NET ZERO HOMES

Design, Construction, Building Science & Technical Standards
for High-Performance Residential Construction

BUILD SMART
VERIFY PERFORMANCE
LIVE COMFORTABLY

NET ZERO HOMES

Design, Construction, Building Science & Technical Standards for High-Performance Residential Construction

A Practical Design, Construction and Verification Manual for Net Zero Homes in British Columbia

From First Concept to Final Handover

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Portions of this manual reference the BC Building Code, the National Building Code of Canada, the BC Energy Step Code, the Zero Carbon Step Code, ENERGY STAR®, Passive House principles, CSA Group standards and ASHRAE standards. These references are provided for general orientation only. This manual does not reproduce the text of any code or standard, and readers must consult the official, current publication of each code or standard directly — see the References & Further Reading section.

All diagrams and illustrations in this manual were created by the author for this publication.

This manual reflects the author's own field research, training, and construction experience. It has not yet been reviewed by an independent building-envelope, mechanical, electrical, structural, energy-modelling, or legal professional. Readers must verify every technical statement against the current, authentic codes, standards, and manufacturer instructions applicable to their project before relying on it — see the Important Notice on the following pages.

IMPORTANT NOTICE

Please Read Before Using This Manual

This manual is an educational and project-coordination resource. It is written to help owners, builders, trades and designers understand, in practical terms, what a high-performance or Net Zero home involves and how a project is typically planned, built, tested and handed over.

This manual does not replace, and must not be treated as a substitute for:

- The current British Columbia Building Code, National Building Code of Canada, or any other applicable code in force at the time of construction.
- Municipal or regional-district bylaws, zoning requirements, and permit conditions.
- Site-specific design, structural engineering, mechanical engineering, or electrical engineering prepared by a licensed professional.
- Energy modelling prepared by a qualified energy advisor.
- Manufacturer installation instructions for any specific product.
- The requirements of any voluntary certification program, including Passive House, ENERGY STAR®, or R-2000.
- The professional and legal judgment of the architects, engineers, energy advisors, and other registered professionals engaged on a specific project.

Requirements change. Code editions are periodically updated, and municipal requirements vary by jurisdiction. Wherever this manual references a code, standard, or program, the reader must verify the current, applicable requirement directly with the issuing body or authority having jurisdiction at the time of construction — not rely on the description in this manual.

> **GUIDING PRINCIPLE**
>
> *A book can explain how a high-performance home is generally designed and built. It cannot replace the judgment of the professionals who are actually responsible for your specific project, on your specific site, under the code in force on the day you pull your permit.*

Building science depends on climate zone, orientation, materials, workmanship, mechanical conditions and many other project-specific factors. Statements in this manual describe how an assembly or system is generally designed to perform when built according to the details described and appropriate for the applicable climate — not a guarantee of outcome for any specific building.

Actual energy performance depends on many factors outside the control of design and construction alone, including occupant behaviour, thermostat settings, weather, appliance use, plug loads, solar production, shading, commissioning quality, and workmanship. This manual distinguishes between designed performance (what the assembly or system is intended to achieve), modelled performance (what an energy model estimates under defined conditions), and measured

performance (what is actually verified once the home is built and tested). None of these should be read as a guarantee of a specific utility bill or energy outcome.

GUIDING PRINCIPLE

This manual will never promise that a specific home "will have zero energy bills" or that a design "guarantees" Net Zero performance. Those are not honest claims for anyone to make about a building that has not yet been tested. What can be promised is a disciplined process: design it correctly, build it correctly, test it, correct deficiencies, and verify performance before calling the job done.

READER'S GUIDE

How to Read This Book

Throughout this manual, statements are labelled so you always know what kind of claim you are reading. This is deliberate: a code requirement, a recommended practice, and one builder's personal opinion are three very different things, and a good technical manual should never blur them together.

CODE REQUIREMENT

What the applicable code, bylaw, or regulation requires. Always verify the current edition and local amendments — see the disclaimer on the previous page.

BEST PRACTICE

A construction practice widely recommended by building-science professionals and standards organizations, beyond the code minimum.

BUILDER'S STANDARD

The author's preferred way of building something — a standard developed through direct field experience, offered as one credible approach, not a code requirement.

DESIGN OPTION

One of several technically viable approaches. The right choice depends on climate, budget, site conditions, and the owner's priorities.

GUIDING PRINCIPLE

The author's own philosophy, values, or way of thinking about a decision — offered as perspective, not instruction.

This manual was drafted with the assistance of AI research and organization tools, but its technical philosophy, construction methodology, project experience, and final judgments are the author's own — developed from the practice of actually building net zero homes in British Columbia, from excavation through commissioning.

Table of Contents

1 Introduction 8
2 Purpose and Scope 10
3 What Is a Net Zero Home? 11
4 BC Codes, Energy Requirements and Municipal Approvals 13
5 Project Team and Professional Responsibilities 16
6 Energy Modelling and Performance Targets 19
7 Building Envelope 21
8 Air Barriers and Airtightness 24
9 Windows, Doors and Thermal Bridging 26
10 HVAC, Heat Pumps and HRV/ERV 28
11 Domestic Hot Water 31
12 Electrical Systems, Appliances and EV Readiness 32
13 Solar PV and Battery Storage 34
14 Construction Sequencing 35
15 Quality Control and Inspections 38
16 Testing and Commissioning 40
17 Third-Party Certification 42
18 Final Inspection, Occupancy and Handover 44
19 Master Construction Checklists 46
20 Conclusion and Continuing Performance 50
A Appendix A — Project Responsibility Matrix 51
B Appendix B — Performance and Testing Record 52
C Appendix C — Homeowner Handover Schedule 53
— References & Further Reading 54
— About the Author 55

CHAPTER 1
GETTING ORIENTED

Introduction

1.1 The Changing Residential-Construction Environment

Residential construction in British Columbia is moving toward higher levels of energy performance. Increasing energy costs, evolving codes, climate considerations, improved technologies and growing demand for healthier homes are changing the way homes are designed and built.

Net Zero homes are an important part of this transition. They are not created by adding solar panels to an otherwise conventional building. They require coordinated decisions about the building envelope, windows and doors, mechanical systems, ventilation, domestic hot water, electrical systems, renewable energy, and construction quality.

1.2 What This Manual Provides

This manual presents a practical framework for planning, designing, constructing, testing, commissioning and handing over a high-performance or Net Zero home in British Columbia. It emphasizes:

- Early performance planning
- Clear professional responsibilities
- Energy modelling
- Continuous insulation and airtight construction
- Moisture and durability management
- Properly sized mechanical systems
- Renewable-energy coordination
- Inspection hold points
- Testing and commissioning
- Complete documentation
- Homeowner education

1.3 The Five Foundations of Net Zero Construction

A successful project generally depends on five connected areas:

- High-performance building envelope: insulation, airtightness, reduced thermal bridging, high-performance openings and moisture control.
- Efficient mechanical systems: properly sized heat pumps, efficient domestic hot water and balanced HRV/ERV ventilation.
- Efficient electrical systems: efficient lighting and appliances, smart energy management, EV readiness and appropriate electrical infrastructure.

- Renewable energy: properly designed solar photovoltaic systems and, where appropriate, battery storage.
- Testing, verification and documentation: modelling, inspections, airtightness testing, commissioning, deficiency correction and final records.



Figure 1.1 — The five connected foundations of a Net Zero home.

GUIDING PRINCIPLE

The central principle behind everything in this manual is simple: design it correctly, build it correctly, test it, correct deficiencies, verify performance, then deliver it properly. Skip a step and the rest of the sequence stops meaning much.

CHAPTER 2
FRAMING THE MANUAL

Purpose and Scope

2.1 Purpose

The purpose of this manual is to help project teams understand what must be considered, when it must be considered, who is responsible, how the work should be coordinated, and how completed performance should be verified.

The intended result is a home that is comfortable, healthy, durable, resilient, energy efficient and practical to operate.

2.2 Scope

This manual covers the principal stages of a residential project, from initial planning through final occupancy and homeowner handover. It addresses:

- Code and energy-performance requirements
- Project planning and professional responsibilities
- Energy modelling and performance targets
- Building-envelope design and construction
- Insulation, airtightness and air-barrier continuity
- Windows, doors, thermal bridges and moisture control
- Heating, cooling, heat pumps and ventilation
- Domestic hot water
- Electrical systems, appliances and EV readiness
- Solar photovoltaic and battery systems
- Construction sequencing and site quality control
- Inspection, testing and commissioning
- Third-party certification
- Final inspection, occupancy and handover
- Checklists, common mistakes and best practices

GUIDING PRINCIPLE

This manual is not a substitute for professional design, engineering, energy modelling, code compliance, municipal approval, or certification-program requirements. It is a coordination tool that sits alongside those things — never in place of them.

CHAPTER 3
THE CORE CONCEPT

What Is a Net Zero Home?

3.1 Definition

A Net Zero home is a highly energy-efficient home designed so that, over an applicable annual period, the energy it produces from renewable sources is approximately equal to the energy it consumes. The exact definition depends on the selected program, modelling methodology and energy boundary.

The home should be viewed as one integrated system in which the envelope, windows, doors, heating, cooling, ventilation, domestic hot water, electrical systems, appliances, controls and renewable-energy systems work together.

3.2 The Basic Principle

The process can be summarized as: reduce energy demand, improve efficiency, control energy loss, add renewable energy, then verify performance.

The first priority is to reduce demand. This is achieved through appropriate orientation and form, continuous insulation, airtight construction, high-performance windows and doors, reduced thermal bridging, efficient mechanical systems, heat-recovery ventilation and efficient hot-water and electrical systems. Renewable energy is then used to offset the remaining demand.

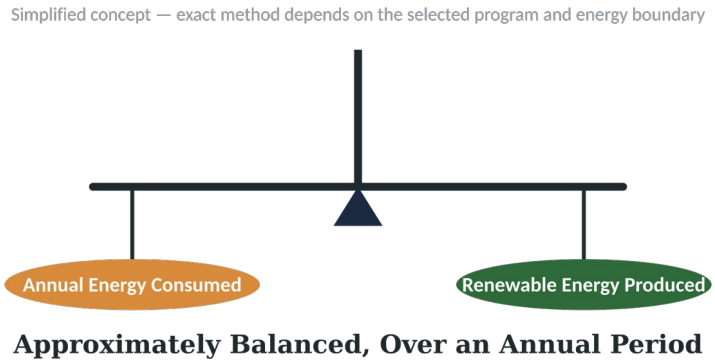


Figure 3.1 — The Net Zero energy balance concept, simplified.

3.3 Net Zero Is More Than Solar Panels

Solar panels installed on a poorly insulated or leaky home do not automatically create a Net Zero home. A deficient building envelope can require substantially more energy and a larger renewable-energy system than necessary.

GUIDING PRINCIPLE

Net Zero is a whole-building performance objective, not a list of green products. I have seen plenty of homes with solar arrays on the roof and a leaky, under-insulated envelope underneath — that is not a Net Zero home, it is a conventional home with an expensive roof.

3.4 Net Zero Compared With Other Terms

These categories are related but are not interchangeable. A specific Step Code level, permit approval, or voluntary certification does not automatically establish Net Zero performance.

Category	Meaning	Main Focus
Conventional code-built home	Meets minimum applicable code requirements	Minimum legal performance
BC Energy Step Code	Performance-based provincial framework with increasing efficiency levels	Building energy performance
ENERGY STAR® home	Certified high-efficiency home meeting applicable requirements	Efficiency and construction quality
R-2000 home	Voluntary Canadian technical standard addressing efficiency, airtightness, ventilation and IAQ	High-performance construction
Net Zero Energy Ready home	Highly efficient home prepared for remaining energy needs to be supplied by renewables	Very low energy consumption
Net Zero Energy home	Home designed so renewable production approximately offsets annual energy use	Very low energy use plus renewables

CHAPTER 4
THE REGULATORY PICTURE

BC Codes, Energy Requirements and Municipal Approvals

4.1 Establish the Regulatory Framework

CODE REQUIREMENT

A Net Zero home must satisfy the applicable British Columbia Building Code, provincial regulations, municipal or regional-district bylaws, zoning requirements, permit conditions, and any additional requirements associated with the chosen performance or certification pathway.

The project team must confirm the Code edition and requirements applicable to the specific permit application. Local requirements may affect zoning, development permits, building permits, servicing, site conditions, environmental matters, demolition, stormwater, utilities, fire and life safety, parking and EV infrastructure.

4.2 BC Energy Step Code

CODE REQUIREMENT

The BC Energy Step Code establishes progressively higher energy-performance requirements using a performance-based approach. It provides flexibility in how a project achieves the required performance. The applicable Step must be confirmed for the project and jurisdiction — a Step Code requirement is a regulatory energy-performance requirement; it is not automatically the same as Net Zero.

4.3 Zero Carbon Step Code

CODE REQUIREMENT

The Zero Carbon Step Code is related to, but separate from, the Energy Step Code. It addresses operational greenhouse-gas emissions through progressively more stringent emissions requirements. Establish both the energy-performance target and the carbon-emissions requirement at the beginning of the project.

4.4 Municipal and Regional Requirements

Before finalizing design, confirm, as applicable:

- Zoning and permitted use
- Setbacks, height, lot coverage and floor area

- Development and building permits
- Demolition permits
- Tree protection and arborist requirements
- Environmental, floodplain and geotechnical requirements
- Utility servicing and connections
- Stormwater management
- Sewer and water connections
- Fire and life-safety requirements
- Heritage requirements
- Parking and EV requirements
- Local energy or carbon requirements
- Restrictions on solar, mechanical equipment or equipment locations

4.5 Pre-Construction Approval Procedure

Before breaking ground, document:

- Applicable Building Code requirements
- Required Energy Step Code level
- Applicable Zero Carbon Step Code level
- Municipal zoning and development requirements
- Required permits and approvals
- Energy-modelling requirements
- Testing and documentation requirements
- Voluntary certification or Net Zero target
- Required professional involvement and sign-offs
- Inspection and occupancy requirements

4.6 Code Compliance Is Not Net Zero Certification

A building permit confirms that the proposed work has satisfied the applicable permit and regulatory requirements to the extent reviewed by the authority having jurisdiction. It does not, by itself, guarantee Net Zero performance. Maintain this distinction:



Figure 4.1 — Code compliance, certification, and verified performance are five distinct milestones.

CHAPTER 5
WHO DOES WHAT

Project Team and Professional Responsibilities

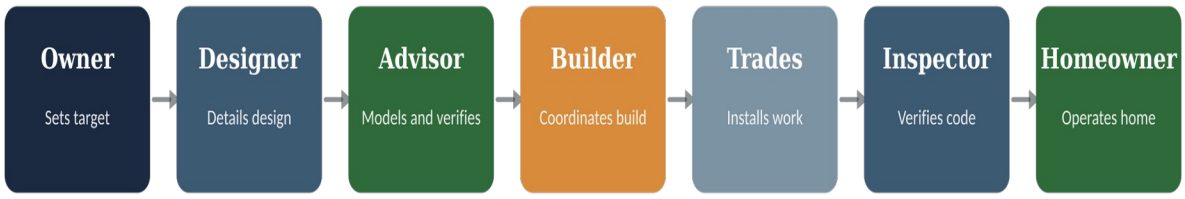


Figure 5.1 — The responsibility chain from target-setting to occupancy.

5.1 Owner or Developer

The owner or developer establishes the performance target, budget, quality expectations, certification requirements and decision-making process. The owner should establish the performance target at the beginning, decide whether the goal is high performance, Net Zero Ready, Net Zero, or certification, approve performance-related budget items, select qualified professionals and contractors, allow adequate time for design, modelling, construction, testing and commissioning, understand that substitutions can affect performance, and make timely decisions when issues arise.

5.2 Architect or Building Designer

The designer coordinates the building form, orientation, envelope, structural requirements, openings and performance-critical details. Drawings and details should show insulation, air barriers, water-control layers, windows, doors, penetrations, transitions and thermal-bridge strategies — performance should be built into the construction documents rather than left only to field instructions.

5.3 Energy Advisor or Modeller

The energy advisor or modeller establishes the performance targets, design comparisons, testing requirements, energy evaluations and certification documentation. The model should be used as an active design and construction tool, not merely as a final compliance document.

5.4 Structural Professional

Structural design must be coordinated with the building envelope. Beams, columns, foundations, balconies, slabs and penetrations can create thermal bridges or interrupt air-barrier continuity.

5.5 Mechanical Professional

The mechanical professional designs heating, cooling, ventilation and domestic hot water. Responsibilities include load calculations, heat-pump selection, HRV/ERV design, duct routing, controls, equipment access, balancing and commissioning.

5.6 Electrical Professional

Electrical planning should address service capacity, heat pumps, domestic hot water, solar PV, battery storage, EV charging, backup power, load management and future electrification.

5.7 Builder and General Contractor

The builder translates the design into a constructed building. The builder must coordinate trades, maintain air-barrier and insulation continuity, control penetrations, schedule hold points, document substitutions, and ensure deficiencies are corrected before work is concealed.

5.8 Site Supervisor or Project Manager

The site supervisor coordinates daily site execution, trade sequencing, inspections, photographs, deficiency tracking, testing appointments and communication of design changes.

5.9 Trade Contractors

Every trade can affect performance. Trades must follow approved details, use specified products, protect the envelope, report conflicts, avoid unnecessary penetrations, and correct identified deficiencies.

5.10 Inspectors, Suppliers and Manufacturers

Building officials and inspectors perform duties within their jurisdiction. Their inspection does not replace the builder’s own quality-control program. Suppliers and manufacturers should provide current specifications, installation instructions, performance data, compatibility information, warranty requirements and maintenance instructions.

5.11 Responsibility Matrix

At project start, document who designs it, who specifies it, who installs it, who inspects it, who tests it, who approves it, and who documents it. A completed responsibility matrix template appears in Appendix A.

5.12 Change Management

Before approving a significant change, review its effect on:

- Energy modelling
- Airtightness
- Thermal performance
- Thermal bridging
- Moisture management
- Mechanical performance
- Electrical capacity
- Certification
- Code compliance
- Cost and schedule

BUILDER'S STANDARD

No major performance-related change gets approved on my projects in isolation — in a phone call, in a hallway conversation, or as a verbal "yeah that's fine." It goes through the same short list above, every time, no exceptions. That discipline is what protects the modelled performance from getting quietly eroded by a dozen small decisions.

CHAPTER 6
MODELLING THE BUILDING

Energy Modelling and Performance Targets

6.1 What Energy Modelling Does

Energy modelling estimates how the building is expected to use energy under defined conditions. It may consider building size, orientation, insulation, air leakage, windows, solar gain, thermal bridges, heating and cooling, ventilation, hot water, lighting, appliances and renewable energy.

6.2 Establish the Target Early

Possible targets include code compliance, a specific Energy Step Code level, ENERGY STAR®, R-2000, Net Zero Ready, Net Zero Energy, or another recognized standard. The selected target must be recorded before major design decisions are finalized.

6.3 Use the Model to Compare Options

The model can compare additional insulation, windows, airtightness, heat pumps, HRV/ERV efficiency, hot-water systems, solar capacity, building geometry and mechanical strategies.

> DESIGN OPTION
>
> The best option on paper is not automatically the product with the highest specification. Consider whole-building performance, cost, constructability, durability and long-term value together — there is usually more than one technically sound way to hit a given target.

6.4 Establish an Energy Budget

A simplified Net Zero concept is: annual renewable energy produced minus annual energy consumed is approximately zero. The actual calculation method depends on the selected program and energy boundary. The team must identify which energy uses are included and how renewable production is credited.

6.5 Model the As-Built Project

The design model can be affected by material substitutions, construction changes, equipment changes, airtightness results, window changes, insulation changes and geometry changes. Significant changes must be communicated to the responsible energy advisor or modeller.

6.6 Make Targets Measurable

Record, where applicable: annual energy target, airtightness target, envelope performance, mechanical efficiency, ventilation performance, renewable-energy production, and certification requirements.

6.7 Model-to-Field Quality Control

Identify the assumptions that must be protected during construction. Create inspection points for insulation, air barriers, windows, doors, mechanical penetrations, ductwork, thermal bridges and solar systems.

6.8 The Performance Roadmap



Figure 6.1 — The performance roadmap, from target to verified result.

CHAPTER 7
THE ENCLOSURE

Building Envelope

7.1 Why the Envelope Matters

The building envelope separates the conditioned interior from the exterior. It includes foundations, slabs, walls, windows, doors, roofs, insulation, air barriers, water-control layers, vapour-control strategies and their connections.

> **GUIDING PRINCIPLE**
>
> *A high-performance mechanical system cannot compensate for a poorly designed or poorly constructed envelope. If I had to choose between an expensive heat pump and a well-detailed envelope, I would build the envelope right every time — it is the one system that is nearly impossible to fix later.*

7.2 Four Principal Control Functions

These layers must work together. A change to one layer can affect the others.



Figure 7.1 — The four control layers of a building envelope.

7.3 Insulation and Effective Performance

Insulation must be continuous, correctly fitted, protected from moisture and coordinated with structural, electrical, plumbing and HVAC work. The effective performance of an assembly is not simply its nominal insulation R-value — framing, fasteners, openings and structural elements can reduce performance.

7.4 Foundations and Slabs

Foundation and slab work should address insulation, thermal continuity, air sealing, moisture and vapour control, service entries, drainage and floor-to-wall transitions. Inspect and photograph critical work before concrete or finishes conceal it.

7.5 Above-Grade Walls

Wall assemblies should clearly identify the thermal layer, air layer, water layer and vapour-control strategy. Pay particular attention to foundation transitions, roof transitions, openings, corners, floors, ceilings, structural elements and service penetrations.

7.6 Roofs and Ceilings

Roof and ceiling assemblies must maintain continuity with the wall air and thermal layers. Inspect attic hatches, recessed lighting, mechanical penetrations, plumbing vents, exhausts, skylights, trusses and roof-mounted equipment.

7.7 Moisture and Durability

Energy efficiency cannot be separated from moisture management. Consider rain exposure, vapour movement, condensation, drying potential, humidity, climate, material compatibility, construction moisture and drainage. The objective is an enclosure that is airtight, watertight, thermally efficient and durable.

7.8 Common Envelope Mistakes

Common failures include insulation gaps, compressed insulation, discontinuous air barriers, unsealed penetrations, poor openings, unplanned structural penetrations, damaged membranes, incompatible sealants and field changes made without envelope review.

7.9 Builder’s Envelope Rule

> **BUILDER'S STANDARD**
>
> At every point in the build, my team needs to be able to answer four questions on the spot: Where is the insulation? Where is the air barrier? Where is the water-control layer? And how does each layer connect to the next assembly? If someone on site cannot answer those four questions for the wall in front of them, we stop and figure it up before we cover it up.

CHAPTER 8
CONTROLLING AIR MOVEMENT

Air Barriers and Airtightness

8.1 The Air Barrier

The air barrier is the continuous layer intended to control uncontrolled air movement through the enclosure. It may be created by membranes, sheathing, taped sheathing, sealed drywall, spray-applied materials, or another approved assembly. The key requirement is continuity around the entire conditioned space.

8.2 Air-Barrier Continuity

The air barrier must connect at foundation-to-wall, wall-to-floor, wall-to-roof, window and door interfaces, corners, mechanical penetrations, electrical penetrations, plumbing penetrations, service entries, structural penetrations, and attic transitions.

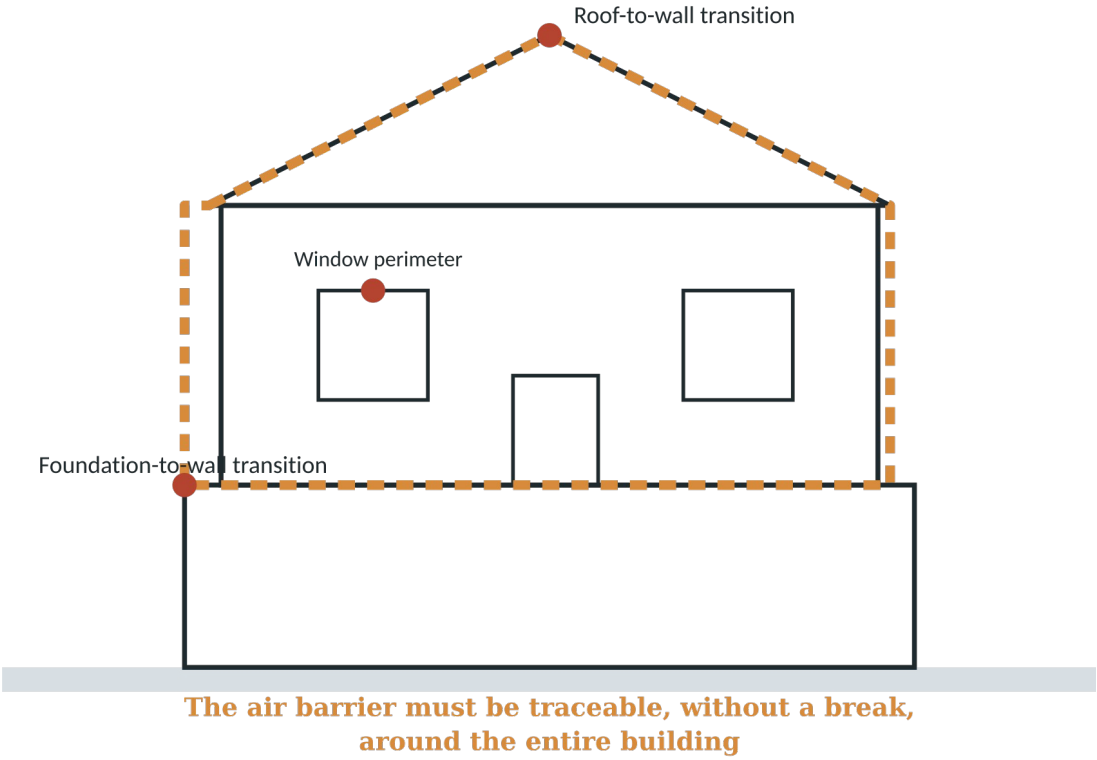


Figure 8.1 — Tracing air-barrier continuity around the building.

GUIDING PRINCIPLE

A practical rule I use on every project: if you cannot trace the air barrier continuously around the building with your finger on the drawing, the design is incomplete. That exercise catches more problems on paper than any amount of arguing about it on site.

8.3 Penetrations

Every penetration is a potential leakage point. Group penetrations where practical, minimize them, and seal them with compatible materials during the correct construction stage. Do not wait until finishes are complete if access to the air seal will be difficult.

8.4 Blower-Door Testing

A blower-door test creates a controlled pressure difference between the interior and exterior and measures air leakage. It should be planned early enough to permit repairs.

BEST PRACTICE

Use this sequence: test, locate leakage, repair, retest. Common leakage locations include openings, electrical boxes, plumbing and HVAC penetrations, attic hatches, and foundation transitions.

8.5 Hold Points and Documentation

Air-sealing work should be inspected before drywall, cladding, insulation or other finishes conceal it. Photograph important concealed work and retain the records.

8.6 Common Airtightness Mistakes

Avoid relying on accidental leakage for ventilation, sealing only visible interior gaps, making unplanned penetrations, failing to coordinate trades, and waiting until final completion for the first airtightness test.

CHAPTER 9
OPENINGS AND CONNECTIONS

Windows, Doors and Thermal Bridging

9.1 Window Selection

Coordinate window selection with the energy model. Consider U-value, solar heat gain, visible light transmission, frame, glazing, spacer, air leakage, water resistance, orientation and shading.

9.2 Solar Gain and Orientation

Window size, orientation, shading, overhangs, adjacent buildings and landscaping can affect both heating and cooling. Large glazing areas should be evaluated using whole-building performance.

9.3 Installation

The window must connect to the surrounding water-control layer, air barrier, insulation and interior finish. Address sill conditions, flashing, perimeter air sealing, drainage, shimming, fastening and insulation around the frame.

9.4 Exterior Doors

Evaluate thermal performance, frame, weather stripping, thresholds, air leakage, flashing, insulation and air-barrier connections. Doors between conditioned space and a garage deserve particular attention.

9.5 Thermal Bridging

A thermal bridge allows heat to flow more readily through a conductive material or connection. Examples include steel, concrete, metal framing, balconies, window frames, fasteners, floor-to-wall connections, roof-to-wall connections and foundation connections. Thermal bridges can increase energy loss, reduce comfort, create cold interior surfaces and increase condensation risk.

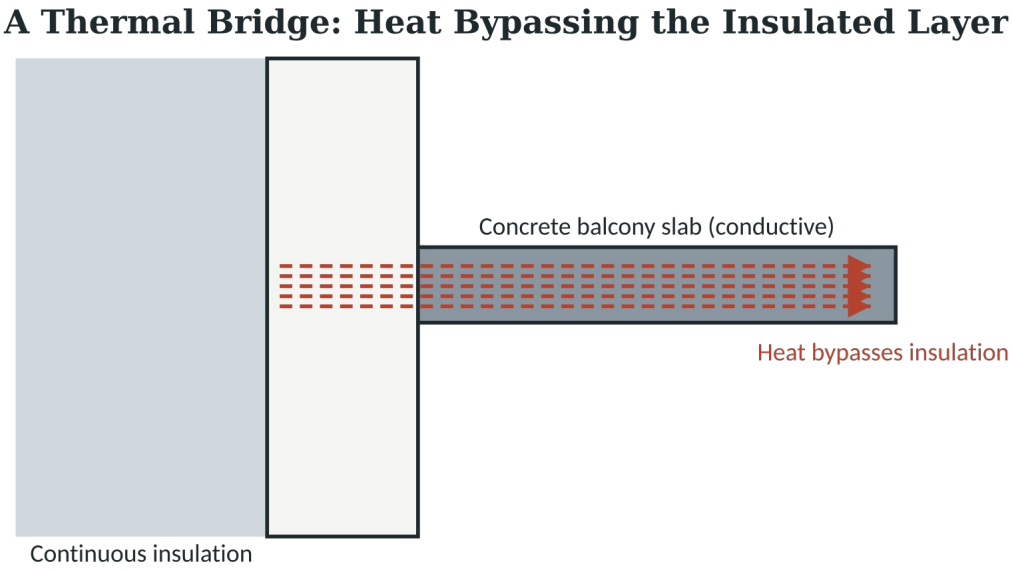


Figure 9.1 — Heat bypassing continuous insulation through a conductive connection.

9.6 Design Strategy

Identify where insulation stops, what crosses it, how heat bypasses it, and how the connection can be improved. Solve thermal bridges during design rather than after construction.

> DESIGN OPTION
>
> Balconies and structural attachments may require thermally broken connections, offset supports, an independent structure, or another solution developed jointly by the architect and structural engineer. There is rarely one "correct" answer here — the right choice depends on the specific structural and architectural constraints of the project.

9.7 Inspection

Verify products, installation, perimeter air sealing, flashing, insulation continuity, sill drainage, fastening, membrane condition and transitions. Photograph concealed details.

CHAPTER 10
COMFORT SYSTEMS

HVAC, Heat Pumps and HRV/ERV

10.1 Start With the Building

Mechanical design should begin with the building's calculated loads. Oversized equipment can short-cycle, reduce efficiency, impair comfort and increase operating costs.

10.2 Heat Pumps

Potential systems include air-source, ducted, ductless, multi-zone, cold-climate and ground-source heat pumps. Selection depends on building design, climate, heating load, distribution, electrical capacity, budget and performance target.

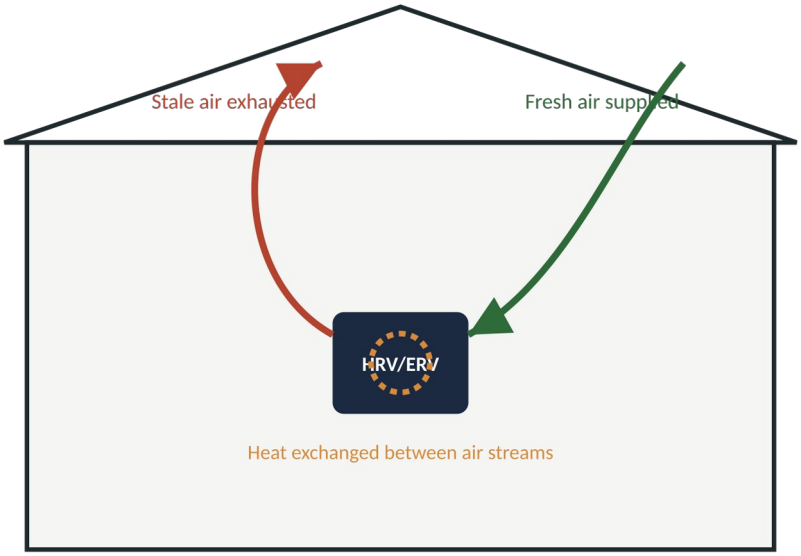
> DESIGN OPTION
>
> Consider low-temperature capacity, efficiency, modulation, defrost behaviour, cooling, noise, refrigerant, backup heat, electrical requirements, service and maintenance. More than one system type can be a technically sound choice for the same house — the right one depends on the specific project.

10.3 Distribution

For ducted systems, coordinate duct size, insulation, airflow, static pressure, routing, balancing, sealing, equipment location and access. Keep ducts within the conditioned envelope where practical.

10.4 Ventilation Is Separate

A heat pump does not replace dedicated ventilation. Airtight homes need controlled ventilation to provide outdoor air and remove pollutants and moisture. An HRV transfers heat between outgoing and incoming air; an ERV transfers heat and a portion of moisture. Selection depends on climate, occupancy, humidity strategy and project requirements.



Balanced Ventilation with Heat Recovery

Figure 10.1 — Balanced ventilation with heat recovery.

10.5 HRV/ERV Installation

Verify airflow rates, supply and exhaust locations, duct sizing, intake and termination locations, filtration, defrost, controls, noise, condensate management, access and service clearance.

10.6 Controls and Commissioning

Controls should be reliable and understandable. Commissioning may include equipment inspection, airflow measurements, duct balancing, HRV/ERV balancing, temperature verification, control testing, condensate inspection and documentation.

10.7 Common Mistakes

Avoid oversizing, selecting equipment before load calculations, poor duct design, duct leakage, poor ventilation planning, poor equipment access, unsealed penetrations, lack of commissioning and inadequate homeowner training.

10.8 Best-Practice Sequence

> **BEST PRACTICE**
>
> Reduce the load, calculate the load, select equipment, design distribution, design ventilation, coordinate installation, balance, commission, verify, then educate the homeowner — in that order, every time.

CHAPTER 11
HOT WATER SYSTEMS

Domestic Hot Water

11.1 System Selection

Select the hot-water system based on occupancy, demand, energy source, space, electrical capacity and the overall energy target. Options may include heat-pump water heaters and high-efficiency electric systems.

11.2 Sizing

Size according to expected demand, occupants, bathrooms, fixtures, recovery rate, storage and peak use. Oversizing can increase cost and standby losses.

11.3 Distribution

Keep piping runs reasonably short, insulate as required, avoid unnecessary oversized piping, minimize dead legs and evaluate recirculation carefully.

11.4 Recirculation

If recirculation is needed, consider demand-controlled, timed, or temperature-controlled operation. The objective is to balance comfort and energy use.

11.5 Commissioning and Handover

Verify equipment, water connections, settings, safety controls, pipe insulation, condensate, electrical connections and operation. Provide the homeowner with maintenance and operating instructions.

CHAPTER 12
POWER INFRASTRUCTURE

Electrical Systems, Appliances and EV Readiness

12.1 Early Electrical Planning

Coordinate service size, heat pumps, domestic hot water, cooking, laundry, solar PV, battery storage, EV charging, backup power, future loads and applicable electrical requirements.

12.2 Efficient Appliances and Lighting

Efficient appliances and LED lighting can reduce electricity use and the required renewable-energy capacity. Consider actual household use, daylight, occupancy controls, dimming and exterior lighting.

12.3 Electrification and Load Management

All-electric homes can simplify renewable-energy integration but may increase peak demand. Consider smart EV charging, heat-pump controls, water-heater scheduling, batteries, load shedding and energy-management systems.

12.4 EV Readiness

> **CODE REQUIREMENT**
> Plan for service capacity, dedicated circuits, conduits, panel capacity, charging location and load management. The exact installation must comply with current electrical, utility, municipal and project requirements — confirm the specific EV-readiness requirements in force for your jurisdiction before finalizing the electrical design.

12.5 EV Energy Boundary

The energy model must state whether vehicle charging is included in the Net Zero calculation. Solar production does not automatically offset EV charging unless the applicable energy boundary and modelling method allow it.

12.6 Quality Control

Verify equipment connections, panel labels, circuit identification, EV infrastructure, solar and battery provisions, controls, inspections and safe operation.

12.7 Future-Ready Strategy

Assess future loads, calculate demand, coordinate mechanical systems, plan EV charging, coordinate solar and battery, install efficient appliances, manage loads, then inspect and commission.

CHAPTER 13
GENERATING AND STORING POWER

Solar PV and Battery Storage

13.1 Role in the Net Zero Strategy

Reduce demand first. Then calculate the remaining energy requirement and size renewable generation using project-specific information.

13.2 PV Design

Consider location, roof orientation, pitch, roof area, shading, panel and inverter efficiency, system losses, expected annual production, service capacity, utility requirements and modelling requirements.

13.3 Roof and Electrical Coordination

Coordinate modules, inverters, mounting, wiring, disconnects, monitoring, utility connection, roof penetrations, battery storage, EV charging and future loads. Roof-mounted systems must not compromise water management or roof durability.

13.4 Battery Storage

Battery storage is not automatically required. Its purpose may be solar shifting, peak-demand reduction, backup power, critical-load support, or energy-management flexibility.

> DESIGN OPTION
> Size the battery according to daily demand, solar production, critical loads, backup duration, usable capacity, efficiency and future loads. Larger is not always better — an oversized battery adds cost without adding proportional value if it rarely discharges fully.

13.5 Backup Power

Identify which loads will be supported during an outage, such as refrigeration, lighting, communications, essential HVAC, security and selected outlets. Homeowners must understand what will and will not operate.

13.6 Safety, Monitoring and Handover

Consider location, fire safety, clearances, temperature, ventilation where applicable, electrical protection, access, manufacturer requirements and current regulations. Commission operation, monitoring, charging, discharging, backup, safety systems and utility connection. Provide shutdown, emergency, maintenance and monitoring instructions.

CHAPTER 14
BUILDING IT IN ORDER

Construction Sequencing

14.1 Sequence for Performance

The schedule should be developed around performance-critical work: plan, prepare, build, inspect, test, correct, then proceed.

14.2 Pre-Construction Review

Review approved drawings, the energy model, envelope details, air-barrier strategy, insulation, windows and doors, HVAC, hot water, electrical and renewable-energy systems, testing, certification and hold points.

14.3 Hold Points

Typical hold points include: foundation and slab insulation; foundation air and moisture control; framing and structural connections; wall insulation and air barrier; window and door installation; roof and ceiling continuity; mechanical and electrical penetrations; pre-drywall inspection; preliminary airtightness testing; final commissioning; and final airtightness testing.

14.4 Construction Stages

Foundation and Slab

Inspect below-grade insulation, slab insulation, transitions, moisture control, service penetrations, drainage and air sealing before concealment.

Framing

Maintain framing accuracy, opening dimensions, structural coordination, envelope continuity and thermal-bridge details. Review field modifications before implementation.

Envelope and Openings

Construct insulation, air, water and vapour-control layers systematically. Install windows and doors with proper flashing, air sealing, insulation, fastening and drainage.

Rough-In

Plan, minimize, seal and inspect each mechanical, electrical and plumbing penetration.

Pre-Drywall

Inspect insulation, air barriers, openings, penetrations, transitions and thermal bridges. Photograph the work, correct deficiencies and obtain approval to conceal.

Testing and Finishes

Perform preliminary testing while repairs remain accessible. Protect the envelope and systems during interior and exterior finishes.

Final Systems

Install and commission HVAC, HRV/ERV, hot water, electrical, PV, battery and EV systems. Complete final tests and records.

14.5 High-Level Construction Sequence

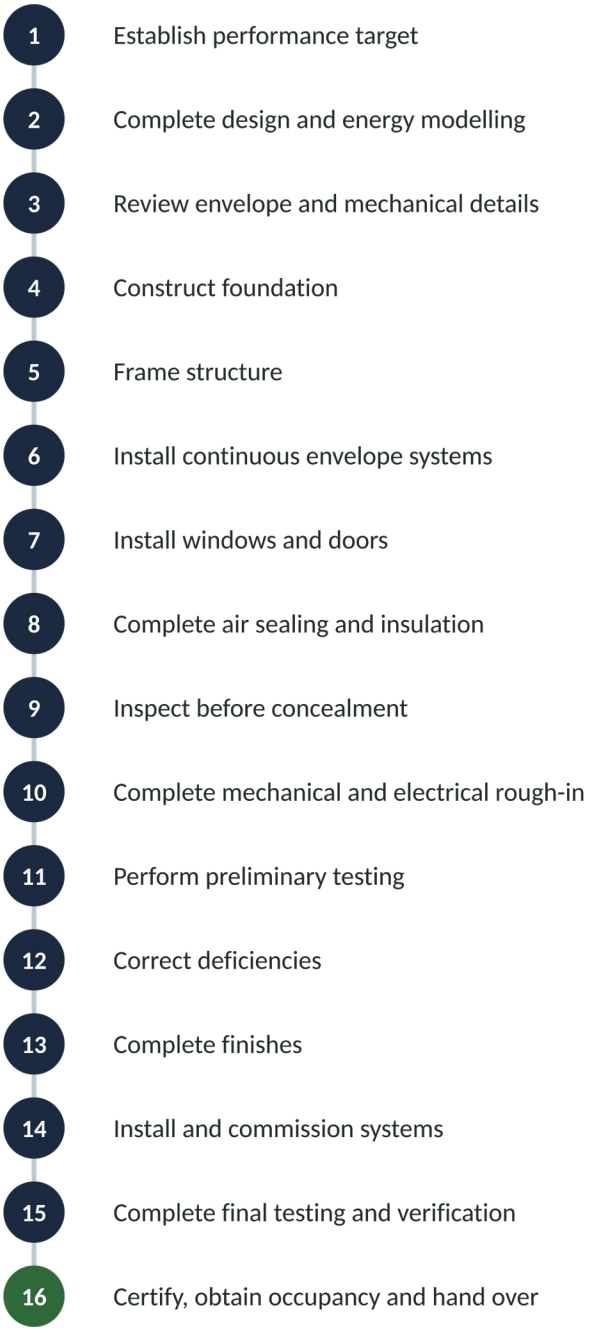


Figure 14.1 — The sixteen-step high-level construction sequence.

CHAPTER 15
BUILDING IT RIGHT

Quality Control and Inspections

15.1 Quality Control Begins Before Construction

Review drawings, targets, envelope, insulation, openings, systems, testing, certification and hold points before work starts. Communicate performance-critical requirements to every trade.

15.2 Inspection Responsibility

The owner establishes expectations, the designer provides details, the energy advisor establishes performance requirements, the builder coordinates, the site supervisor monitors, trades install, and inspectors and professionals verify as required.

15.3 Inspection Hold Points

> **BEST PRACTICE**
> Establish mandatory inspection points for foundations, waterproofing, framing, insulation, air barriers, openings, penetrations, pre-drywall work, preliminary testing, commissioning and final verification. A hold point that exists only on paper is not a hold point — work should not proceed past it without a completed, documented sign-off.

15.4 Deficiency Management

Use this process: identify, document, assign, correct, re-inspect, then close. A deficiency is not closed merely because a trade has been asked to return — the correction must be verified.

15.5 Documentation

Maintain inspection checklists, photographs, delivery records, product specifications, substitutions, deficiency reports, corrective actions, test results and commissioning reports.

15.6 Final Quality Review

Before occupancy, confirm the envelope, airtightness, insulation, openings, HVAC, HRV/ERV, hot water, electrical, solar, battery, EV readiness, controls, testing, documentation and certification requirements.

15.7 Quality-Control Principle

BUILDER'S STANDARD

Plan, inspect, document, test, correct, verify. Six words, but I run every project against that sequence — if a stage does not fit into one of those six steps, it usually means something has been skipped.

CHAPTER 16
PROVING PERFORMANCE

Testing and Commissioning

16.1 Plan Testing Early

Identify required tests, targets, responsibilities, timing, specialists, documentation and corrective procedures during design and construction.

16.2 Airtightness

Use preliminary testing where practical. Locate leakage, repair, retest, and document the final result against the applicable target.

16.3 Diagnostic Testing

Thermal imaging may help identify missing insulation, thermal bridges, unusual heat-loss areas and leakage patterns under suitable conditions. It is a diagnostic tool, not a replacement for required performance tests.

16.4 Ventilation and HVAC

Verify HRV/ERV supply and exhaust airflow, balance, controls, intake, termination, filtration, defrost, noise and vibration. Verify heat-pump model, capacity, installation, controls, airflow, operating modes and defrost.

16.5 Hot Water and Electrical Systems

Verify hot-water equipment, settings, safety controls, piping, condensate and recirculation. Complete required electrical inspections for panels, heat pumps, water heaters, EV charging, solar, batteries, controls and backup systems.

16.6 Solar and Battery

Commission modules, wiring, inverters, monitoring, production, utility connection, charging, discharging, backup, critical loads, safety and emergency procedures.

16.7 Performance Verification

Testing should answer one question: was the home built as designed? Compare actual results with applicable targets for airtightness, energy, ventilation, HVAC, hot water, renewable production, electrical systems and certification.

16.8 Homeowner Orientation

Demonstrate heating, cooling, ventilation, thermostats, hot water, solar monitoring, battery operation, EV charging, filters, maintenance and service contacts.

16.9 Commissioning Sequence

BEST PRACTICE

Design, construct, test, correct, retest, commission, document, educate. That final step — educate — gets skipped more often than any other, usually because everyone is exhausted by handover day. It is also the step that determines whether the home actually performs the way it was designed to, once the builder is gone.

CHAPTER 17
INDEPENDENT VERIFICATION

Third-Party Certification

17.1 Purpose

Third-party certification can provide independent verification, a defined standard, documented performance, structured quality control and confidence for homeowners.

17.2 Select the Pathway Early

Possible pathways may include Net Zero or Net Zero Ready certification, R-2000, ENERGY STAR® , provincial or municipal programs, or another recognized standard.

> **CODE REQUIREMENT**
> Confirm current requirements directly with the applicable certifying organization before relying on any description in this manual — certification requirements are updated periodically and vary by program.

17.3 Certification Is Not Code Compliance

Maintain this distinction: building-code compliance, then energy-performance compliance, then certification, then verified Net Zero performance. Each is a separate milestone.

17.4 Certification Process

The pathway may require design review, energy modelling, envelope inspections, airtightness testing, mechanical verification, renewable-energy documentation, photographs, product information, approved substitutions and final records.

17.5 Builder's Responsibility

The builder should understand the requirements, coordinate trades, protect performance-critical work, schedule inspections, maintain documentation, correct deficiencies and communicate changes.

> **GUIDING PRINCIPLE**
> *Certification should verify quality, not create quality. A certification badge on a poorly built home is a paperwork exercise; a well-built home that happens to also carry certification is the actual goal.*

17.6 Final Certification and Homeowner Value

Before final certification, confirm inspections, testing, airtightness, commissioning, renewable-energy verification, documentation, deficiency closure and performance requirements. Provide the certification and supporting documents to the homeowner.

CHAPTER 18
CLOSING OUT THE PROJECT

Final Inspection, Occupancy and Handover

18.1 Internal Final Inspection

Confirm completion of the envelope, air sealing, insulation, openings, finishes, HVAC, HRV/ERV, hot water, electrical, solar, battery, EV charging, plumbing, drainage, safety systems and controls.

18.2 Regulatory Approval

> **CODE REQUIREMENT**
> Complete applicable building, electrical, plumbing, fire, mechanical, energy, municipal, utility and professional approvals before occupancy.

18.3 Final Testing Records

Organize blower-door results, energy evaluations, HVAC commissioning, ventilation balancing, hot-water commissioning, electrical inspection, PV and battery commissioning, controls verification and certification documents.

18.4 Deficiency Review

Use: inspect, record, correct, verify, close. Performance-related deficiencies deserve particular attention because they can affect energy, comfort, durability and certification.

18.5 Homeowner Orientation

Explain heating and cooling, thermostats, HRV/ERV, filters, hot water, electrical panels, solar, batteries, EV charging, controls, shut-offs, emergency procedures and maintenance.

18.6 Handover Package

Provide, where applicable:

- Final drawings and specifications
- Envelope information
- Energy model and energy rating
- Airtightness results
- Certification documents
- HVAC and HRV/ERV manuals

- Commissioning records
- Electrical, PV, inverter, battery and EV documents
- Manufacturer manuals
- Warranties
- Maintenance schedules
- Monitoring instructions

18.7 Post-Occupancy Follow-Up

Where practical, follow up after occupancy to identify comfort, ventilation, controls, energy-use, equipment, moisture and homeowner issues while they remain manageable.

18.8 Final Handover Principle

> **GUIDING PRINCIPLE**
>
> *The home is approved. The building is complete. Systems are commissioned. Performance is verified. Deficiencies are resolved. Documentation is delivered. The homeowner understands the home. Handover is not the finish line — it is the point where responsibility for day-to-day performance passes from builder to owner, and that handoff deserves to be done properly.*

CHAPTER 19
FIELD REFERENCE

Master Construction Checklists

These checklists are field references. They do not replace approved drawings, specifications, professional advice, codes, bylaws or certification requirements.

19.1 Pre-Construction

- ☐ Performance target established
- ☐ Building Code requirements confirmed
- ☐ Energy Step Code requirements confirmed
- ☐ Zero Carbon requirements confirmed
- ☐ Municipal requirements confirmed
- ☐ Energy advisor appointed where required
- ☐ Energy model completed and reviewed
- ☐ Envelope strategy established
- ☐ Air-barrier strategy identified
- ☐ Insulation assemblies confirmed
- ☐ Windows and doors confirmed
- ☐ HVAC and ventilation design completed
- ☐ Domestic hot-water system selected
- ☐ Electrical, EV, PV and battery requirements confirmed
- ☐ Testing and commissioning plan established
- ☐ Certification requirements established
- ☐ Hold points established
- ☐ Trade responsibilities communicated

19.2 Foundation and Slab

- ☐ Foundation insulation installed correctly
- ☐ Slab insulation installed correctly
- ☐ Thermal transitions reviewed
- ☐ Waterproofing completed
- ☐ Moisture control completed
- ☐ Service penetrations identified
- ☐ Air sealing completed
- ☐ Drainage completed
- ☐ Concealed work photographed
- ☐ Required inspection completed

19.3 Framing and Structure

- ☐ Framing conforms to drawings
- ☐ Structural penetrations reviewed
- ☐ Thermal bridges identified
- ☐ Balcony connections reviewed
- ☐ Floor-to-wall transitions coordinated
- ☐ Roof-to-wall transitions coordinated
- ☐ Window and door openings correct
- ☐ Unnecessary penetrations avoided
- ☐ Envelope continuity maintained

19.4 Envelope

- ☐ Insulation type and thickness confirmed
- ☐ Insulation continuous and properly fitted
- ☐ Gaps and compression corrected
- ☐ Air barrier identified and continuous
- ☐ Water-control layer continuous
- ☐ Vapour-control strategy followed
- ☐ Foundation, wall and roof transitions complete
- ☐ Corners detailed
- ☐ Structural and service penetrations sealed
- ☐ Thermal bridges addressed
- ☐ Envelope inspected before concealment

19.5 Windows and Doors

- ☐ Products match approved specifications
- ☐ Rough openings prepared
- ☐ Sills and flashing completed
- ☐ Perimeter air sealing completed
- ☐ Insulation around frames completed
- ☐ Structural fastening completed
- ☐ Water drainage completed
- ☐ Operation verified
- ☐ Air-barrier interfaces inspected

19.6 Airtightness

- ☐ Air-barrier location identified
- ☐ Transitions inspected
- ☐ Electrical, plumbing, HVAC and service penetrations sealed
- ☐ Attic access sealed
- ☐ Openings sealed
- ☐ Foundation and roof transitions sealed
- ☐ Preliminary blower-door test completed where applicable
- ☐ Leakage corrected
- ☐ Final blower-door test completed
- ☐ Result documented

19.7 HVAC and HRV/ERV

- ☐ Equipment matches design
- ☐ Loads and capacity confirmed
- ☐ Ductwork installed and sealed
- ☐ Duct insulation completed where required
- ☐ HRV/ERV installed
- ☐ Intake and exhaust completed
- ☐ Condensate drainage completed
- ☐ Controls installed
- ☐ Maintenance access provided
- ☐ Airflows measured and balanced
- ☐ Commissioning completed

19.8 Domestic Hot Water

- ☐ Correct equipment installed
- ☐ System properly sized
- ☐ Electrical and water connections completed
- ☐ Safety controls verified
- ☐ Piping insulated where required
- ☐ Recirculation commissioned where applicable
- ☐ Condensate completed where applicable
- ☐ Temperature settings verified
- ☐ System commissioned

19.9 Electrical, Appliances and EV

- ☐ Service capacity confirmed
- ☐ Panel installed and labelled
- ☐ Heat-pump and hot-water circuits completed
- ☐ Efficient appliances selected where applicable
- ☐ Lighting installed
- ☐ EV-ready infrastructure completed
- ☐ EV charger installed where applicable
- ☐ Load management installed where applicable
- ☐ Electrical inspection completed

19.10 Solar PV and Battery

- ☐ PV designed and sized
- ☐ Roof layout and shading reviewed
- ☐ Roof penetrations sealed
- ☐ Modules and inverter installed
- ☐ Electrical connections completed
- ☐ Utility requirements satisfied
- ☐ Battery installed where applicable
- ☐ Backup loads identified
- ☐ Controls and monitoring verified
- ☐ System commissioned
- ☐ Homeowner instructions provided

19.11 Pre-Drywall

- ☐ Envelope inspected
- ☐ Insulation inspected
- ☐ Air barrier inspected
- ☐ Windows and doors inspected
- ☐ Mechanical, electrical and plumbing penetrations sealed
- ☐ Thermal bridges reviewed
- ☐ Photographs taken
- ☐ Deficiencies corrected
- ☐ Approval to conceal obtained

19.12 Final Testing

- ☐ Final blower-door test complete
- ☐ Airtightness target achieved
- ☐ PV commissioned
- ☐ Battery commissioned where applicable

- ☐ HRV/ERV balanced
- ☐ HVAC commissioned
- ☐ Hot water commissioned
- ☐ Electrical systems inspected
- ☐ Controls tested
- ☐ Energy-performance requirements verified
- ☐ Certification requirements completed

19.13 Final Inspection and Handover

- ☐ Municipal final inspection complete
- ☐ Occupancy approval obtained
- ☐ Deficiencies closed
- ☐ Energy documents complete
- ☐ Certification documents complete
- ☐ Manuals and warranties provided
- ☐ Maintenance information provided
- ☐ HVAC and HRV/ERV orientation complete
- ☐ Solar, battery and EV orientation complete where applicable
- ☐ Emergency procedures explained
- ☐ Final package delivered

CHAPTER 20
CLOSING THOUGHTS

Conclusion and Continuing Performance

A Net Zero home is not achieved by one product, one trade or one inspection. It is achieved through coordinated planning, accurate modelling, careful envelope design, disciplined construction, efficient mechanical and electrical systems, renewable-energy integration, testing, commissioning, documentation and homeowner education.

> **GUIDING PRINCIPLE**
>
> *The project team's continuing objective is: reduce demand, protect the envelope, operate efficient systems, verify performance, and maintain the home properly. The home should continue to provide comfort, health, durability, resilience and lower energy demand throughout its service life.*

The final handover is therefore not the end of performance management; it is the beginning of informed operation and maintenance.

APPENDIX A

Project Responsibility Matrix

A starting template. Adapt roles and tasks to the actual project team and confirm final responsibility assignments in writing before construction begins.

Task	Owner	Designer	Advisor	Builder	Trade	Inspector	Homeowner
Set performance target	Lead	Advise	Advise	Review	Understand	Review	Understand
Establish energy model	Approve	Coordinate	Lead	Info	Product data	Review	Receive
Envelope design	Approve	Lead	Review	Constructability	Install	Inspect	Receive
Air-barrier installation	Review	Detail	Verify target	Coordinate	Install	Test	Maintain
HVAC design	Approve	Coordinate	Model	Coordinate	Install	Commission	Operate
PV and battery	Approve	Coordinate	Model	Coordinate	Install	Commission	Operate
Quality control	Expect	Details	Verify	Lead	Perform	Verify	Review
Testing	Fund/ approve	Coordinate	Lead/ support	Schedule	Support	Perform	Receive
Handover	Accept	Documents	Energy records	Lead package	Manuals	Approvals	Learn/ maintain

APPENDIX B

Performance and Testing Record

Project:

Address:

Builder:

Energy Advisor / Modeller:

Certification Pathway:

Item	Target	Actual	Date	Responsible Party	Status
Annual energy performance					
Airtightness					
HRV/ERV airflow balance					
HVAC commissioning					
Domestic hot water					
Solar PV production					
Battery operation					
Electrical inspection					
Certification					

APPENDIX C

Homeowner Handover Schedule

System or Document	Delivered	Orientation Complete	Notes
Final drawings	☐	☐	
Energy model / rating	☐	☐	
Airtightness report	☐	☐	
Certification documents	☐	☐	
HVAC manuals	☐	☐	
HRV/ERV instructions	☐	☐	
Filter schedule	☐	☐	
Hot-water instructions	☐	☐	
Electrical panel schedule	☐	☐	
Solar PV information	☐	☐	
Battery information	☐	☐	
EV charger information	☐	☐	
Warranties	☐	☐	
Maintenance schedule	☐	☐	
Emergency shut-off instructions	☐	☐	
Service contacts	☐	☐	

BACK MATTER

References & Further Reading

This manual references, but does not reproduce, the following codes, standards and programs. Always consult the official, current publication directly — code editions and program requirements are updated periodically.

British Columbia Building Code

→ BC Codes — Province of British Columbia (official portal)

→ BC Building Code 2024 — Province of British Columbia

National Building Code of Canada

→ Codes Canada Publications — National Research Council Canada

Passive House Principles

→ Passive House Institute — official site

ENERGY STAR®

→ ENERGY STAR Canada — Natural Resources Canada

Canadian Standards Association (CSA Group)

→ CSA Group — official site and standards search

ASHRAE

→ ASHRAE — official site and standards

GUIDING PRINCIPLE

A book published in 2026 that hard-codes a single code edition into every chapter goes stale the day the code is revised. Wherever this manual mentions a code or standard, treat the reference as a pointer to go verify — not as the current rule itself.

BACK MATTER

About the Author

Mandeep S. is a licensed residential builder in British Columbia with more than a decade of experience in residential construction. He has completed all seven core competency examinations required for residential builder licensing in the province, and maintains his continuing professional development (CPD) requirements every year, with a particular focus on energy-efficient home construction and building science.

This manual is drawn directly from that field experience: planning, designing, constructing, testing and handing over high-performance and net zero homes, from excavation through commissioning.

> **BUILDER'S STANDARD**
>
> Before publication, add your licence number and licence class exactly as they appear on your BC residential builder licence, along with any additional designations you hold. Stating credentials precisely — rather than rounding up — is what makes this section credible to a builder, engineer, or homeowner who checks.

Acknowledgements: this manual was written from the author's own field experience and independent research, with AI-assisted drafting and organization. It has not yet been reviewed by an independent building-envelope, mechanical, electrical, structural, energy-modelling, or legal professional. As stated throughout this manual, readers must verify every technical statement against the current, authentic codes, standards, and manufacturer instructions applicable to their project before applying it.