PLAYBOOK

Planning for High-Performance Buildings

From ZEBx's Net-Zero Energy-Ready Playbook Series

January 2022

Overview

Designing a high-performance building relies on early planning and the collaboration of many disciplines to both realize the project objectives and achieve a design that meets energy targets, while managing design and construction costs. The process of successfully delivering high-performance buildings requires more coordination and planning in the early design phases than code-minimum buildings. This playbook outlines process and planning considerations for high-performance buildings with a focus on energy, but similar considerations will be applicable to many other aspects of the building, such as comfort, durability, and GHG reductions.

Examples of High-Performance Standards

The Province of British Columbia (BC) has set a goal that new buildings must be "net-zero energy-ready" by 2032. This means that developers, designers, and contractors need to learn and master strategies for designing and constructing high-performance buildings such as those built to Step 4 of the BC Energy Step Code (Step Code), the Passive House standard, or a zero emissions building.

BC Energy Step Code Step 4 - The Step Code consists of a series of steps representing increasing levels of energy-efficiency. Buildings designed and constructed to Step 4 meet the highest level of performance for Part 3 buildings under the Step Code. Step 4 buildings must meet stringent targets for Thermal Energy Demand Intensity (TEDI) and Total Energy Use Intensity (TEUI) and are also required to undergo airtightness testing.

Passive House Standard - The Passive House standard is a near-net zero energy building performance standard that is being adopted around the world, often as a voluntary target. Passive House design is based on the principle that a high-performance building enclosure will reduce the amount of heating and cooling needed for the building. This allows for the use of small mechanical systems to meet the heating and cooling demand and opens the opportunity to meet this demand with renewable energy. The Passive House standard places requirements on the space heating and cooling demand (similar to TEDI), airtightness of the building enclosure, and the Primary Energy Renewable Demand[1] (similar to TEUI).

Zero Carbon Building Standard - The Zero Carbon Building (ZCB) standard, administered by the Canada Green Building Council, provides a path to recognize buildings that achieve Net Zero Carbon by evaluating carbon emissions across the building's life cycle. To achieve certification for new buildings, the requirements include modelling a zero-carbon balance, a life cycle analysis, reporting the total quantities of refrigerants, providing a quote for carbon offsets, and providing a Zero Carbon Transition Plan if on-site combustion is used.

Zero Emissions Buildings

Zero emission is a term used for buildings that have reduced their greenhouse gas (GHG) emissions to the point where their remaining emissions may be offset through on-site generation or procurement of renewable energy and offsets. The City of Vancouver has laid out key strategies and requirements for buildings to reach zero emission targets in their Zero Emission Building Plan (ZEBP). In addition to energy performance metrics, the City has set targets for operational Greenhouse Gas Intensity (GHGI).

Benefits of High-Performance Buildings

In addition to meeting more stringent code requirements, there are many benefits to high-performance buildings:

Comfort and Health

- Reduced drafts from air leakage and cold surfaces
- Reduced potential for overheating when combined with solar shading strategies
- Superior sound-dampening of exterior noise through the use of high-performance windows, increased insulation, and continuous air barriers
- Improved thermal comfort and occupant health in comparison to conventional buildings
- Continuously ventilated and filtered air with the use of heat recovery ventilators

Climate Change Mitigation and Adaptation

- Less combustion of fossil fuels resulting in fewer carbon emissions
- High-performance building enclosures able to withstand the effects of extreme seasonal temperatures
- Ability to maintain indoor air quality during smoke events with high-efficiency air filtration in the ventilation system

Quality and Value

- Improved moisture management reduces the risk of mould growth caused by condensation
- Improved quality assurance and control process ensures a more durable building and fewer warranty claims
- Expedited permitting for high-performance buildings by some BC municipalities
- Higher floor space ratio for high-performance buildings allowed by some BC municipalities
- Reduced energy consumption relative to code-minimum buildings
- Higher potential sales value as a result of lower operating costs and higher quality

Cost-Effective Building Design

The benefits of a high-performance building are most easily achieved when teams start to plan early and take advantage of an integrated design approach. Design teams that implement these key strategies can achieve significantly lower project costs than teams that overlook them.

The Value of Early Planning and Integrated Design

Early planning and integration of the design team at the outset of the project allows teams to streamline the project delivery and minimize the costs associated with subsequent design and construction phases. Including experienced team members from each discipline at this stage also ensures that key elements are captured early, avoiding surprises down the line.

Other benefits of early planning include:

- Optimized building systems (e.g., building enclosure and HVAC systems)
- Reduced delays and streamlined project delivery
- Reduced change orders and associated costs
- Improved building performance outcomes

©Nelson Mouellic

©Nelson Mouellic

Avoid the "Retrofit Approach"

Focusing on early stage planning during pre-design also avoids the "retrofit approach" experienced by many developers and design teams that are new to high-performance building projects. By focusing on early stage problem-solving, issues are resolved long before construction and occupancy, avoiding the need for future costly retrofits or major corrections.

How Much Does a High-Performance Building Cost?

A cost analysis by ZEBx and BTY Group, looked at seven high-performance, mid-rise, multi-unit residential buildings that meet Step 4 of the Step Code or the Passive House standard[2]. This study found that these high-performance buildings can cost 30% less than similar code-minimum buildings. The buildings that saw the greatest reduction in costs were those with project teams that were familiar with the construction methods for high-performance buildings.

Another study by the Passivhaus Trust in the UK looked at historical Passive House developments and found that the construction of Passive House buildings cost between 4% and 9% more than conventional buildings[3]. A study by Reshape Strategies and Morrison Hershfield compiled findings from a variety of actual and theoretical cost studies and found that Step 4 buildings cost between 3% and 10% more compared to conventional buildings[4], and the 2018 Metrics Research report by BC Housing, Morrison Hershfield, E3 Eco Group, and Integral Group, looked at theoretical costs and found that buildings could achieve all steps of the Step Code for less than 4% more than conventional buildings[5]. Project teams that employ an integrated planning and design development process may experience little to no additional costs compared to conventional construction. These additional design efforts can pay off many times over through reductions in hard construction costs.

Case Study: The Orion

The Orion is a three-storey, multi-family residential building in Pemberton, BC developed by Vidorra Developments Ltd. The building was designed and constructed to meet Step 4 of the Step Code, far above the code minimum requirements of the City of Pemberton, and did so while maintaining costs below conventional construction.

The Orion team was able to deliver this building for a total project cost of \$9.4M, 5% less than the original project budget. \$1.0M was used for soft costs and the remaining \$8.4M was used for construction, coming out to \$2,271/m² (\$211/ft²) of the gross floor area (excluding parkade). Altus Group's 2019 Canadian Cost Guide estimated that a similar wood-framed residential building located in Vancouver and constructed to meet Step 1 of the Step Code cost between \$2,573 and \$3,455/m² (between \$239 and \$321/ft²), 12% to 34% more than the Orion.

The Orion team was able to achieve these lower costs by leveraging their previous experience with high-performance buildings and by streamlining their collaboration and design processes to optimize the building systems.

The Orion. Photo credit Vidorra Developments Ltd. For a full case study, visit ZEBx.org.

Deliverables Matched to Project Performance Objectives

Like conventional buildings, high-performance buildings are designed and constructed in phases, with key deliverables completed during each phase. An overview of the typical phases of a building project is illustrated in the timeline below, including a sample set of high-performance project deliverables that will be discussed in greater detail in the following sections. A better understanding of these phases can help the project team to avoid costly design changes and construction change orders. Defining deliverables for each phase of the development will allow project teams to monitor and ensure that the project is on track from all perspectives.

Pre-Design	Schematic Design	Design Development	Construction Documents	Pre-Construction	Construction	Occupancy
Develop Owner's Project Requirements (OPR)	Conduct Integrated Design Meeting Generate First Energy Model Identify High-Performance Strategies	Establish Key Details Early Optimize Window and Shading Systems	Develop Construction Drawings and Specifications Train Site Team Develop Verification Plan	Conduct Pre-Construction Meeting Perform Mock-Ups and On-Site Training	Conduct Enclosure and Mechanical Reviews Conduct Ventilation Commissioning Conduct Airtightness Testing	Provide Occupant Handbook Conduct Post-Occupancy Monitoring

Owner's Project Requirements

The Owner's Project Requirements (OPR) is a document that sets out the goals and requirements for the project as defined by the owner. The OPR includes a general project description, objectives, programming requirements, project budget and schedule, performance criteria, and often, commissioning processes. Overall, it provides the criteria and key information needed to assist the team in starting the pre-design stage of the project. Throughout the course of a project, the OPR provides a touchstone against which to track the success of the proposed design in meeting the identified requirements. An OPR can also be updated through the course of the project if the owner's priorities or objectives for the project change.

A successful project begins with a well-developed OPR that establishes realistic constraints for the project and the design team, while ensuring that the owner's needs are fully addressed. Strategies to consider when developing an OPR for a high-performance building include the following:

☑ Specify Certification

Require the building to be certified to a specific standard, such as the Passive House Classic standard (as maintained by the Passive House Institute), rather than simply Passive House principles. This reduces the risk of scope creep and helps to set project requirements and an appropriate budget.

☑ List Deliverables

If certain documents or deliverables are required to meet certification or compliance, these should be explicitly listed in the OPR. Key deliverables can also be identified in the OPR to assist with tracking progress.

☑ Specify Sustainability Requirements

Including detailed and unambiguous sustainability targets such as thermal energy demand intensity, GHG emission intensity, or certification, clearly establishes the design objectives.

☑ Outline Performance Testing

Ventilation commissioning and airtightness testing are required under many high-performance standards (e.g., Passive House). Ensure that any testing requirements are outlined in the OPR.

☑ Hire Experienced Consultants

All key consultants (i.e., architect, building enclosure consultant, mechanical consultant, energy consultant) should have experience on similar projects with high-performance objectives. Experience with the relevant standard or code (e.g., Passive House or Step Code) is ideal. If team members lack experience, the OPR should stipulate training requirements for the members of the project team that do not have experience with performance targets.

☑ Specify a Budget

A total project budget should be laid out within the OPR. The budget should include both hard (i.e., construction costs) and soft costs (e.g., consultant fees, project administration, permitting, etc.).

☑ Include a Measurement & Verification (M&V) Plan

If desired or necessary for third-party certification, an M&V plan should be developed to guide the installation of metering and sub-metering equipment to monitor the building's performance post-occupancy.

Deliverables For Schematic Design

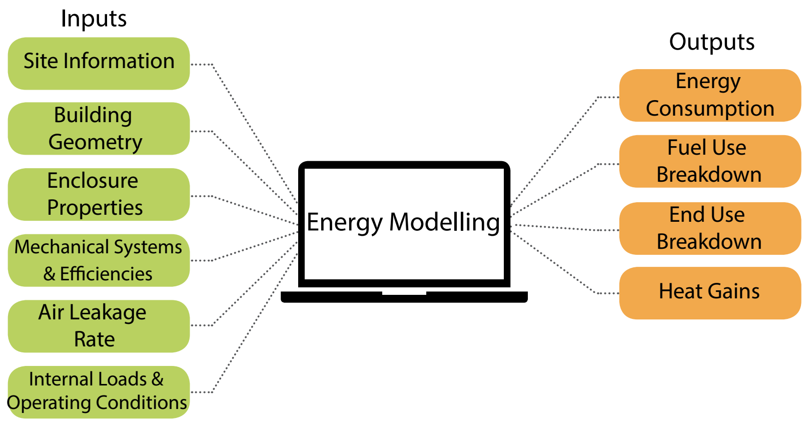
Integrated Design Meeting

An early-stage integrated design meeting is a brainstorming session held at the beginning of the project to lay out project goals, identify strategies, and begin addressing challenges. Ideally, all project team members should be present to collaborate on the design and offer their expertise and experience gained from other projects. This includes the owner/developer along with all key consultants. It is also beneficial to involve a cost estimator (e.g., cost consultant, construction manager, etc.) at this stage, as high-level costing is critical in determining what impact the budget will have on design. Given the potentially large number of attendees for these sessions, effort should be made to create a meeting structure that ensures that project objectives are reviewed, and that each team member has the opportunity to clearly articulate key challenges and opportunities from their perspective.

Beginning this collaborative process early in the project helps to address key decisions early and reduces the likelihood of design changes later in the process. It is important to finalize as many of these decisions as possible during the schematic design (SD) stage. It is typically most effective to establish a basis-of-design (e.g., assumptions, criteria, etc.) so that other related aspects of the design can be coordinated, and potential alternatives can be compared against it.

The First Energy Model

The first energy model is produced based on the assemblies, details, and components included in schematic design documents. This model includes thermal bridging estimates and basis-of-design mechanical systems. Developing a preliminary energy model at this stage provides an assessment of the building's systems and opportunities to explore design options, while allowing the team to tune the design to achieve its goals. This model is critical for reviewing building form, window-to-wall ratio, shading, airtightness, building enclosure thermal performance, and key thermal bridges (e.g., balcony connections, shear walls, window-to-wall interfaces, etc.), as well as comparing centralized to semi-centralized and decentralized ventilation systems.



Benefits of Energy Modelling

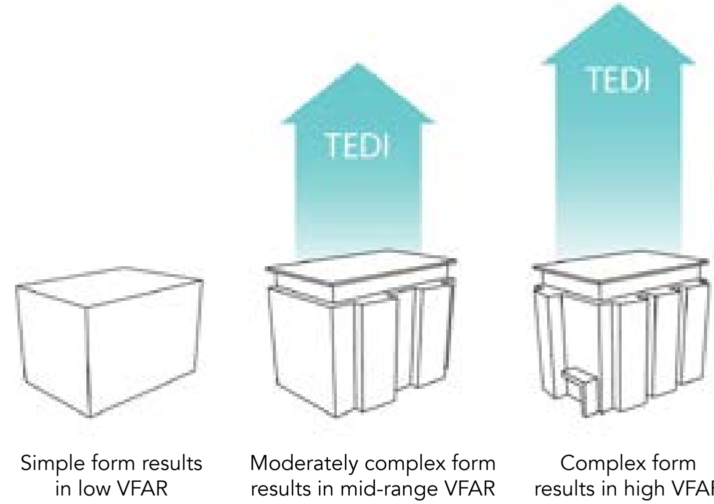
A preliminary, whole-building energy model helps drive the design and rule out strategies that do not meet the OPR or performance requirements. The model can be used to assess which design measures have the most or least impact on energy performance, and to find the most cost-effective approach for achieving a desired outcome. Importantly, energy modelling can also be used to assess other performance criteria, such as the risk of overheating.

Identifying High-Performance Design Strategies

Optimizing Form Factor

A building's massing is central to achieving TEDI targets. In addition, more complex building forms (with corners and step-backs) can result in more thermal bridging. Additional insulation can be used to compensate for more thermal bridging, but this compensation strategy also raises construction costs. A simple form that is easy to build offers better energy performance and the opportunity for cost savings.

The University of British Columbia's Skeena Residence utilizes a simple building form to meet the Passive House standard. Photo credit Andrew Latreille.

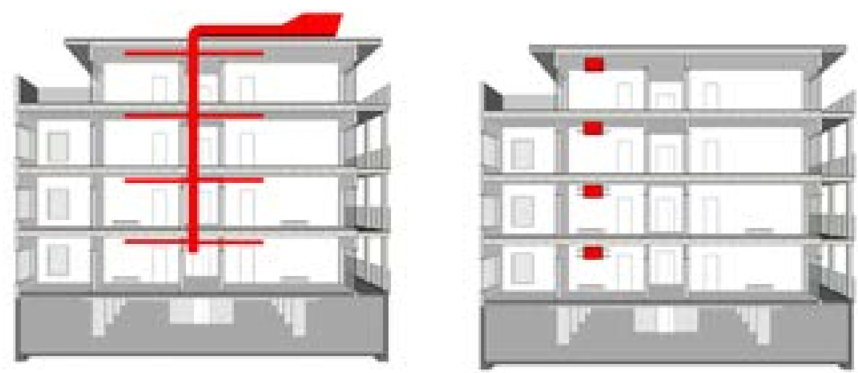


$$\textbf{Vertical Surface Area to Floor Area Ratio (VFAR)} = \frac{\textbf{Surface area of vertical enclosure}}{\textbf{Building floor area}}$$

A complex form results in more thermal bridges and heat loss, while a simple form has the potential to reduce overall heat loss and meet the project's TEDI target.

Planning Mechanical and Plumbing Early

Early-stage evaluation of mechanical system options helps to make recommendations on system performance, achieve desired effective performance, and understand equipment sizing. High-performance buildings require highly efficient heat recovery ventilation, well-insulated domestic hot water pipes, and right-sized cooling/heating systems. These systems require adequate space for equipment and ducts. The layout of the ducts and other mechanical components should be planned when designing the building's floorplan, rather than trying to squeeze them in afterwards.



The choice of a centralized (left) or decentralized (right) ventilation system can greatly affect the layout of the building.

Optimizing Ventilation

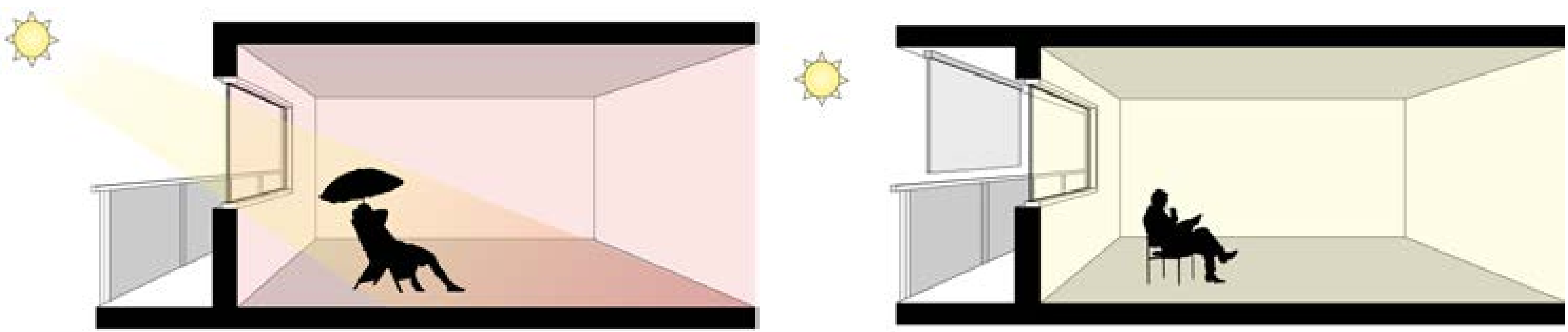
Using high-efficiency energy/heat recovery ventilators (E/HRV) as part of the building design reduces the heating and cooling demand of the building, while providing fresh air to individual units. Design teams can optimize ventilation systems by decoupling them from the heating and cooling systems, allowing for ventilation rates to be independent of heating and cooling demand.

Defining Assemblies

High-performance building enclosures are designed with higher R-values, fewer thermal bridges, low U-value windows (e.g., triple glazed), and a continuous air barrier system. Key assemblies and systems should be defined early, as wall assembly thicknesses can impact building layouts and design, and can also be key cost drivers.

Designing for Overheating

Uncontrolled solar heat gains and rising temperatures due to climate change can increase interior temperatures considerably and lead to overheating problems. Energy modelling can be used to assess the risk of internal overheating so that the team can begin developing strategies to mitigate overheating, enhance thermal comfort, and reduce cooling loads.

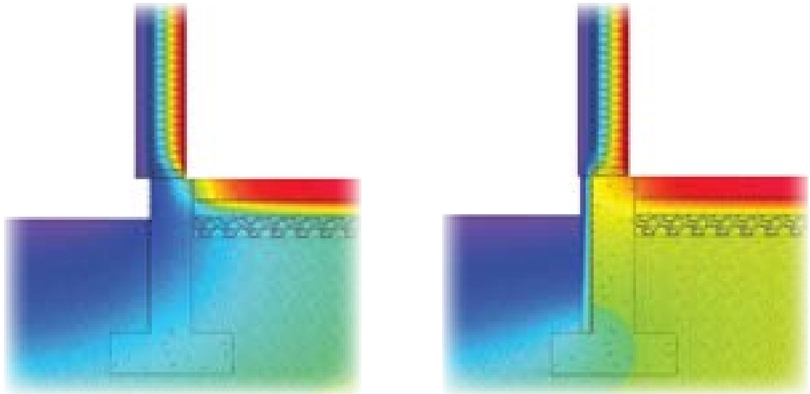


Unobstructed summer solar radiation can cause overheating leading to occupant discomfort (left). Designing for overheating by implementing window and shading strategies reduces the risk of overheating (right). Strategies used to reduce the risk of overheating include low U-value windows, a low solar heat gain coefficient glass, exterior roller shades, and an overhang.

Deliverables For Design Development

Establishing Key Details Early

During the design development (DD) stage, key architectural, mechanical, and electrical building systems are designed, including selection of materials and equipment choices. For example the layout for the domestic hot water system is finalized, the thermal bridging details are refined, and the ventilation rates are established. Key details are developed such as shear walls, balconies, and shading attachment strategies. Thermal models of these details should be prepared as part of the DD energy model update.



Extensive thermal bridging (left) leads to heat loss. Thermal models of key details should be created to ensure that thermal bridges are minimized (right).

Optimizing Window and Shading Systems

Developing strategies and preliminary specifications for window and shading systems is critical during the DD stage. Placing windows where they are serving a specific purpose, such as for views, daylighting, or ventilation, will help optimize performance and project costs. If a window is not serving a purpose, it should be removed from the design.

Optimizing Window-to-Wall Ratio

Optimizing the window-to-wall ratio helps to manage the cooling and heating loads of the building while maintaining daylighting requirements, as well as access to views. Typically, high-performance buildings use a window-to-wall ratio of 20% to 40%.

Exterior Shading

Exterior shading systems help mitigate the risk of overheating and optimize heat gains, especially where active cooling systems are not used. Exterior shading can be provided by fixed overhangs or vertical fins that shade adjacent glazing. Manual or automated operable shades can be used to allow more control and better optimization.

Deliverables For the Construction Documents Stage

Developing Construction Drawings and Specifications

Developing and thoroughly reviewing drawings and specifications during the construction documents (CD) stage ensures that key strategies are implemented and that the energy model is consistent with the construction documents. Multiple reviews are required to allow for iteratively refining the design. Consultants will make recommendations for quality assurance during construction, including specific recommendations regarding mock-ups, testing, and inspections. Key details and systems where mock-ups and testing will be beneficial are also noted. A final quality assurance review of the completed construction documents should be conducted to confirm that comments and recommendations have been incorporated and any inconsistencies have been addressed. This phase will require continuous communication and coordination between the various members of the design team.

©Nelson Mouellic

©Nelson Mouellic

Selecting the Field Review Team

Having a team of field reviewers that is experienced in high-performance systems, details, and installation procedures will help ensure that the building meets the design intent. Additional training of the field review team will also help improve quality control and assurance during construction. Each member of the field review (or site) team should be trained for their individual role and understand what is expected of them within that role. This includes how to properly document their work through photographs and site reports, and how to prepare the site for any testing that may occur to minimize work on the day of the test.

©Nelson Mouellic

The Verification Plan

Along with the development of the construction documents, a verification plan should be developed. This plan outlines the quality assurance (QA) and quality control (QC) protocols for the project, including insulation reviews, air barrier reviews, mechanical reviews, airtightness testing, and ventilation commissioning. Given the range of scopes covered, it is likely that multiple disciplines may contribute to this plan. It should include:

- The number and interval of planned site visits
- A plan for monitoring and grading insulation installation in all assemblies
- A plan for monitoring and verifying the continuity of the air barrier in all assemblies and components
- A plan for testing, such as airtightness testing or water testing, including who will conduct these tests
- A plan for commissioning, such as HVAC or ventilation commissioning, including who will conduct the commissioning
- A plan for occupant training, including who will conduct the training

Deliverables For Pre-Construction

Pre-Construction Meetings

Pre-construction meetings involve the design consultants, general contractor, and specific trades and take place prior to beginning work on-site. The meetings are held to review scopes of work, construction documents, submittal and testing requirements, and to lay out the general goals and strategies for construction. This sometimes involves educating site personnel on high-performance building practices and review procedures. The verification plan and any other QA/QC plans are reviewed to ensure construction is implemented to the standards required for high-performance buildings. These meetings occur throughout construction as different key trades begin their work.

Each pre-construction meeting is tailored to a specific discipline and/or trade. Simply including the general contractor and no other key trades can lead to problems such as missed details during construction. It is critical that all construction team members, including key trades, understand the key design strategies and project goals.

Mock-Ups and On-Site Training

Many high-performance assemblies, systems, and details are tested prior to or during construction through mock-ups. Mock-ups are a sample portion of the detailing completed before the main installation, either as a part of the building or a separate and temporary structure. They provide an opportunity to review the installation and confirm quality standards, as well as to review any potential issues and resolve them prior to conducting the bulk of the work. Mock-ups also allow the construction team to become familiar with the required materials and techniques, and in some cases can also be used as training opportunities. Mock ups are a critical step is establishing the quality standards required for a high-performance building.

Deliverables For Construction

During construction, frequent site visits are made by the field review team to review aspects related to confirm that assemblies, systems, or other components are meeting the design intent. These reviews also provide a higher level of quality assurance and help to identify deficiencies and determine appropriate solutions. Many codes and standards also require detailed documentation, as well as testing of components throughout the construction process. Some also require commissioning of systems prior to occupancy.

Buildings Enclosure and Mechanical Reviews

During construction, periodic field reviews of the mechanical systems and building enclosure installation are undertaken by the respective consultants. The following steps should be carried out during these site visits:

- Meet with the general contractor and provide a field review report to summarize observations and recommendations
- Confirm that the construction of the building enclosure is being constructed in general conformance with the construction drawings and specifications
- Identify incorrect building enclosure details and assist in determining appropriate solutions
- Review on-site building enclosure mock-ups
- Review the ventilation systems, including equipment and ducting
- Review space heating and cooling systems, including equipment, ducting, piping, and controls
- Review the domestic hot water system, including equipment, piping, and controls

Ventilation Commissioning

The building's ventilation system should be tested to ensure that it provides the required airflow. A qualified and experienced testing and balancing agent should measure the supply and return airflow and balance the system as required. The results of this testing and balancing must be recorded in order to issue a ventilation commissioning report if this is required by the specifications, codes, or standards. The commissioning report documents whether the system, as installed, is able to meet the design requirements.

Airtightness Testing

The most common way to test the airtightness of a building enclosure is a blower door test. These tests use calibrated, high-powered fans to pressurize and/or depressurize the building and measure the rate of air leakage from the building.

Performing a minimum of two whole building airtightness tests is recommended - one mid-construction test and one final test. A mid-construction test is done during construction, at a point when the air barrier system is largely complete. A final or compliance test is undertaken when the building is complete prior to final occupancy. The first test enables teams to use qualitative methods such as infrared imaging and smoke to visually identify air leakage paths. The second and final test is required under many codes and standards to demonstrate compliance with energy performance targets. New buildings built to meet Step Code are required to undertake quantitative airtightness testing for code compliance. Passive House Certification also requires quantitative airtightness testing.

©Nelson Mouellic

Deliverables at Occupancy

Occupant Handbook

Many occupants have never lived in a high-performance building before and may not be aware of how the equipment works or how best to utilize the features. Occupants and building managers need to understand how the building is designed for its full potential to be realized. This can be accomplished through education and training, or may take the form of an operations handbook, video, and/or presentation. At a minimum, an occupant handbook should be created for the property or building manager and the occupants. The handbook should provide the information necessary to understand what makes their building different and how to operate it efficiently, as well as who to contact if there is an operational issue. It should include an overview of the high-performance components of the building and a description of their basic operation and maintenance requirements.

Post-Occupancy Monitoring

Post-occupancy monitoring can provide the design team with valuable feedback for future projects. A good set of OPR's will include an M&V plan for post-occupancy monitoring. This can be accomplished through metering and sub-metering of equipment to monitor both energy and water usage, and in some cases, indoor air quality as well. On-going monitoring helps to address the following:

- Confirming building performance for certification or reporting for high-performance building standards
- Providing a baseline for comparing year-over-year building performance
- Providing a long-term, accurate method of obtaining data and tracking the performance of the building's systems for recommissioning
- Verifying that the building is performing as designed and identifying performance issues with building systems and equipment
- Providing information to improve energy consumption modelling and prediction efforts for future projects
- Encouraging the owner to be proactive in maintaining building performance

Additional Resources

To learn more about the topics covered in this playbook, please consult the following publications:

- A Developer's Guide to Passive House Buildings. Passive House Canada.
- Passive Design Toolkit. City of Vancouver. July 2009.
- BC Energy Step Code Builder Guide. BC Housing. December 2018.
- BC Energy Step Code Design Guide & Supplemental. BC Housing. July 2019.
- Zero Emissions Building Plan. City of Vancouver. July 2016.
- Passivhaus Construction Costs. Passivhaus Trust. October 2019.
- 2018 Metrics Research Full Report Update. BC Housing, Morrison Hershfield, E3 Eco Group Inc., and Integral Group. September 2019.
- Orion: Near-Zero Emissions Multi-Unit Residential Building. Zero Emissions Building Exchange. October 2020.
- Draft Owner's Project Requirements. ASHRAE. January 2019.
- Guide to Low Thermal Energy Demand for Large Buildings. BC Housing. 2018

Endnotes

1 Source: Primary Energy Renewable Demand is the modelled total primary energy use of the building multiplied by PER factors as maintained by the Passive House Institute.

2 Source: Construction Cost Analysis of High-Performance Multi-Unit Residential Buildings in British Columbia https://www.zebx.org/wp-content/uploads/2021/06/Cost-Analysis-of-High-performance-MURBBs.pdf

3 Source: Passivhaus Construction Costs

http://passivhaustrust.org.uk/UserFiles/File/research%20papers/Costs/2019.10_Passivhaus%20Costs.pdf

4 Source: BC Energy Step Code Costing Studies Analysis http://energystepcode.ca/app/uploads/sites/257/2019/11/BC-Energy-Step-Code-Costing-Studies-Analysis-Rev1.pdf

5 Source: 2018 Metrics Research Full Report Update https://energystepcode.ca/app/uploads/sites/257/2018/09/2018-Metrics_Research_Report_Update_2018-09-18.pdf

zebx

RDH

Net-Zero Energy-Ready Playbook Series

For more playbooks, case studies and videos, visit zebx.org/resources

This case study was supported by:

INTEGRAL cleanBC BETTER BUILDINGS

BC Hydro Power smart

Natural Resources Canada Ressources naturelles Canada

Front cover photo credit: Integra Architecture & Sam Mendl