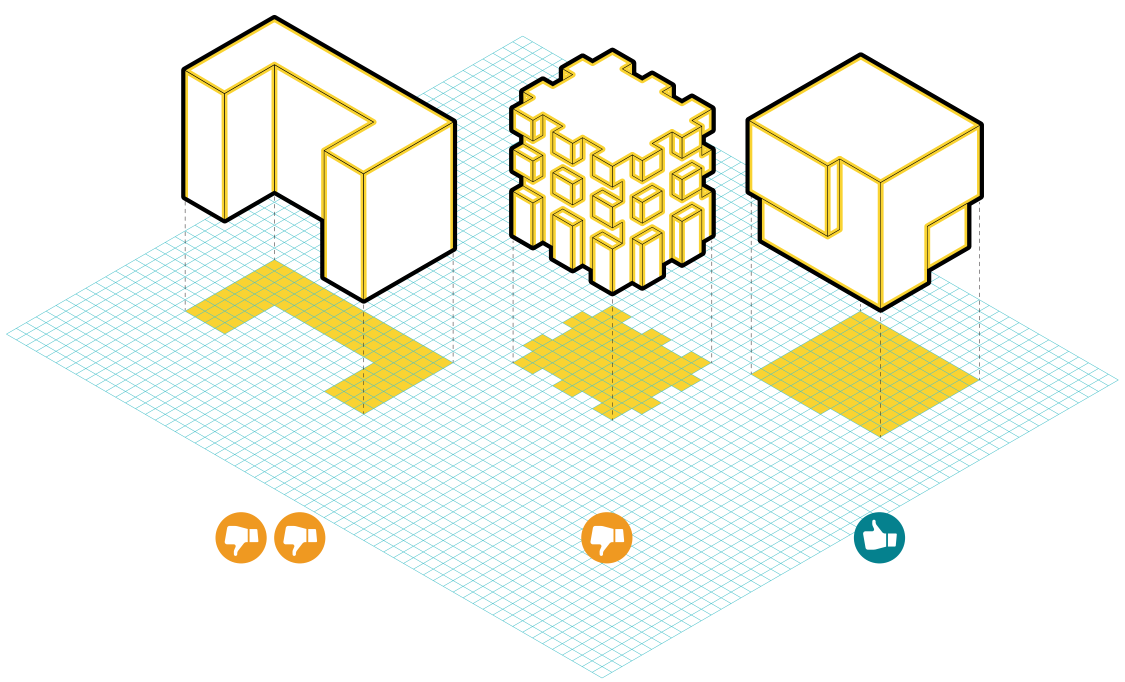
# 04.1 Passively Cool the Building

The use of passive cooling strategies is an important way to either reduce or remove heat from a space without increasing the building's overall energy use.

Some passive strategies can be applied across an entire building's design and should be considered in early stages of the design process for greatest impact, while others (such as adding vegetation) can be added later on. Additional details on using passive design to increase energy efficiency can be found in the main body of the BC Energy Step Code Design Guide.

### Building Shape and Massing

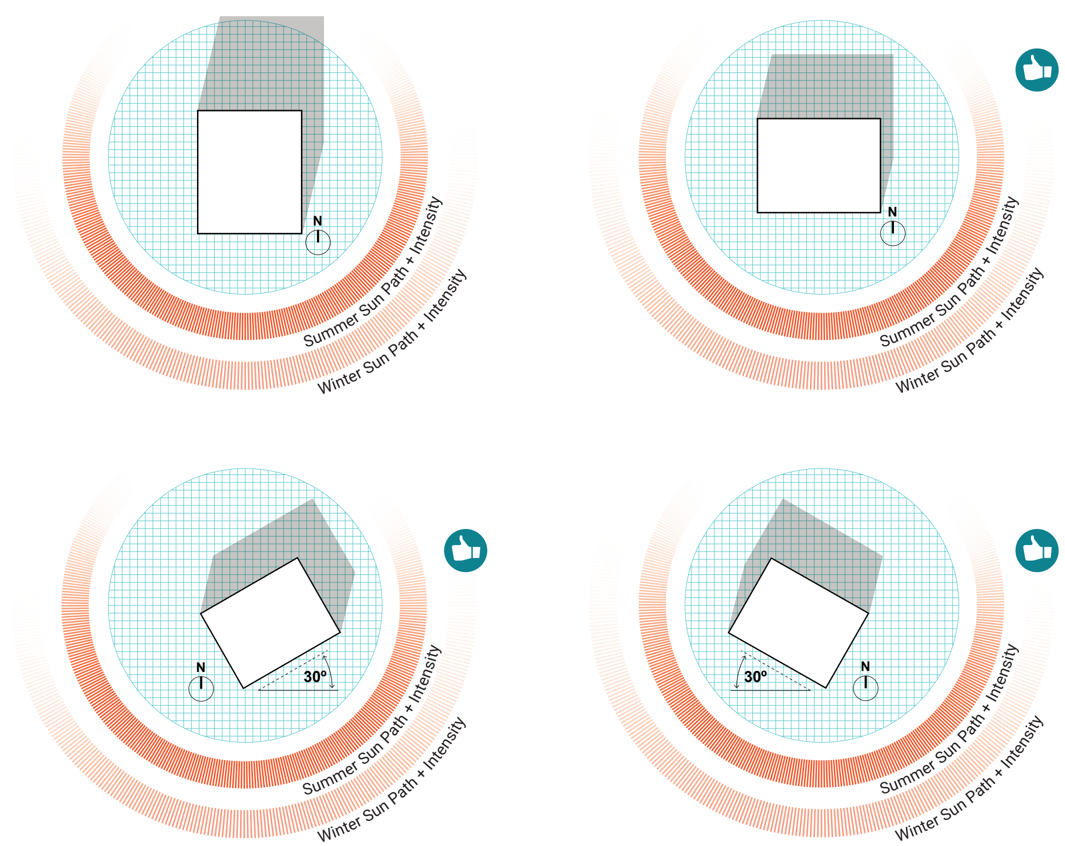
A simple shape and compact massing can help reduce heat losses in the winter. However, complex massing may provide better access to passive cooling strategies, such as operable windows and self-shading from solar gains. Designers should explore means of maximizing building energy efficiency through shape and massing, while considering the potential benefits of a particular geometry to mitigate overheating.



### Building Orientation

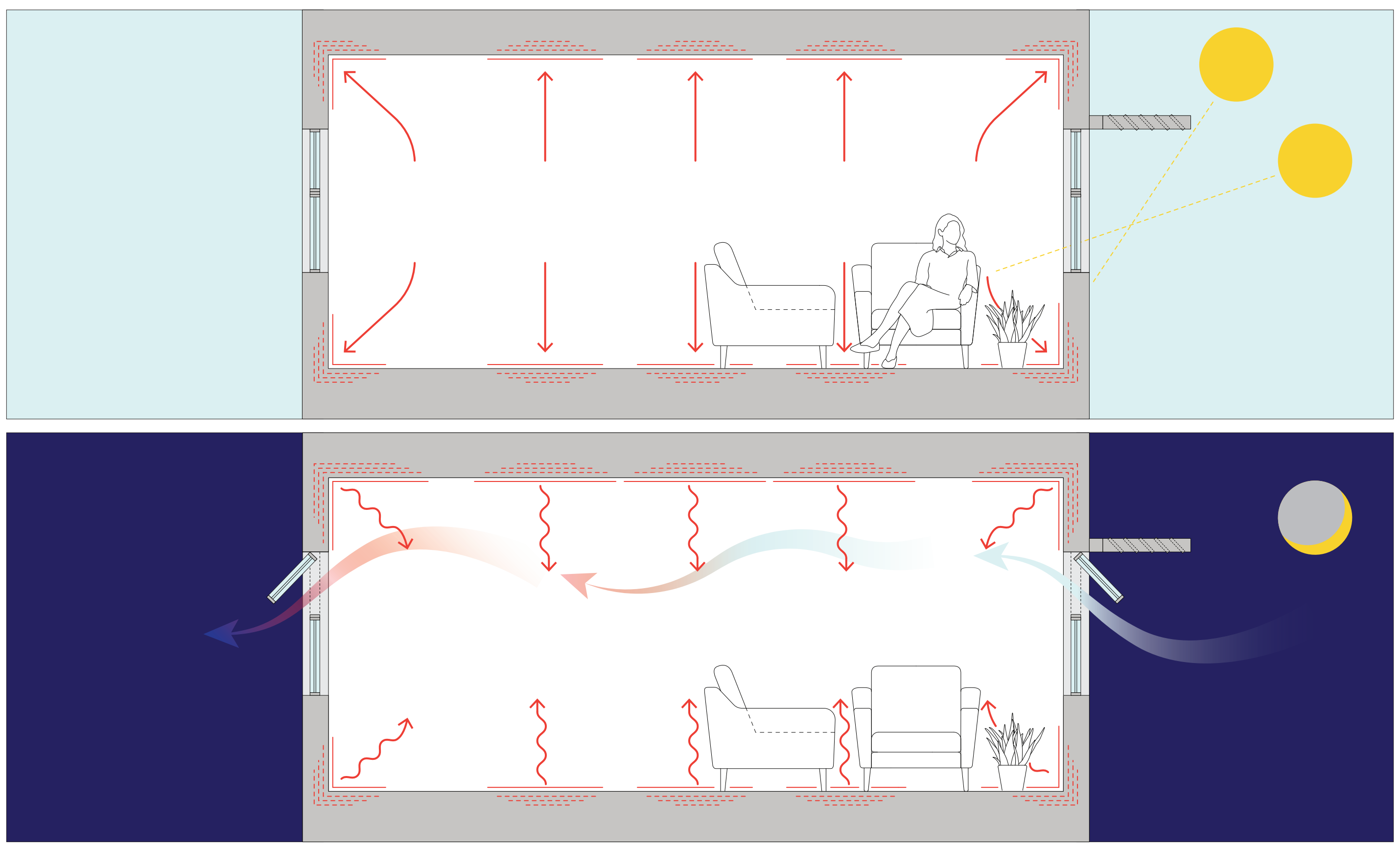
While a building's orientation is often determined by the site's size, shape and general constraints, orientation can be optimized to balance energy performance and overheating.

Building orientation should maximize the south and north facades and minimize the east and west facades. Windows and effective shading can then be optimized on south and north facades to maximize solar gains for "free heating" in the winter, while blocking gains in the summer.



## Thermal Mass

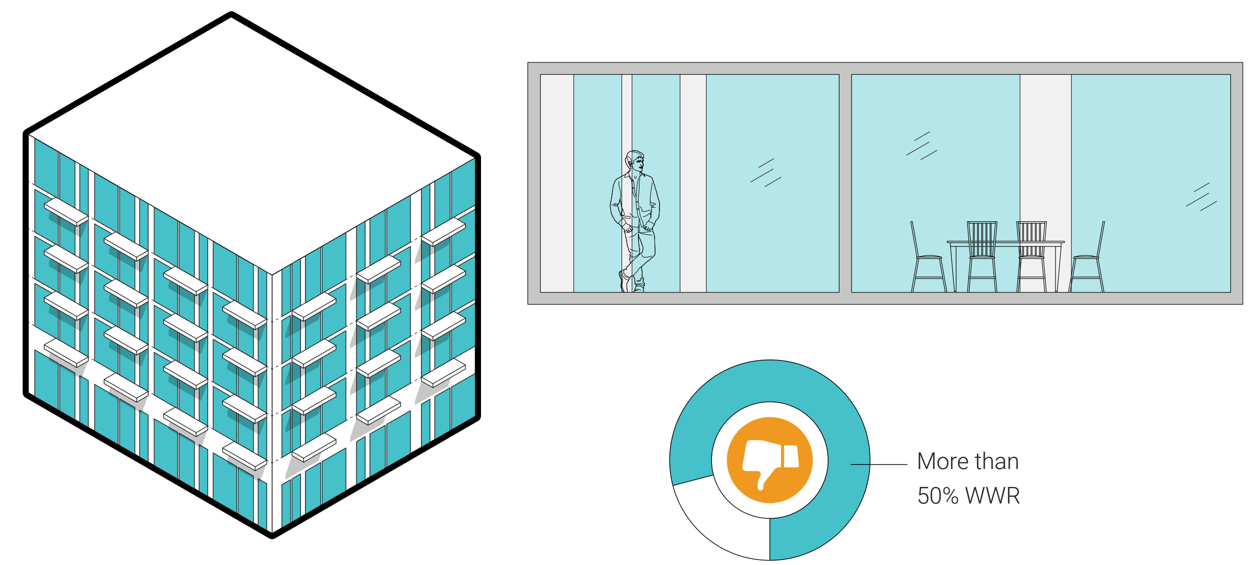
Thermal mass refers to a material's ability to absorb and store heat. Buildings with high thermal mass can absorb and store heat during the day when temperatures are high, reducing cooling energy requirements. This heat is then released at night when temperatures are cooler, and can be removed using passive strategies such as operable window or vents.



## Window Design

Lower window-to-wall ratios can reduce solar gains in the summer while also reducing heating energy requirements in the winter. To maximize control over heat gains, south and north facades should have higher window-to-wall ratios than on the east and west facades.

While higher U-values help reduce winter heat losses, they can also retain heat in the summer, and should be used in combination with other passive cooling strategies.

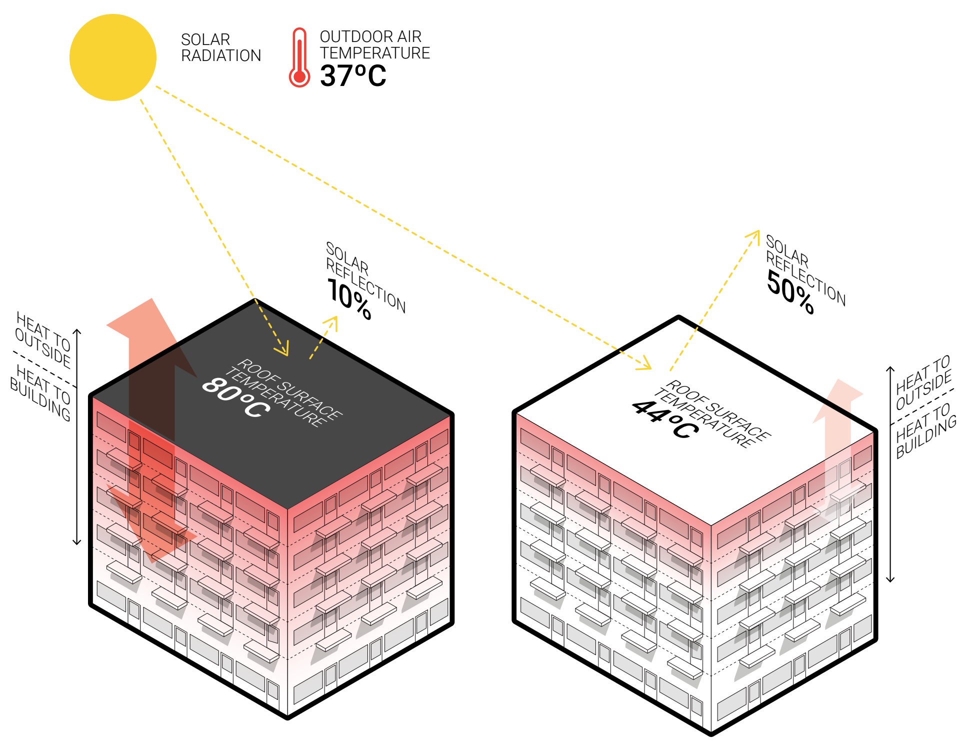



**KEY TAKEAWAY**

Consider building-level passive cooling strategies early on in the design process to minimize overheating in passively-cooled buildings, and reduce overall energy consumption in mechanically-cooled buildings.

## Cool Roofs

Roofs that are designed to reflect solar gains can help reduce the amount of heat let into the space, partiuclarly in buildings that have a higher roof-to-floor area ratio. Designers should consider using reflective materials and colours, proper insulation (to reduce downward heat transfer), and green roofs with planted materials that absorb solar radiation. Cool roofs have the added benefit of reducing local heat island effect and reducing the overheating potential for both the building and its surrounding neighbourhood.




**CASE STUDIES**

### The Impact of Orientation on Overheating

Credit: BC Housing and Horizon North Manufacturing

To assess the impact of a building's orientation on overheating, Focal Engineering modelled a modular housing building in Burnaby, BC. The model assumed a 24% window-to-wall ratio (WWR) and operable windows for passive cooling. The project was targeting Step 3 of the BC Energy Step Code and so was required to meet a TEDI target of 30 kWh/m$^2$/year. It also could not exceed 200 overheating hours per year.

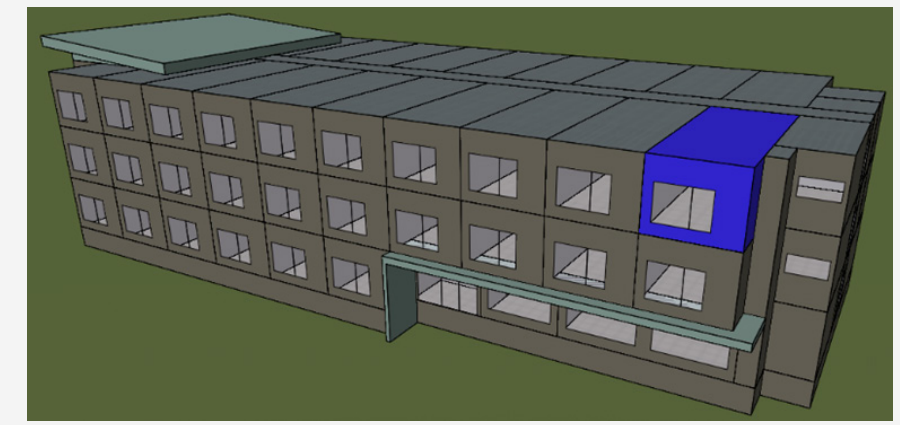
The case study focused on a corner suite located on the top floor and explored the impact of two orientations on overheating.

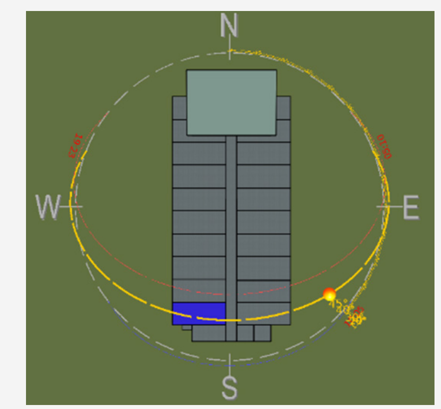
- ***Run 1:*** *West-facing suite*
- ***Run 2:*** *South-facing suite*

The results of the exercise showed that the west-facing suite (Run 1) experienced excessive overheating and a total of **247 overheating hours**. In this scenario, additional cooling or design modifications would be required to achieve the project's targets.

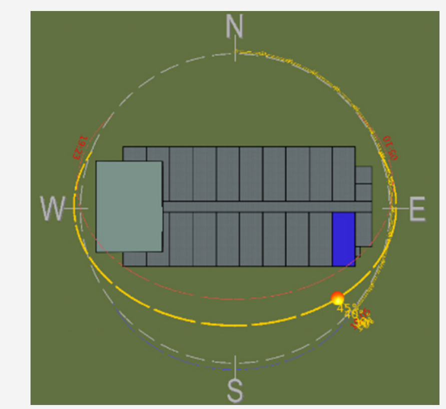
In contrast, the south-facing suite (Run 2) achieved a lower overall risk of overheating at **156 overheating hours**.

Overall, the study demonstrates the importance of evaluating all of BC Energy Step Code targets early on in the design process when decisions such as orientation can still be impacted, to ensure both occupant comfort and code compliance.






**Run 1:** West-facing suite




**Run 2:** South-facing suite

**ADDITIONAL RESOURCES**

**Building Shape & Massing, Building Orientation, Thermal Mass & Window Design**: Vancouver Passive Design Toolkit, July 2009

**Building Massing, Windows Design:** BC Energy Step Code Design Guide

**Cool Roofs**: Mitigating New York City's Heat Island with Urban Forestry, Living Roofs and Light Surfaces, October 2006

# 04.2 Use Shading to Block Solar Heat Gains

Incoming solar radiation, or solar gains, are a major contributor to overheating. Designs have to manage solar gains carefully to make sure that unwanted solar gains are minimized while ensuring that the building can still harness useful solar gains in the winter for passive heating. A key way to achieve this balance is to use different shading strategies for each façade and for different spaces within the building.

## Exterior Window Shades

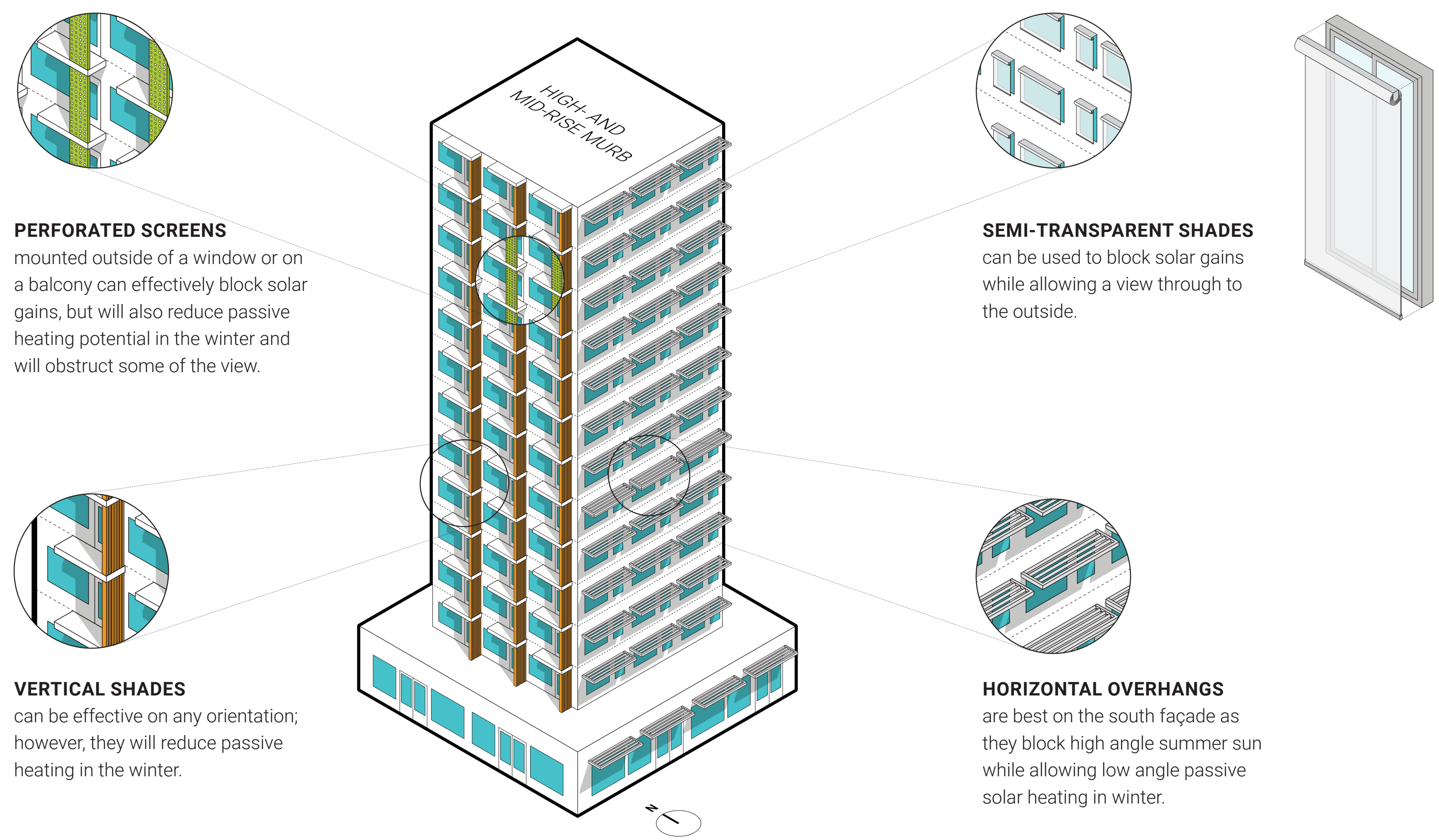
Exterior shades are the most effective at passive cooling, as they prevent solar gains from entering the space entirely. Designers can consider multiple types of exterior window shading.

**FIXED SHADES** can block direct radiation from the sun in the summer while allowing passive heating in the winter.

**OPERABLE SHADING** can be adjusted as needed, either manually or automatically.

- ***Manually-operated shades*** *give occupants more control, but rely on occupants to be present in order to be effective.*
- ***Automatically-controlled shades*** *are more reliable in preventing unwanted solar gains, but reduce occupants' control over their space and are more expensive to install and maintain.*

While interior window shades are often used, they are less effective as they allow solar gains to enter into the space, causing the shades themselves to absorb heat.




**PERFORATED SCREENS** mounted outside of a window or on a balcony can effectively block solar gains, but will also reduce passive heating potential in the winter and will obstruct some of the view.

**SEMI-TRANSPARENT SHADES** can be used to block solar gains while allowing a view through to the outside.

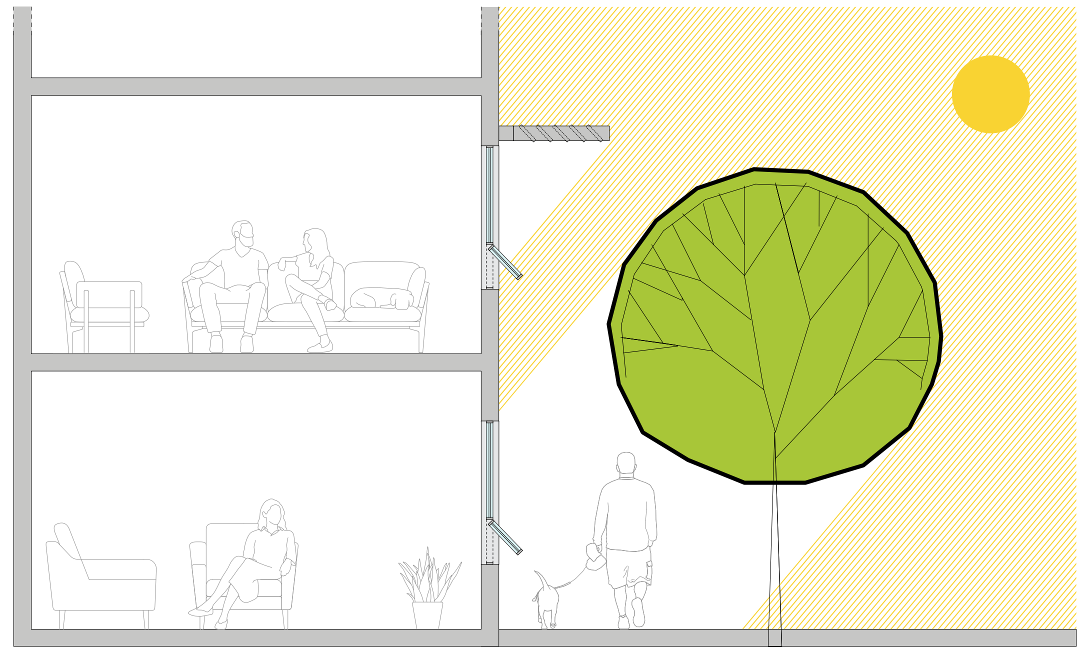
**VERTICAL SHADES** can be effective on any orientation; however, they will reduce passive heating in the winter.

**HORIZONTAL OVERHANGS** are best on the south façade as they block high angle summer sun while allowing low angle passive solar heating in winter.

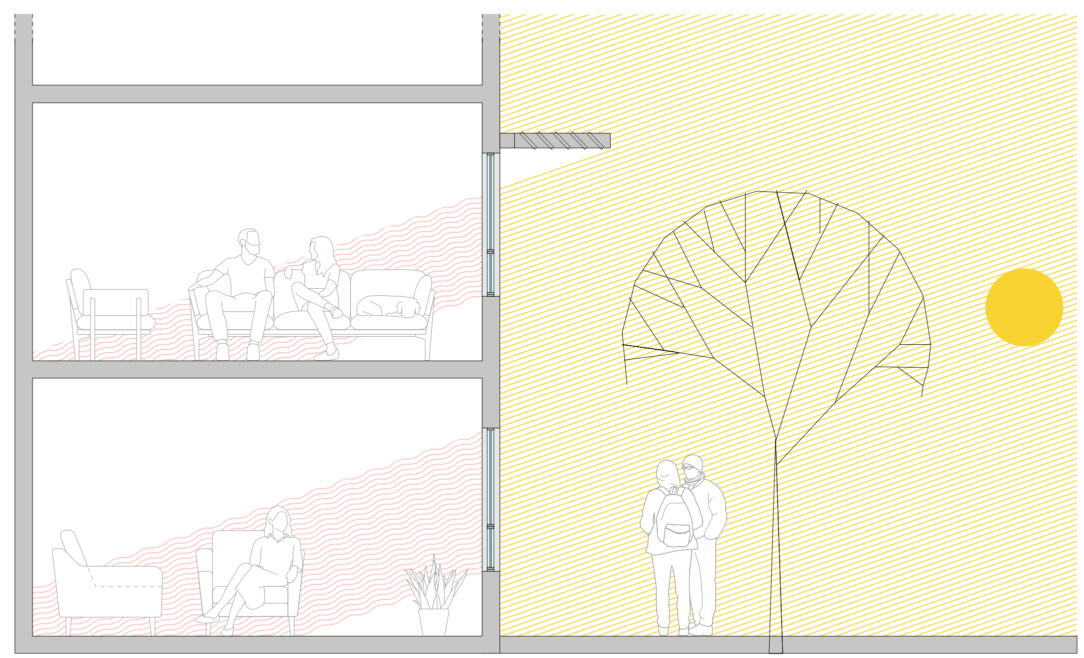
## Vegetation

Exterior shading can be achieved by strategically selected and designed vegetation. In the summer, deciduous trees and other foliage can provide shade to windows while allowing solar gains to enter in the winter. Designers should consider the height of the vegetation (both current and future) and its distance from the building.

While vegetation can effectively shade all building orientations, it will require maintenance and will increase the building's water usage, which will have more of an environmental impact as the climate warms and more locations experience droughts It is recommended that drought-resistant, indigenous species be considered wherever possible, with the possible addition of grey and/or rainwater capture.



**SUMMER** SOUTH/WEST FACING FACADE

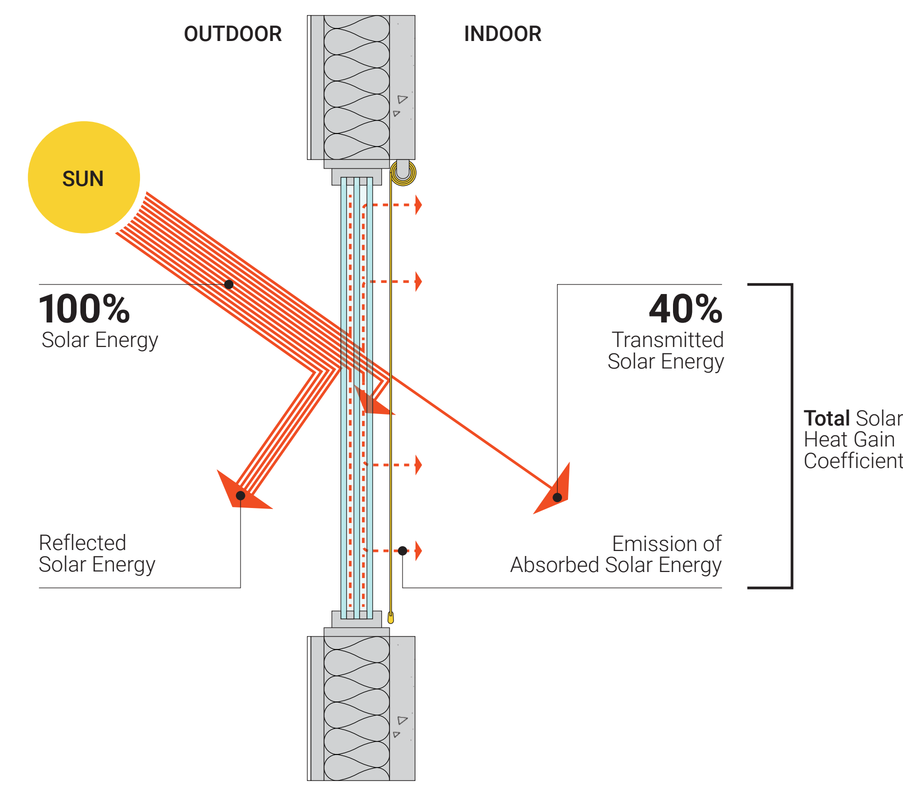


**WINTER** SOUTH/WEST FACING FACADE

## Solar Heat Gain Coefficient

Solar Heat Gain Coefficient (SHGC) is an important element in glazing selection and can be optimized for each façade of a building. Selecting glazing with an appropriate SHGC means finding the right balance between preventing overheating and reducing a building's thermal energy demand.

A SHGC of 0.4 means that 40% of the solar heat gains that land on the outside window surface enter into the space. A low SHGC reduces the risk of overheating. However, a SHGC lower than 0.28 starts to impact Visible Light Transmittance (VLT), which can make spaces darker and require additional lighting energy — adding  more internal gains (heat) to the space. Conversely, a high SHGC allows more solar radiation to pass through the glazing, which reduces the building's need for heating energy but can increase the risk of overheating.

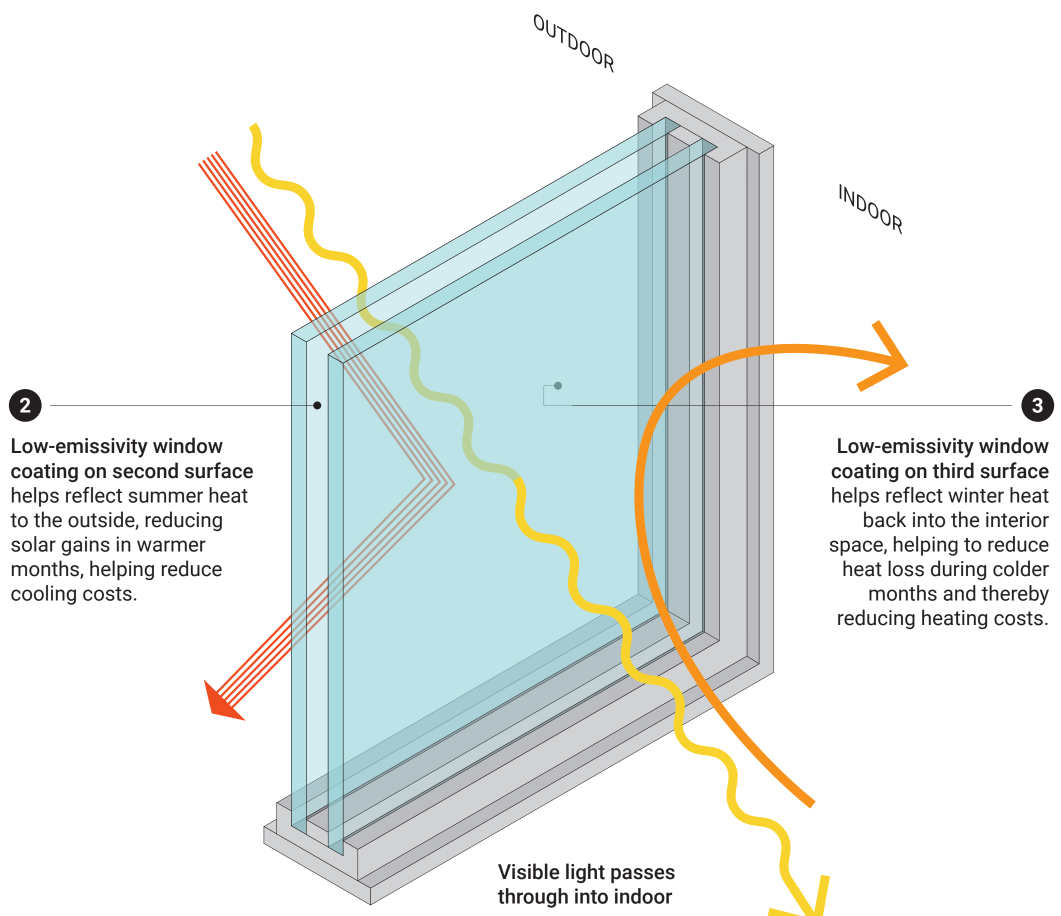


## Window Coatings

Window coatings, such as low-emissivity coatings, reduce the amount of radiation transferred through windows while allowing light to pass through.

## Electrochromic Glazing

Electrochromic glazing technology allows for automatic or manual control of a glazing tint and solar heat gain properties. These products have a similar effect to exterior automatically controlled operable shades.




## Shading Strategies Comparison

| | Fixed External Shades | Manual Shades | Automatic Shades | Vegetation | SHGC Selection | Window Coatings |
|---|---|---|---|---|---|---|
| Livability | 👍👍 | 👍 | | 👍👍 | | |
| Aesthetic | 👍👍 | | | 👍👍 | | |
| No additional maintenance required | | | | | 👍👍 | 👍👍 |
| Controllability | | 👍👍 | 👍 | | | |
| No increase in need for indoor lighting | | | | | 👍* | |
| Glare control | 👍 | | | 👍 | 👍* | 👍 |

**LEGEND** 👍 Good 👍👍 Better * Some SHGC reductions may impact visible light transmittance

**KEY TAKEAWAY**

- Install a reflective, cool roof to reflect heat away from the building
- Maximize glazing on the south façade and shade it appropriately to harness solar gains when they're wanted, while keeping east and west glazing low
- Select glazing with a low U-value and a SHGC that balances the need to prevent overheating (i.e. a low SHGC) with the need for free heating (i.e. a higher SHGC)

**CASE STUDIES**

### Shading in Vancouver's Olympic Village

Several of the Olympic Village's buildings feature diverse shading strategies. Of note are the automatically controlled shades that are mechanically raised and lowered in response to measured incoming solar gains. This strategy helps to block solar heat gains when they are greatest, and avoids relying on occupants to remember to lower them. Shades are also semi-transparent so occupants can still enjoy an unobstructed view to False Creek and downtown.

**Top** *The Brook at False Creek, Vancouver, BC*
**Bottom** *Semi-transparent shades from inside suite*

# 04.3 Cooling via Natural Ventilation

Once other passive design strategies have been explored, the risk of overheating can be reduced even further by removing heat gains from inside a building using methods of natural ventilation.

Natural ventilation is the process of increasing the flow of outdoor air into a space through openings in the building envelope, such as windows. Using natural ventilation help reduce a building's reliance on mechanical systems to provide cooling and help occupants achieve thermal comfort for most of the year. Many occupants also like being able to open a window to adjust their indoor environment.

The most effective way to achieve natural ventilation is through the use of operable windows or vents in the building envelope. There are several aspects that need to be considered to ensure that they are as effective as possible.

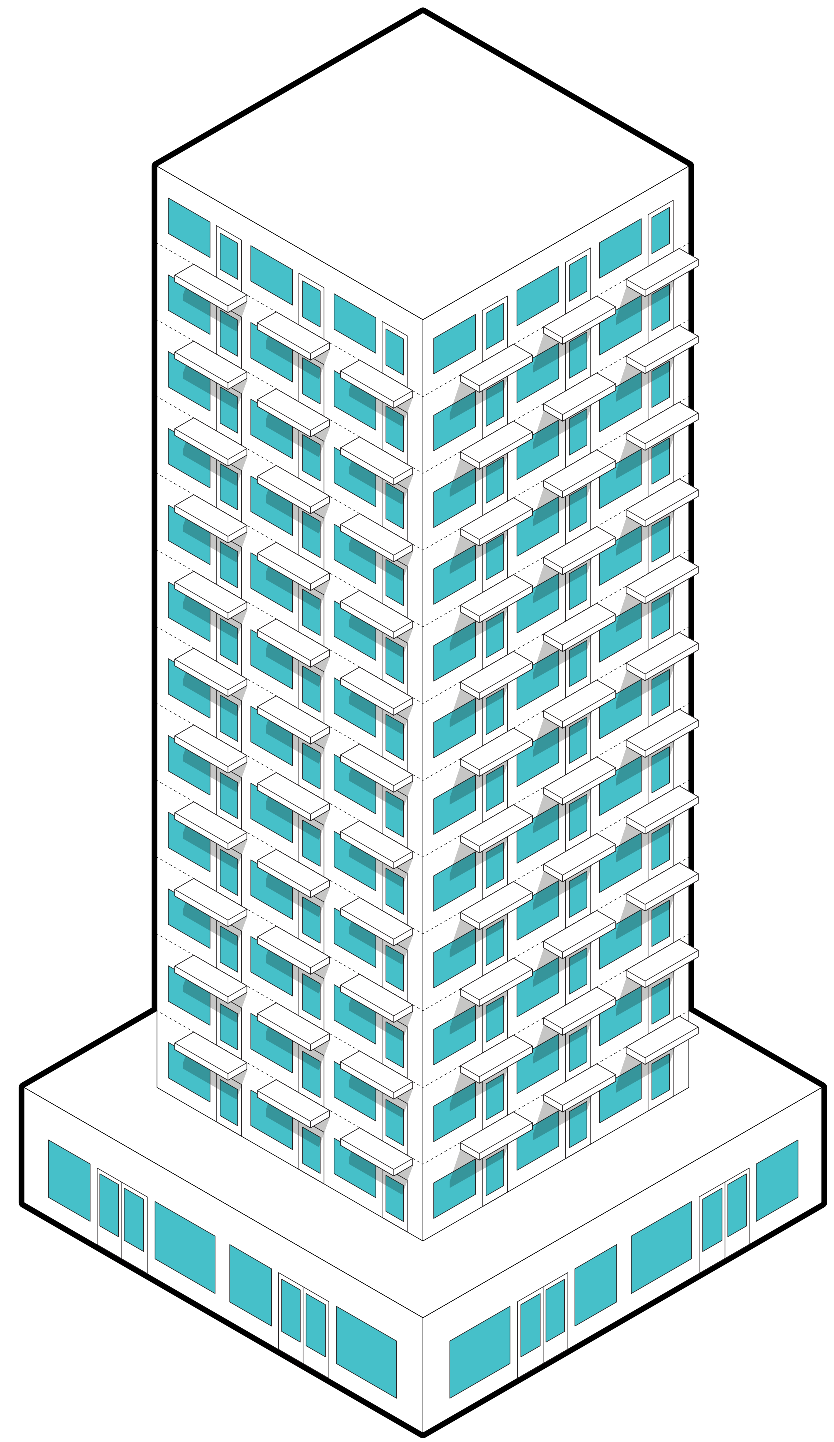
**CONTROL**
Automatic controls can be programmed in common areas to open windows and/or vents based on a schedule or sensed input. Manual window controls should come with instructions for occupants on when to open or close windows to maximize the potential of natural ventilation and cooling.

**OUTSIDE CONDITIONS**
Occupants will be less likely to open windows if exterior conditions are unfavourable, such as noise, poor air quality (e.g. noise, smoke, dust or smells) or uncomfortable conditions (high temperatures or humidity).

**OPERATION AT NIGHT**
Nighttime ventilation allows buildings to be passively pre-cooled in preparation for the next day. Openings and vents should be designed to restrict access by people or animals where necessary, and located away from sources of allergens and pollutants.

**EFFICIENCY**
Operable windows often have a higher (worse) U-value than fixed windows and can decrease building airtightness. Designers should look for windows with lower overall U-values, consider the effectiveness of the window seal, and look for a multi-point locking mechanism to ensure airtightness.

**LOCATION**
The location of the residential unit, elevation and height, will impact the size of opening required, especially if only single-sided ventilation. Wind pressure will have a greater impact as height increases and external gains can vary across a single elevation due to shading from neighbouring buildings.



**POSITION**
The vertical position of openable windows and vents should be considered to mitigate the risk of unintended access on the lower floors or fall hazards on the upper floors.

**SIZE**
The size a window, the depth of its opening, and any restrictions on how far they can open should all take Code requirements and safety concerns considerations into account. Small operable windows or vents that are restricted may be ineffective in providing natural ventilation and cooling.

### Key issues to keep in mind when designing for operable windows:

- *Indoor and outdoor air temperatures will be similar when windows are open, which can cause thermal comfort issues at higher temperatures, particularly as the climate warms.*
- *Air quality can become a concern when using operable windows for cooling, since the air isn't filtered before entering the room.*
- *Building occupants may be less likely to open their windows if they are located in a noisy area, reducing the effectiveness of the strategy.*

**CASE STUDIES**

## The Impact of Operable Windows

BC Housing and Nanaimo Affordable Housing Society

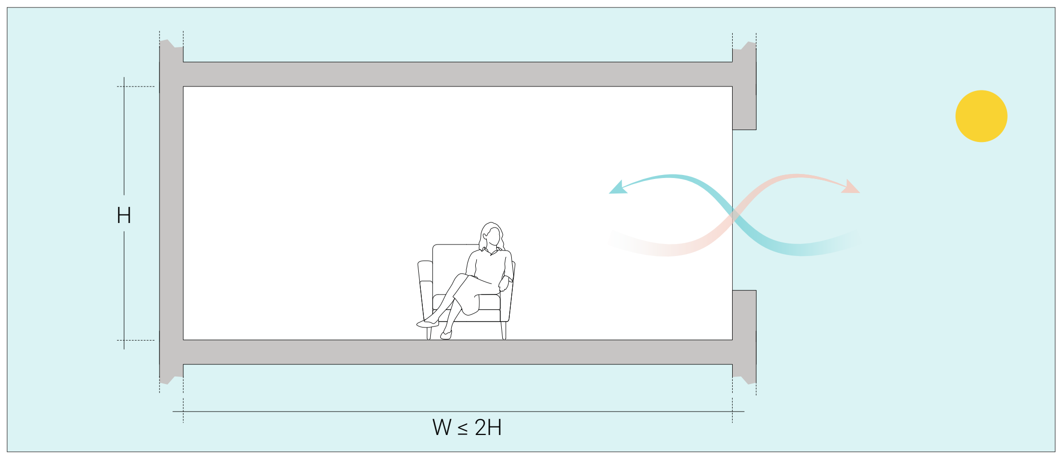
A concrete and wood frame affordable senior housing facility was modelled to explore the impact of operable windows on the building's potential for overheating. As its original design resulted in **2,788 overheating hours** (far above the 200-hour target), two passive cooling strategies were modelled to see if they made a difference.

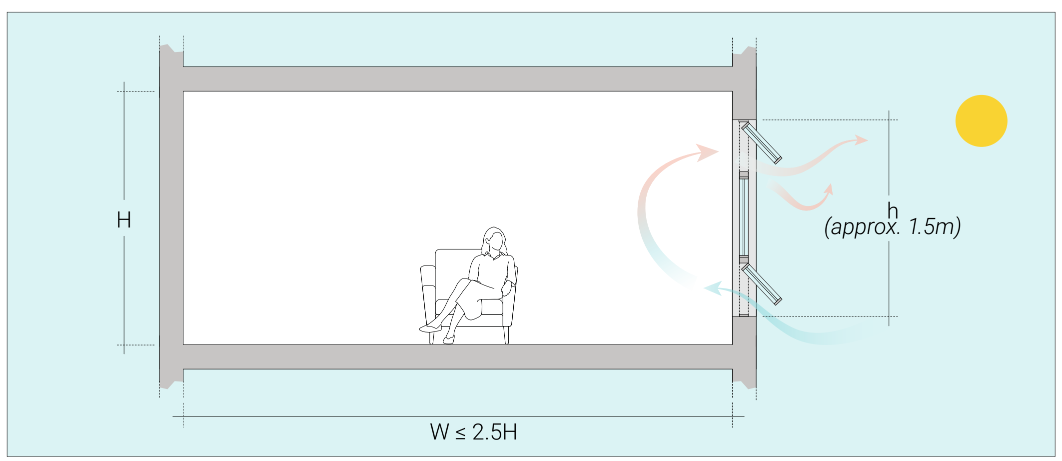
First, horizontal and vertical shades were added to several southeast and southwest facing windows. This resulted in a noticeable reduction in thermal discomfort, down to **1,864 overheating hours.** To further reduce overheating, operable windows were then included. Windows were assumed to be open between 6am-10pm (when occupants are awake to open them), when room temperatures exceeded 23°C, and when the outside air temperature was lower than indoor air temperatures. This resulted in a significant reduction in overheating, down to only **162 overheating hours.**

**Above** *Low Hammond Rowe Architects (LHRA)*

## Single Sided Ventilation

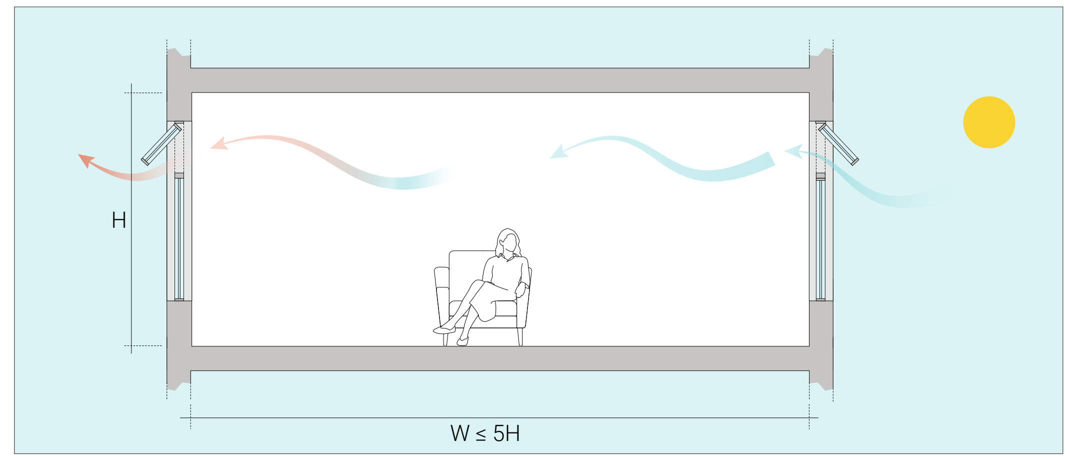
Spaces can be naturally ventilated where openings are placed on one side of the space. However, this approach tends to be less effective, in that a single opening is limited in terms of how much of the space can be sufficiently ventilated. When using single-sided ventilation strategies, opening areas should be as large as possible.




## Cross Flow Ventilation

Placing windows on different facades generates greater air flow, due to the difference in pressure between different facades. As cross-ventilation is twice as effective as single-sided ventilation, openings can be smaller than those used in single-sided ventilation.




## Designing Right

To successfully implement passive ventilation cooling strategies, each space of a building must be designed to allow a sufficient volume of airflow to counteract any heat gains. Designers should design the façade to ensure solar gains are minimized, and model interior spaces using dynamic simulation tools. Modelling to higher standards, such as ASHRASE 55.1 or the CIBSE Technical Memoranda, will help identify the potential risk of overheating and allow an exploration of the impact of various passive and active approaches. Using future climate files (e.g. RCP 8.5 for 2050) in modelling will ensure the building's resilience resilience in the coming decades.

**KEY TAKEAWAYS**

Include operable windows and vents into building design to reduce the need for active cooling.

Consider window/vent size and placement for optimal airflow.

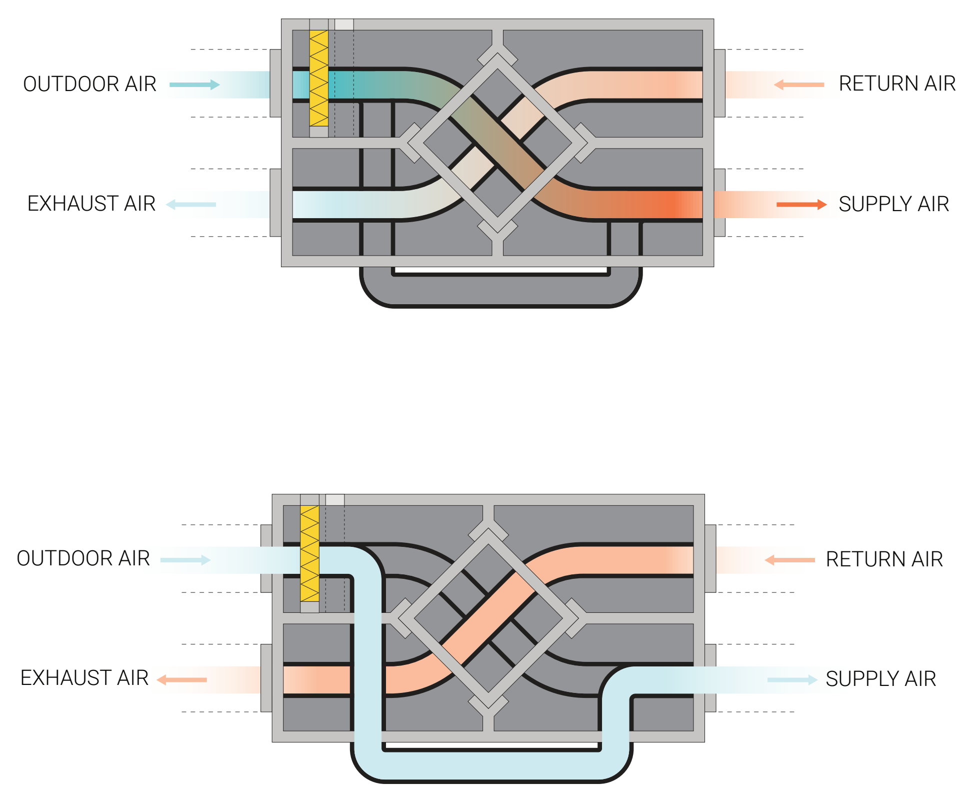
# 04.4 Couple Passive Cooling with Active Approaches

Passive cooling strategies have several benefits, from lower energy use to increased occupant comfort. However, they are increasingly insufficient in providing thermal comfort during the warmer months of the year.

Passive systems can be enhanced by incorporating fan assistance to help increase overall airflow. This is a cost-effective solution to improve thermal comfort in the shorter term, and reduces the need to add a source of mechanical cooling during warm periods that would add to the building's overall energy demand.

## Use a Bypass in Heat Recovery Ventilation

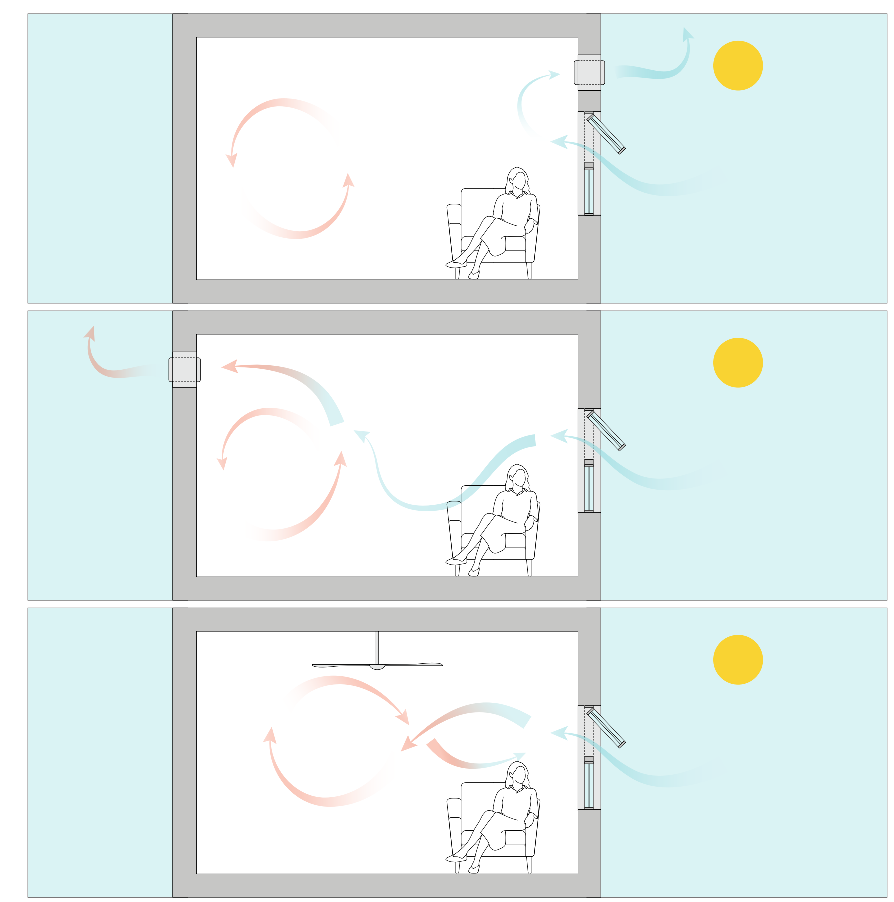
Many high-performance buildings use heat or energy recovery ventilation (H/ERV) strategies to reduce winter heating loads. Where these systems are used, they can be designed to include a bypass for summer, which allows cooler outside air to avoid absorbing any heat from the warm air being exhausted. This approach can be used when indoor building temperatures are higher than outdoor summer temperatures, and can be used in parallel with operable windows and vents to enhance the passive ventilation.




## Drive Air Movement with Exhaust Fans

Air movement can also be increased using supply or exhaust fans. This strategy is particularly effective in rooms or suites with a single orientation – in other words, where natural cross-flow ventilation is impossible. When outdoor temperatures are cooler than inside temperatures, an open window at one end of a space and an active exhaust fan at the other will drive air movement.

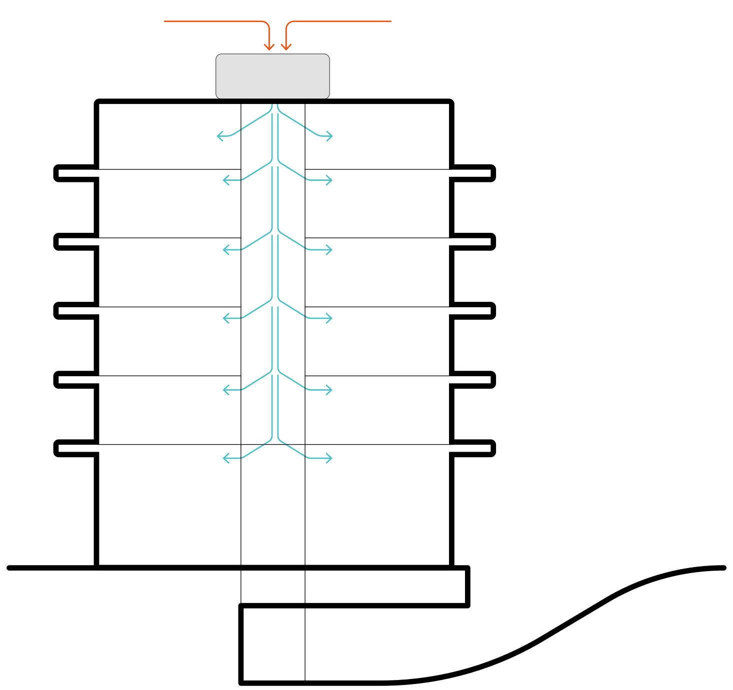
Ceiling fans can be effectively used to increase air movement within a space, improving the thermal comfort for occupants.



## Temper Supply Air

Central ventilation units are commonly used in rental buildings and buildings in higher climate zones in BC, and can be adapted to provide a degree of cooling to each suite at minimal capital cost. For example, a central HRV used to supply and exhaust air to and from each suite can be outfitted with a cooling coil to temper the supply air. During the summer months, this approach can deliver a significant portion of the required cooling.

When tempering the supply air, increasing the supply air ventilation rate above the ASHRAE minimum flow rates will increase the cooling capacity and provide longer-term resilience for the building. The impact of the additional fan energy on the TEUI should be assessed and considered during the design process.



**CASE STUDIES**

### Vidorra Developments

Vidorra Developments' Orion project in Pemberton, BC is an example of hybrid cooling applied in the local context. This three-storey residential building has 45 condominium units, and focuses on both a high-performance envelope and reduced loads. The envelope features triple-pane windows built with solar control glass that are set in the middle of the wall to limit thermal bridging, coupled with double walls insulated for a combined performance of R42. The roof is insulated to R70, and is equipped with solar panels that generate most of the building's needed energy. This envelope-first approach minimizes the need for more complex HVAC systems.

Passive cooling at Orion relies primarily on the low heat loss/gain envelope and solar control glass, but also employs night flushing by running the energy recovery ventilator (ERV) at double the ventilation rate to reset the building's thermal mass for the next day. Higher energy use from increasing the airflow is offset by using a high-performance ERV. When necessary, the project can also provide mechanical cooling using air-sourced heat pumps. This approach minimizes envelope penetrations and is extremely cost effective compared to conventional construction due to its simplicity.

**Top** *Orion, Vidorra Developments*
**Bottom Left** *Soffit insulation with simple ventilation ductwork*
**Bottom Right** *Wood frame structure with triple-pane windows set in the middle of walls*

# 04.5 Add a Source of Cooling

While designers should always make use of passive cooling solutions first, peak summer conditions today are already starting to make these strategies insufficient in providing occupants with thermal comfort year-round. When passive strategies are no longer viable on their own, mechanical cooling is required.

High-performance, energy efficient, active technologies such as heat pumps are frequently used as a means of cooling in high-performance buildings, as they can provide both heating and cooling using BC's low-carbon electricity. Heating and cooling can be distributed around a building using one of three mediums: air, water or refrigerant.

### AIR

Using the ventilation system in a suite or building to deliver cooling via a cooling coil can be a cost-effective solution. However, their use can increase a building's overall energy use, which will negatively impact the TEUI of a high-performance building. Designers can consider zoning the ventilation system where there are significant variations in the need for cooling (e.g. because of different solar gains) in different parts of the building to reduce energy demand.

### WATER

Using water in place of air is a more energy efficient way to remove heat from a space. Where a building uses simultaneous heating and cooling, rejected or "waste" heat can also be easily distributed to areas of the building that need it, which improves the energy efficiency of the system even further. However, this requires designers to include a hydronic distribution system in addition to the building's ventilation distribution system, which can increase overall capital costs.

### REFRIGERANT

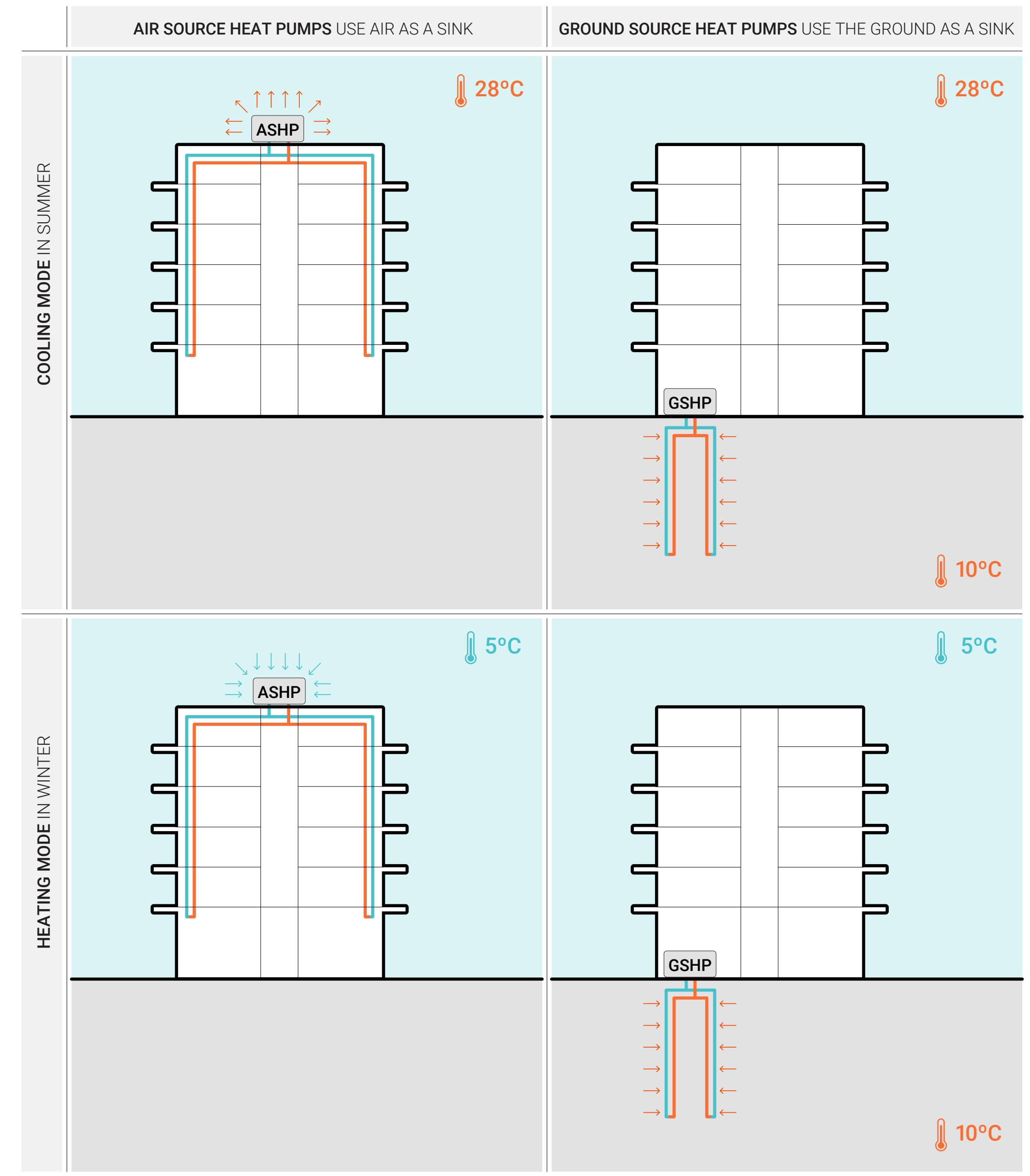
Refrigerant is a fluid used in heat pumps that changes its state from a liquid to a gas and back again, and is very efficient at moving energy around a building. Refrigerants also make use of smaller pipe sizes than those required for chilled water or for ducts, which can help in building design. However, designers must carefully consider the type of refrigerant they specify to avoid those with significant Global Warming Potential, or GWP.

## Heat Pumps

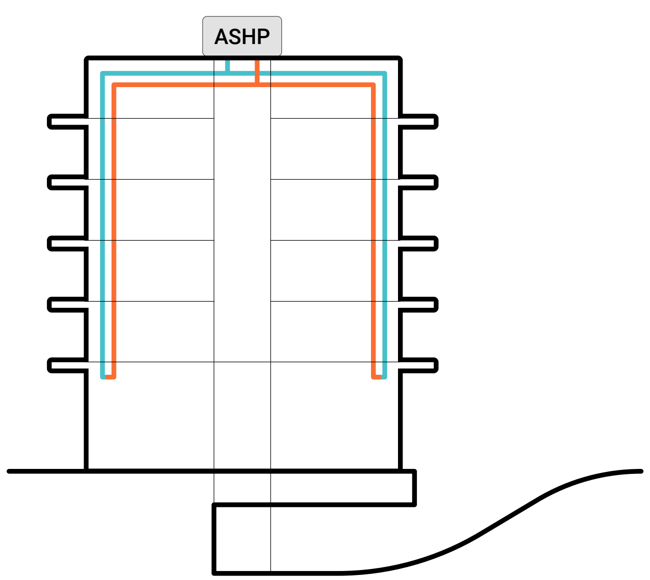
Heat pump technologies are designed to different levels of efficiency. Heat pump efficiency is generally measured in terms of its coefficient of performance (COP), which is a measure of how efficiently the pump converts electricity into usable thermal energy. Selecting a high-efficiency heat pump can limit the impact of active cooling systems on a building's Total Energy Use Intensity (TEUI).

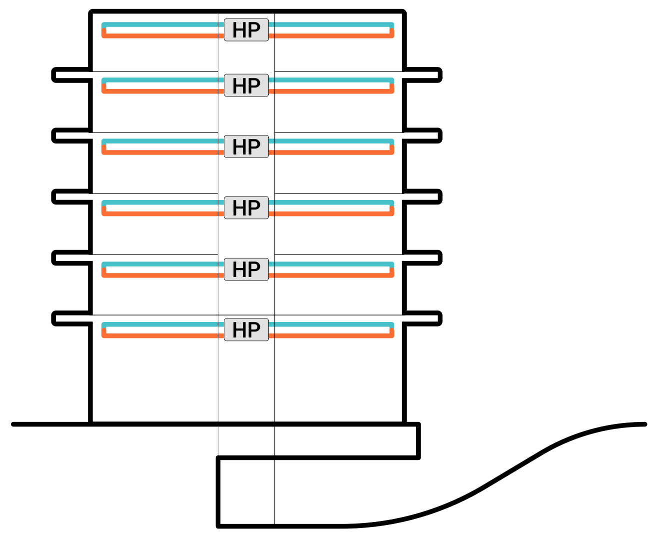
**Air Source Heat Pumps (ASHP)** use air as a heat sink. The efficiency of air source heat pumps varies as the outdoor air temperature changes from season to season. Since peak winter and summer air temperatures can decrease the COP of an air source heat pump, they are less ideal for use in climate zones with temperatures that vary significantly.

**Ground Source Heat Pumps (GSHP)** use the ground as a heat sink, and a fluid to move thermal energy between the ground and the building. As ground temperatures remain relatively constant throughout the seasons, variations in their efficiency are minimal. However, additional infrastructure is required to access the sink, and so they can be more expensive to install.



## Central or Distributed Cooling



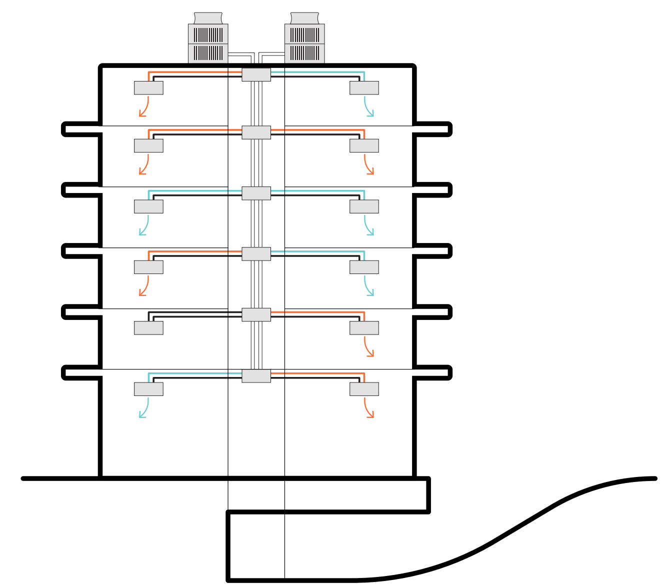




Cooling provided by heat pumps can be distributed by either a centralized or decentralized system.

**Centralized systems** often make use of a central cooling unit (such as a rooftop ASHP) that generates the cold air, water or refrigerant that is in turn supplied to each zone in the building. Central systems typically incur lower costs to design, install, and maintain, but are less useful where cooling is required in only a few spaces of a building.

**Distributed systems** have multiple heat pumps located throughout the building that supply each zone or a group of zones. This approach offers greater flexibility in building design, but typically makes for higher capital costs.

## VRF Systems



**Variable refrigerant flow (VRF)** or Variable Refrigerant Volume (VRV) systems are gaining traction in North America because of their ability to provide heating and cooling simultaneously. Some systems can also move heat from areas that are too hot to areas where heat is required, increasing the system's overall efficiency. VRF/VRV systems allow thermal comfort to be maintained across multiple suites of a building that have varying heating and cooling loads without the need to add a secondary system. Like heat pumps, both water and air-cooled VRF/VRV systems are available on the market.

### Issues to keep in mind when selecting a mechanical cooling option:

- *Select systems that make use of low-carbon energy to reduce a building's GHGI*
- *Select a cooling system with a higher coefficient of performance (COP) to minimize the impact on the building's TEUI*
- *Carefully consider how to size, operate and zone a mechanical cooling system to optimize performance, especially if different spaces experience different peak temperatures at different times of the day*
- *Where possible, connect residential suits to commercial retail units via a common cooling system to allow waste heat to be transferred between different space uses, improving overall efficiency*
- *Locate external equipment in such a way that building occupants and neighbouring buildings won't be affected by noise*

#### ROUGH-IN FOR FUTURE COOLING

Where a project either does not require mechanical cooling today or lacks the funding to provide it, design teams can consider "rough-ins" to allow mechanical cooling to be installed later. For example, designers can plan future routes for running future refrigeration or chilled water lines, specify equipment with space to add a cooling coil, or size airflow rates to meet future cooling loads. The provision of future electrical capacity to accommodate future mechanical cooling, both building-wide and in specific spaces, should also be considered.

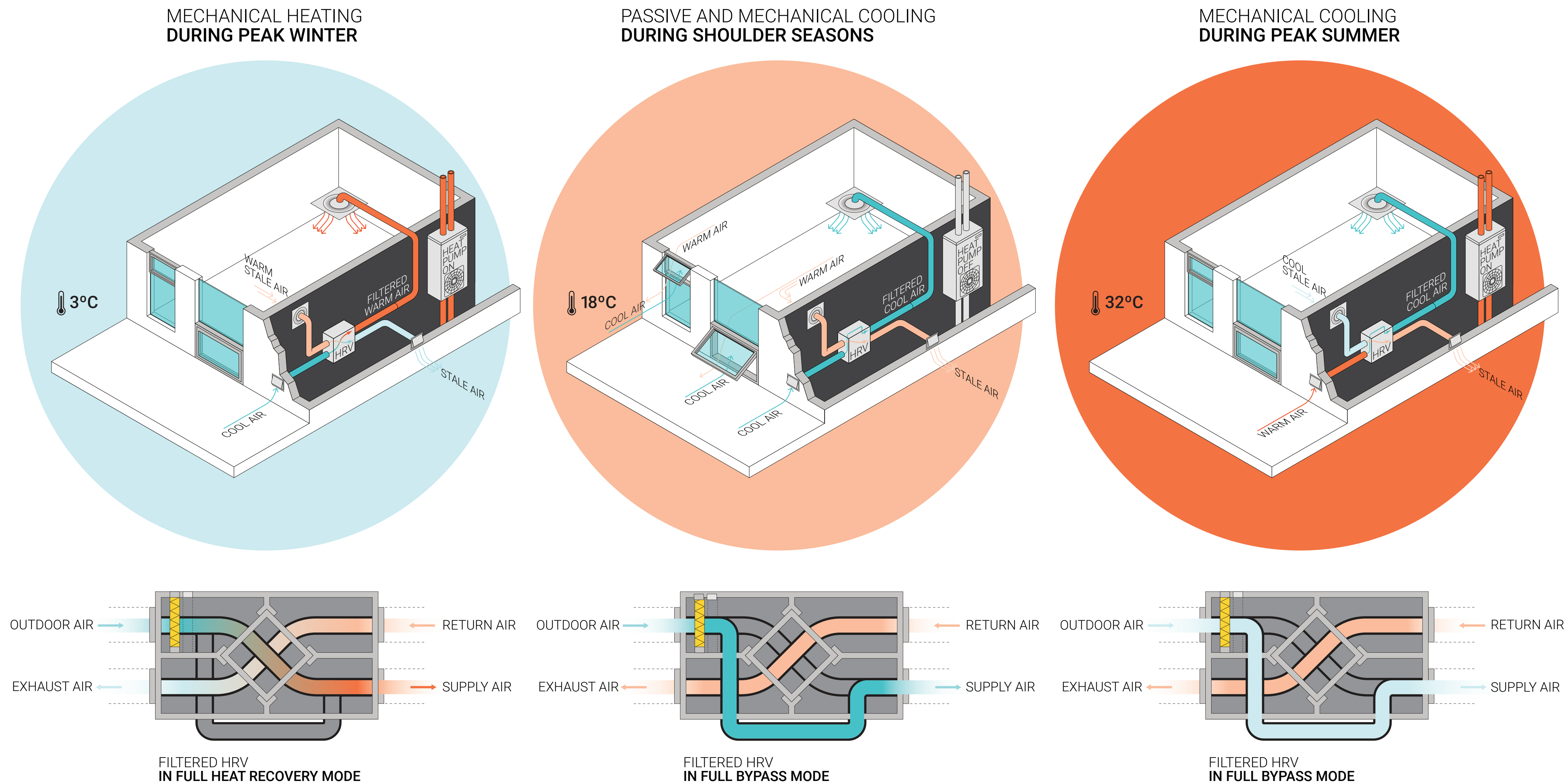
## Mixed Mode Systems

Mixed mode systems offer the ability to cool mechanically-ventilated spaces via both natural ventilation and mechanical cooling. What option is used at any given time is often guided by external conditions.

Under current average summer temperatures, operable windows provide an adequate source of cooling. This strategy helps to reduce energy use, as mechanical cooling is not necessary.

When outdoor summer temperatures become too hot, or when outdoor air quality is poor, mechanical cooling can be used to maintain thermal comfort instead. This strategy helps to maintain indoor air quality as air is filtered through the mechanical system.

Mechanical cooling systems that allow for increased capacity in the future improve a building's resilience to increasing future temperatures. Separating mechanical cooling potential from ventilation air wherever possible helps to increase the overall efficiency and flexibility of the system.




**KEY TAKEAWAYS**

Provide a source of mechanical cooling to complement passive cooling measures to ensure thermal comfort is achieved under current and anticipated peak conditions.

Separate ventilation and cooling systems to improve system flexibility and optimize energy efficiency.

CASE STUDIES

## Cambie Gardens

Cambie Gardens is a master-planned community in Vancouver designed to provide community members with access to health and support services alongside independent living options. Each unit includes in-suite controlled forced-air cooling, heating, and ventilation, controlled by LCD smart thermostats that allow residents to control temperatures, even when away from home. The building uses air source heat pumps and boilers with fan cool units, as well as low-E windows to increase insulation and UV protection.

**Above** *Cambie Gardens, IBI Group*

**Above** *Cambie Gardens, IBI Group*

## Modello

The Modello development in Burnaby combines variable refrigerant flow (VRF) zoning with a ground source heat pump system for heating and cooling. This combination allows for precise temperature control over the many floors of the building, regardless of the time of day, season, or unit orientation. Each unit is also equipped with individual thermal metering, allowing occupants to control both their comfort and utility costs. Additional features include LED lighting connected to motion sensors, and roller shades for the floor to ceiling windows that can be motorized and integrated with smart home technology.


**Above** *Modello, Chris Dikeakos Architects Inc.*

**Above** *Modello, Chris Dikeakos Architects Inc.*

# 04.6 Filter the Air

As forest fires increase across British Columbia, the risk of air quality advisories also increases. This and other sources of poor air quality can be addressed in building design by making sure that mechanical ventilation systems that provide cooling are also designed for a higher level of filtration.

Designers should identify the number and intensity of local sources of air pollutants to determine the level of filtration that should be used. In general, designers should try to exceed industry standards of MERV 8 by using a minimum of MERV 13 filters in system design. However, higher performance filters often have higher maintenance costs, as they require replacement more often. Failure to replace filters according to their schedule will also result in lower performance. This is particularly a risk where filters are maintained by occupants themselves.

Where higher levels of filtration are inappropriate or unfeasible, systems can be designed to accommodate additional filtration media, or the use of higher performing filters during air quality advisories. Designers can incorporate higher performance filters into ventilation units with minimal upsizing of the fans where they are used for short durations (e.g. during air quality advisories). Activated carbon filters should be used in buildings located in areas with high concentrations of gaseous contaminants (e.g. VOCs).

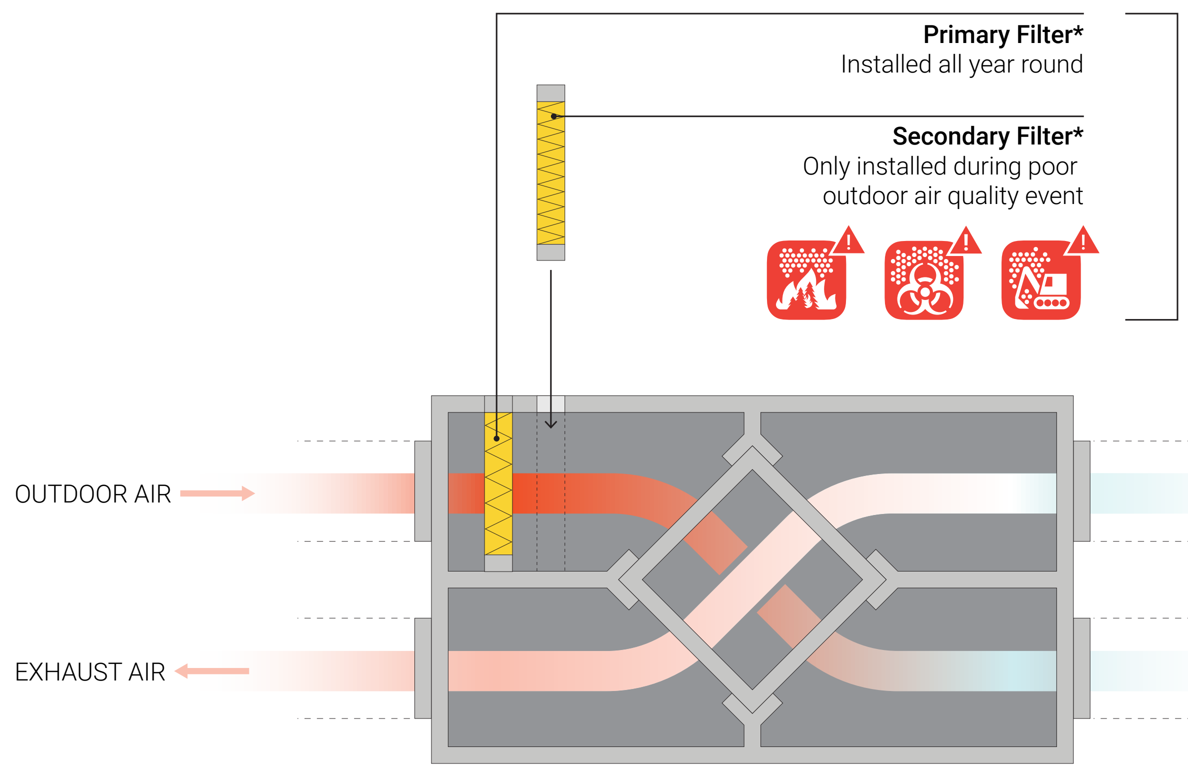
Building operators must ensure all filters are replaced as required and that secondary filters are removed upon air quality advisory ending.

## Dedicated Outdoor Air Systems

Dedicated outdoor air systems (DOAS) are systems used to provide 100% of a space in a building with fresh outdoor air, flushing the building of contaminants and improving air quality. DOAS are most effective in improving air quality when compared with other ventilation systems, and should be designed to include heat recovery to improve energy efficiency.

### Issues to keep in mind when designing for indoor air quality:

- *Ensure any air intakes to mechanical ventilation systems are located as far away from allergens and pollutants as possible, and on the shaded side of the building. Protect intakes from pests and animals.*
- *Use demand control ventilation to control pollutant concentrations in a space and reduce energy use by supplying only the amount of outdoor air that is required.*
- *Reduce the impact of higher performance filters on energy efficiency by selecting filters with a minimum depth of 100mm.*




**Adding higher performance filters can increase the building's TEUI.** To reduce the impact on energy efficiency, designers should select deeper filters.

*Note that filters can be either internal to the unit, or external downstream of the supply fan.

### Key Terms

**MERV** (or minimum-efficiency reporting value) is a measurement scale designed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers) ASHRAE to rate the effectiveness of air filtration systems. The scale ranges from MERV 1 to MERV 16, depending on the minimum particle size that is filtered out of the air.

**HEPA** (or high-efficiency particulate air) is a type of air filter that works by forcing air through a fine mesh that traps harmful particles such as pollen, pet dander, dust mites, and smoke. To meet the HEPA standard, air filters must remove 99.97% of particulates greater than or equal to 0.3 μm from the air that passes through them.

**ACTIVATED CARBON** is a method of filtering that uses chemical absorption to remove contaminants and impurities. Activated carbon has properties that allow it to remove volatile organic compounds (VOCs), odours, and other pollutants, but do not remove fine particles such as dust, pollen, and smoke. For this reason, they are best used in concert with other types of air filters (e.g. HEPA or MERV 13).

**KEY TAKEAWAY**

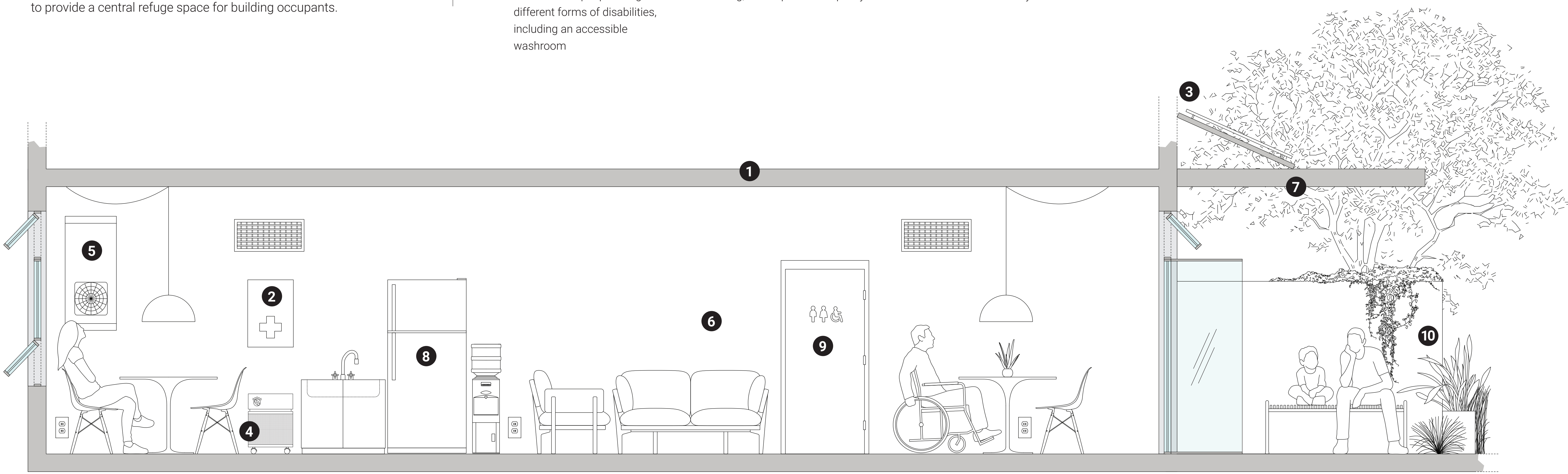
Select filters with a minimum performance of MERV 13 for year-round air quality, and swap in even higher performing filters during poor air quality events.

# 04.7 Include a Refuge Area into Building Design

Designing one or more common areas inside a MURB as a refuge area can help build overall resilience to both air quality advisories and heat events.

Refuge areas help ensure that both occupants and where possible, community members at large have a place of respite in the event their own units become uncomfortable or unsafe. These spaces can be included alongside or in place of some of the more advanced strategies noted in this guide in order to provide a central refuge space for building occupants.

1. Design the space for enhanced seismic resilience
2. Ensure emergency supplies are provided, including food and potable water. Consider rainwater collection with filtration as a reliable source of water
3. Connect the refuge area to a low-carbon source of back-up power and storage
4. Provide higher levels of filtration, either in the form of centralized or portable filters
5. Connect the space to a source of mechanical heating and cooling
6. Set up the space to provide both private and social areas that are accessible to people living with different forms of disabilities, including an accessible washroom
7. Ideally, provide access to a treed area outside to provide shading, cooling, and improved air quality
8. Provide food storage and potable wate, with potential connections to a rainwater collection system
9. Provide an accessible washroom for people of all different abilities
10. Plant outdoor vegetation that offers connection to nature



**CASE STUDIES**

## Skeena Terrace

With 234 units constructed between 1960 and 1963, Skeena Terrace offers a variety of subsidized housing options in East Vancouver. While there is no active cooling provided to individual units, the complex has two spaces designed to act as refuge areas when necessary: one reading room of approximately 585 sf in a 6-storey building, and a larger amenity building in the central courtyard that serves all the tenants. During hot weather events, both spaces are equipped with portable air-conditioning units. These spaces were also designed to promote socializing between tenants and are used for community development programs delivered by BC Housing. Outside, the property offers ample greenspace for those looking to escape their warm units, with planting beds and a children's playground, and is generally well-shaded, including large trees planted along the west lot line.

**Right** *Skeena Terrace, Vancouver, BC*
*Underwood McKinley Cameron*

# Appendix

# A1 Glossary of Terms

**ACCEPTABILITY LIMITS** A specific indoor operative temperature at which the potential of overheating becomes a concern, which varies depending on the building's location.

**ACTIVATED CARBON** A method of air filtration that can remove volatile organic compounds (VOCs), odours, and other pollutants, but does not remove fine particles such as dust, pollen, and smoke. For this reason, they are best used in concert with other types of air filters (e.g. HEPA or MERV 13). An activated carbon filter must be replaced when its cleaning capacity has been used up.

**AIR-SOURCE HEAT PUMP** A highly energy efficient heat pump-based system that uses low-grade heat from the ambient air and uses it as a source of heat to condition building interiors.

**AIRTIGHTNESS** The measure of a building envelope's resistance to the leakage of air in or out of a building.

**BUILDING ENVELOPE (ENCLOSURE)** The elements that make up the outer shell of a building that separate indoor from outdoor spaces. A building's envelope prevents or controls the entry of heat, water, air, noise, and light from entering or leaving.

**CLIMATE ZONE** A region of the country defined by its average temperature (based on heating degree days). Climate zones in British Columbia range from Climate Zone 4 in Vancouver to Climate Zone 8 in the far north.

**COEFFICIENT OF PERFORMANCE (COP)** A measure of how efficiently a heat pump converts electricity into usable thermal energy.

**DEMAND CONTROL VENTILATION (DCV)** A system that automatically adapts the airflow rate in a space to the actual occupant load, based on the $CO_2$ exhaled by those occupants. By reducing the amount of fresh air brought in when occupant loads decrease, DCV can save energy and put less demand on the system.

**DRY BULB** The true thermodynamic temperature of the air when measured by a thermometer exposed to the air but shielded from radiation and moisture.

**ELECTROCHROMIC GLAZING** Technology that allows for automatic or manual control of a window's tint and solar heat gain properties.

**ENERGY EFFICIENCY** A measure of the effectiveness of energy use. A building with high energy efficiency requires less energy to perform the same tasks (e.g. heating, cooling, ventilation, etc.) as a building with lower energy efficiency.

**ENERGY RECOVERY VENTILATION (ERV)** A ventilation device that captures the energy from stale air as it leaves a building and uses the warmth to temper or pre-heat incoming fresh supply air before circulating it to occupants. It also captures some of the humidity in the air to help temper indoor climates — in summer, humidity is removed from incoming air prior to being injected into a building; in the winter, the reverse process occurs.

**FAÇADE** The exterior face of a building.

**GLAZING** Windows on a building.

**GLOBAL WARMING POTENTIAL (GWP)** A measure of how much heat a greenhouse gas traps in the atmosphere compared to carbon dioxide ($CO_2$).

**GREENHOUSE GAS INTENSITY (GHGI)** A measure of the emissions intensity of a building's emissions, measured and expressed in tonnes or kilograms of carbon dioxide equivalent per square metre per year ($CO_2e/m^2/year$).

**GROUND SOURCE HEAT PUMP (GEOEXCHANGE)** A heat pump-based heating and cooling system that uses low-grade heat stored in the ground to condition interior building spaces.

**HEPA (OR HIGH-EFFICIENCY PARTICULATE AIR)** A type of air filter that works by forcing air through a fine mesh that traps harmful particles such as pollen, pet dander, dust mites, and smoke. To meet the HEPA standard, air filters must remove 99.97% of particulates greater than or equal to 0.3 µm from the air that passes through them.

**HEAT RECOVERY VENTILATOR (HRV)** A ventilation device that captures heat from stale exhaust air as it leaves a building and uses the warmth to temper or pre-heat incoming fresh supply air before circulating it to occupants.

**HIGH-RISE MURB** A multi-unit residential building of six storeys or higher, often designed and built using concrete construction techniques.

**HYDRONIC** The practice of using a water-based medium to distribute heat (providing both heating and cooling) throughout a building. Hydronic systems can use either radiators, in-floor systems, and in some cases, in-ceiling systems.

**MASSING** A building's general shape and size.

**MECHANICAL COOLING** Active systems that use energy to lower the temperature within a space, including heat pump systems, variable refrigerant flow systems, and mixed mode systems.

**MINIMUM-EFFICIENCY REPORTING VALUE (MERV)** A measurement scale designed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to rate the effectiveness of air filtration systems. The scale ranges from MERV 1 to MERV 20, depending on the minimum particle size that is filtered out of the air. Filters with efficiencies lower than MERV 13 are unlikely to provide protection from wildfire smoke.

**MURB** Multi-unit residential building

**NATURAL VENTILATION** The process of intentionally exchanging air in a building to replace stale air with fresh air from the building exterior, using non-mechanical means such as stack effect, cross ventilation, design elements, and operable windows.

**ORIENTATION** The way that a building is situated on a site, including the positioning of windows and rooflines, which can affect energy loads, solar heat gain, and thermal comfort.

**OVERHEATING** The state of high indoor temperatures in a building that can affect occupant thermal comfort, health and wellbeing, and productivity. Dangerously high temperatures can cause health risks, particularly in vulnerable populations. Toronto Public Health and Public Health England have both recommended that indoor temperature be no higher that 26°C.

**PART 3 BUILDING** A building over three storeys in height or over 600 square metres in footprint. Part 3 also includes some buildings of three storeys or less in height or under 600 square metres in area that are of a specific use. This includes larger buildings intended for residential, commercial, or industrial activities, as well as as well as buildings intended for public gatherings, residential care, or detention.

**PART 9 BUILDING** A building three storeys and under in height and with a footprint of 600 square metres or less. Part 9 buildings include small buildings intended for residential, commercial, or medium-to-low hazard industrial activities.

**PASSIVE SURVIVABILITY** A building's ability to maintain healthy, liveable conditions in the event of extended loss of power or water, or in the event of extraordinary heat waves, storms, or other extreme events.

**PEAK CONDITIONS** The instantaneous amount of heating or cooling that the building will require in order to maintain a specific indoor temperature during the coldest or warmest time of the year, respectively.

**RELIEF OPENING** In natural ventilation design, large openings at the top of a building that are used to vent warm air driven by the stack effect.

**SHADES** Systems installed on the exterior or interior of a building that are used to block unwanted solar heat gains. These can be manually-operated or automatically controlled.

**SHOCK** An acute natural or human-made event or phenomenon threatening major loss of life, damage to assets and a building or community's ability to function and provide basic services (e.g. heat wave, urban interface fire).

**SOLAR HEAT GAIN** The increase in thermal energy in a building as it absorbs incoming solar radiation.

**SOLAR HEAT GAIN COEFFICIENT (SHGC)** The fraction of solar radiation that is transmitted through a window, expressed as a number between 0 and 1. The lower the SHGC, the less solar heat the window transmits.

**STACK EFFECT** A phenomenon that occurs in taller buildings, this pressure differential between the interior and exterior drives the movement of interior air. Under cooler temperatures, it often creates positive pressure, which forces warmer air out of the enclosure at the upper portions of walls and the building and draws cooler air into lower portions.

**STRESS** A chronic (i.e. ongoing or cyclical) natural or human-made event or phenomenon that renders a building or community less able to function and provide basic services (e.g. increased average summer temperatures).

# A1 Glossary of Terms

**THERMAL COMFORT** The state where an occupant is satisfied with the temperature of a particular space. Thermal comfort is highly subjective and can depend on individual characteristics, behavioural factors, cultural norms, and environmental conditions.

**THERMAL ENERGY DEMAND INTENSITY (TEDI)** A measure of the total heating energy necessary to maintain a comfortable indoor temperature over the course of a year, expressed in kilowatt hours per square metre per year (kWh/m²/year).

**THERMAL RESILIENCE** The ability of a building's thermal conditions to adapt to the effect of power outages by using/modifying traditional active cooling, improving weatherization and insulation, increasing air circulation, reducing solar gains through windows, using natural ventilation, cooling external surfaces, minimizing internal heat gains, and cooling in place.

**TOTAL ENERGY USE INTENSITY (TEUI)** A measure of the total amount of energy used by a building over the course of a year, per unit of building area, measured and expressed in kilowatt hours per square metre per year (kWh/m²/year). TEUI encompasses all energy used in a building, including plug loads (e.g. lighting, appliances) and process loads (e.g. elevators, mechanical systems, and fans).

**UNMET COOLING HOURS** For spaces that make use of mechanical cooling, the time that a cooling system is unable to achieve the desired indoor temperature.

**U-VALUE** A measure of how well a building element conducts heat. The lower the U-value, the greater the material's insulating properties. U-values are expressed in SI units of W/(m²K) and U.S. units of BTU/(hr °F ft²). U value is the inverse of R value.

**VARIABLE REFRIGERANT FLOW (VRF)** A highly energy efficiency refrigerant-based heating and cooling technology.

**VULNERABLE POPULATIONS** Groups and communities at a higher risk for poor health as a result of the barriers they experience to social, economic, political, and environmental resources, as well as limitations due to illness or disability. These include children, pregnant women, elderly people, people with low incomes, and people who are ill or immunocompromised.

**WATER-SOURCE HEAT PUMP** Also known as ground source heat pumps, these are highly energy efficient heat pump-based systems that extract and dissipate heat using water or the ground. When compared to air, the temperatures of these mediums remain relatively constant throughout the seasons, limiting variations in efficiency.

**WINDOW-TO-WALL RATIO (WWR)** The percentage of a building's façade that is made up of glazing.

# A2 Image Sources

**PAGE 14**
*Vancouver Airport CWEC 2016*
**Source** http://climate.weather.gc.ca/prods_servs/engineering_e.html

**PAGE 15**
*Global Average Surface Temperature Change*
**Source** Adapted from Figure SPM.7a from http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

**PAGE 16**
*1st and Clark, Vancouver, BC*
**Source** BC Housing/Focal Engineering

**PAGE 21**
*3986 Norland Way, Burnaby, BC*
**Source** Horizon North/Focal Engineering

**PAGE 24**
*Olympic Village, Vancouver, BC*
**Source** Susan MacDougall

**PAGE 26**
*10 Buttertubs Drive, Nanaimo, BC*
**Source** Low Hammond Rowe Architects (LHRA) https://www.lhra.ca/home/

**PAGE 29**
*Orion, Vidorra Developments, Pemberton, BC*
**Source** Dennis Maguire Architect / Rob Nadeau http://orionpemberton.com/

**PAGE 33**
*Cambie Gardens, Vancouver, BC*
**Source** IBI Group https://www.ibigroup.com/

*Modello, Burnaby, BC*
**Source** Chris Dikeakos Architects Inc. http://www.dikeakos.com/

**PAGE 36**
*Skeena Terrace, Vancouver, BC*
**Source** BC Housing

**ILLUSTRATIONS**
*Assets for illustrations produced by Dimensions.Guide*
**Source** https://www.dimensions.guide/