Technical Guideline Development for High Performance Coastal First Nations Housing

UBC Sustainability Scholars / CEEN 596

Final Report

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Executive Summary

This CEEN596 and UBC Sustainability Scholars project has evaluated a number of standards, technologies and methods for new home construction in the remote communities of the Great Bear Initiative Coastal First Nations in British Columbia. Current home construction in these communities does not address a number of technical, social, economic and cultural needs. The key issues to be addressed in new home construction, and the recommended solutions proposed in this study are summarized below:

Existing Housing Issue	Solutions for New Housing
Issue #1: Water Leakage and Pooling	• Rainscreening • Covered entryways and steel doors • Effective gutters and eavestroughs • Weatherproof building envelope • Sealed ducts and other openings • Graded site and well-drained foundation • Sufficient ventilation
Issue #2: Mould	• Elimination of basement or crawlspace • Airtight building envelope • Mechanical ventilation • Heat pump or forced air heating • Mould-resistant drywall, insulation and paint
Issue #3: Cold and Drafty Spaces	• Airtight building envelope • Slab on grade foundation • Heat recovery ventilation • Heat pump or forced air heating
Issue #4: Inadequate Gathering Space	• Passive solar design • Open floor plans • Flexible common areas
Issue #5: Food Preparation and Storage	• Larger kitchens and pantries • Outdoor preparation facilities for fish and game • Adequate ventilation for cooking areas • Canning rooms or smokehouses if desired
Issue #6: Energy Efficiency and Sustainability	• Passive solar design + triple glazed windows • Advanced framing techniques • Extensive use of insulation • Airtight building envelope • Sealed ducts and other openings • Heat pump space heating + advanced controls • LED lighting and energy efficient appliances • Use of recycled or sustainable materials • Heat recovery ventilation
Issue #7: Affordability	• Use of affordable insulation materials • Minimizing shipping to remote communities • Passive solar design • Airtight building envelope
Issue #8: Local Capacity and Materials	• Use of locally available material when possible • Use of local labour and expertise when possible

Table of Contents

Executive Summary 2
Table of Contents 3
Objectives 7
Project Mentor 7
Data and Methods 7
Context 8
Energy Efficiency in the Great Bear Communities 8
Meeting Community Needs 9
Baseline 10
Issues with Existing Homes 10
Issue #1: Water Leakage and Pooling 10
Issue #2: Mould 10
Issue #3: Cold and Drafty Spaces 10
Issue #4: Inadequate Gathering Space 11
Issue #5: Food Preparation and Storage 11
Issue #6: Energy Efficiency and Sustainability 11
Issue #7: Affordability 11
Issue #8: Local Capacity and Materials 11
Baseline Energy Consumption 12
Green Building Standards 14
Efficiency Standards in BC 14
EnerGuide 14
ENERGY STAR® for New Homes 15
R-2000 15
Passive House (Passivhaus) 15
Net Zero Ready (CHBA) 16
LEED Canada for Homes 16
BUILT GREEN® BC 17
Power Smart New Homes 17
Benchmark Standards for Coastal BC 17
The House as a System 19
Home Energy Breakdown 19
Performance Targets 20
Climate 21
Background 21
Key Considerations for Coastal Homes 25
Mould 25
Climate Change 25
Extreme Wind 26
Site Selection and Passive Solar Design 27
Site Selection 27
Passive Solar Basics 27
Thermal Mass 28
Key Considerations for Coastal Homes 29
Performance Targets 30

Technology Comparison 31
Meeting Community Needs 32
Foundation and Frame 33
Foundations 33
Crawlspaces 33
Basements 34
Slab on Grade 34
Framing 35
Stick-Build 35
Advanced Framing Techniques 35
Prefabricated Frame 36
Key Considerations for Coastal Homes 37
Foundations 37
Framing 37
Performance Targets 38
Technology Comparison 39
Meeting Community Needs 40
Insulation 41
R-Values 41
Fiberglass 41
Cellulose 41
Rigid Foam Insulation 41
Key Considerations for Coastal Homes 42
Performance Targets 43
Technology Comparison 43
Meeting Community Needs 44
Weatherproofing and Airtightness 45
Barriers 45
Weatherproofing 46
Sealing 46
Weather Stripping 46
Rainscreen 46
Eavestroughs 46
Key Considerations for Coastal Homes 47
Sealing and Weather Stripping 47
Barriers 47
Weatherproofing 48
Performance Targets 48
Technology Comparison 49
Meeting Community Needs 50
Windows and Doors 51
U-Factors 51
Windows 51
Window Insulation 51
Panes 51
Low-e Glass 51
Thermal Break 52
Doors 52

Key Considerations for Coastal Homes 52
Windows 52
Doors 53
Performance Targets 53
Technology Comparison 53
Heating and Cooling Sources 54
Types of Heating and Cooling Sources 54
Forced Air Furnace 54
Heat Pump 55
Electric Baseboard Heating 55
Wood or Pellet Stove 56
Space Heaters 56
Radiant Heating 56
Air Conditioners 57
Key Considerations for Coastal Homes 57
Heat Pumps 57
Radiant Heat 58
Passive House Heating 58
Advanced Control Systems 58
Community Constraints 59
Performance Targets 60
Technology Comparison 60
Meeting Community Needs 61
Ventilation 62
Natural Ventilation 62
Mechanical Ventilation 62
Key Considerations for Coastal Homes 63
Heat Recovery Ventilation 63
Mould Control 64
Ducts 64
Performance Targets 64
Technology Comparison 65
Meeting Community Needs 65
Water Heating and Electrical Loads 66
Lighting 66
LED 66
CFL 67
Incandescent 67
Water Heating 67
Storage-Type Water Heaters 68
On-Demand Water Heaters 68
Solar Thermal and Heat Pump Water Heaters 68
Appliances 68
Onsite Renewables 69
Key Considerations for Coastal Homes 69
Lighting 69
Water Heating 70
Onsite Renewables 71

Performance Targets 71
Technology Comparison 72
Meeting Community Needs 74
Cost Analysis 75
Energy Savings 75
Case Studies 76
Cost Effectiveness 78
Performance Targets 79
Best Practices Summary 80
Performance Targets Summary 80
Technology Summary 82
Community Needs Summary 84
Conclusion and Recommendations 85
References 86
Appendix A: Industry Expert Design Meeting Agenda 92
Participants 92
Purpose 92
Agenda 92
Outcomes 93
Preliminary Design Criteria 93

Objectives

This UBC Sustainability Scholars and CEEN596 project is designed to support the collaboration of Pinna Sustainability with the Great Bear Initiative Coastal First Nations. The guiding objective of the work is to enhance the performance of buildings in Coastal First Nations communities in British Columbia. With a goal of improving the comfort and energy performance of these buildings, as well as considering long-term resiliency, the project proponents have identified three key objectives:

1. To reduce the energy demand of housing in Coastal First Nations communities
2. To transition away from dependence on fossil fuel energy sources in these communities
3. To provide housing which improves community health, well-being and resiliency

Project Mentor

The Project Mentor was Gillian Aubie Vines, Principal Consultant at Pinna Sustainability. Gillian is an expert in sustainable development and has had extensive involvement with projects at the intersection of science, planning, communication and public policy. Pinna Sustainability is collaborating with the Great Bear Initiative (GBI) Coastal First Nations to develop a long-term plan for increased energy efficiency in Coastal First Nations communities. This project, focusing on the development of a technical guideline for new high performance housing is a subset of the larger plan. Amy Seabrooke and Gary Hamer at BC Hydro were also involved as technical resources and mentors.

Data and Methods

The first phase of the project involved a review of the currently established practices for new home construction. This included dialogue with the communities as well as a literature review of currently applicable codes, standards and methods. A meeting of construction industry experts was conducted, bringing together this combined knowledge in order to inform recommendations for this and future work.

The research component of the project investigated a number of green, energy efficient, or high performance building practices and their applicability to the Coastal First Nations context. Technical aspects of these practices include, but are not limited to, building envelope design, heating and cooling technologies, energy efficient appliances and energy sources, and passive solar design. Some technologies and methods were found to be more applicable to the coastal BC climate than others.

In addition to purely technical considerations, some of the social, economic and logistical challenges of home construction in remote communities are addressed. This includes the availability of local resources, constructability, cost-effectiveness and implementation. It is also important that the technical recommendations fit into the social context of the community and are consistent with development, health and cultural goals.

Context

The Great Bear Initiative Coastal First Nations is an alliance of eight communities on the North and Central coast of British Columbia. Many of these communities are very remote, and are serviced by islanded electricity grids which rely largely on fossil fuels. There is a commitment in these communities to reduce dependence on fossil fuels and improve community well-being, and the development of energy efficient and culturally appropriate housing is a central objective in achieving this goal.

The purpose of the project is to create a guideline of technical best practices for new home construction within the Great Bear Initiative Coastal First Nations communities. This work pays close attention to energy efficiency and conservation and cultural appropriateness of homebuilding in this remote area, while considering economic feasibility and successful implementation.

Specific project objectives are to create a guideline for new home construction that considers:

- Appropriateness for the remote nature of the communities
- Applicability to the challenging coastal British Columbia climate
- Affordability and constructability given limited budget and resources
- Long-term resiliency of the building with consideration of climate change
- Impact of the building performance on energy use and fossil fuel dependence

Energy Efficiency in the Great Bear Communities

As of December 2015, the status of energy efficient housing in the eight GBI communities is summarized below:

Community	Nation	Population	Energy Efficient Homes Status
Metlakatla	Metlakatla	100	A community energy champion is driving local interest and exploring modular construction.
Hartley Bay	Gitga'at	157	Energy management initiative, lighting and HVAC retrofits and smart micro-grid since 2008. [65]
Klemtu	Kitasoo	282	Energy efficiency initiative with energy audits and upgrades and ultra-efficient housing pilot.
Bella Bella	Heiltsuk	1396	Lessons learned from Vancouver Coastal Health Passive House project. Interest in local capacity building and economic opportunities.
Bella Coola	Nuxalk	2139	Local energy efficiency and building standard with six homes constructed to date.
Rivers Inlet	Wuikinuxv	65	Energy efficiency seen as a key piece of large housing upgrade project.
Old Massett	Haida	607	Community interest in ultra-efficient homes.
Skidegate	Haida	781	New energy efficiency policies and home designs; large scale heat pump retrofit project.
Council of the Haida Nation	Haida	4635	Working to support the activities in Skidegate and Old Massett.

The location of the GBI communities are shown in the map below. While the remoteness of the communities varies, they are all very distant from major cities, and experience similar climate conditions and energy supply challenges.

[1]

Meeting Community Needs

The cultural and traditional practices of the Coastal First Nations communities have been influenced by the geography, climate and landscape of coastal British Columbia for thousands of years. The Great Bear Initiative was created in order to address common challenges and goals among communities on the Central and North Coast and Haida Gwaii.

Part of this commitment is to develop and promote a conservation-based economy, of which energy efficient and culturally appropriate housing is a key element. The best practices for new home construction presented here must be further informed by the experience of elders and residents in each community, as well as by the unique climactic and local conditions of each communities.

Baseline

Issues with Existing Homes

Existing on-reserve homes in the GBI communities have several issues that need to be addressed when considering the best practices for new home construction. Based on dialogue with community leaders, a few key issue areas have been identified to focus on [2, 3, 4, 5].

Issue #1: Water Leakage and Pooling

Many homes in the Coastal First Nations communities experience issues with **water entering the building** through leaks in the building envelope (walls, roof and foundation). This issue may be worsened when rain is driven into the building by high winds, forcing it under cladding (siding, brick or stucco) and through gaps around windows, doors and ductwork.

Water may also enter the home as a result of inadequate drainage causing water to pool. This may be the result of low permeability or improperly sloped soil around the building site, or by inadequate or poorly maintained eavestroughs.

Finally, water may enter the house through entryways when occupants enter or leave the home. Many entryways are not adequately protected from the elements.

Issue #2: Mould

Perhaps the biggest single issue in the existing building stock is the growth of mould in homes. Mould growth is the result of **inadequately ventilated spaces and air leakage** through building envelopes. These factors combined encourage moist air to enter hidden spaces in the building – such as inside walls and ceilings – where it creates ideal conditions for mould growth.

When hidden, mould growth may go unnoticed for years and cause a variety of health issues including respiratory disease. Elders and children are at particularly high risk in mould-infested homes.

Issue #3: Cold and Drafty Spaces

Existing homes may be **poorly insulated**, which can lead to them being uncomfortably cold to live in, especially in winter. Inadequate insulation, especially in floors, is detrimental to thermal comfort. Homes may also have large amount of air infiltration, leading to “leaky” homes that suffer from cold drafts.

In order to compensate for these issues, many occupants in the existing building stock make use of space heaters. These can supplement the main heating system but do not address the problems inherent to the buildings. The use of space heaters also further increases energy consumption, whereas addressing the insulation and air leakage issues would decrease it.

Issue #4: Inadequate Gathering Space

The cultures of the GBI communities have traditionally been based on multi-generational housing, with elders, parents and children living together in a family home. The Coastal First Nations traditions also include community gatherings. These **traditional practices have not been considered** in much of the existing building stock.

There is a desire in the communities for housing to be more flexible, allowing for larger gatherings in common areas while still providing privacy and adequate living spaces.

Issue #5: Food Preparation and Storage

Kitchens and food storage areas are often inadequate in the existing building stock. The cultural practices in the Coastal First Nations communities include communal meals and gatherings, whether for families or including members of the wider communities. The existing food preparation areas are also **not designed to consider traditional practices** such as fish and game preparation or food preservation through smoking or canning.

Issue #6: Energy Efficiency and Sustainability

The existing housing stock has **not been designed to be energy efficient** compared to best practices, and many homes are not built considering the sustainability aspects of water use, energy use, and materials. Community values dictate that the next generation of homes be constructed in a sustainable manner and consider the impact of home construction on the environment.

Issue #7: Affordability

Though there is a strong desire to pursue the construction of high performance and energy efficient homes, there are also economic constraints which limit the overall budget for a new home. The communities **seek solutions that are cost-effective**, and provide a high return on investment in terms of energy savings as well as in resiliency, comfort and cultural appropriateness.

Issue #8: Local Capacity and Materials

Existing homes, as well as many more modern and energy-efficient homes in the Central and North Coast of BC, have not been built to **maximize the use of local materials**, but have relied on materials shipped over long distances to remote communities. Many existing practices also do not emphasize the use of local labour and expertise in the construction of new homes, and therefore do not contribute to capacity building in communities.

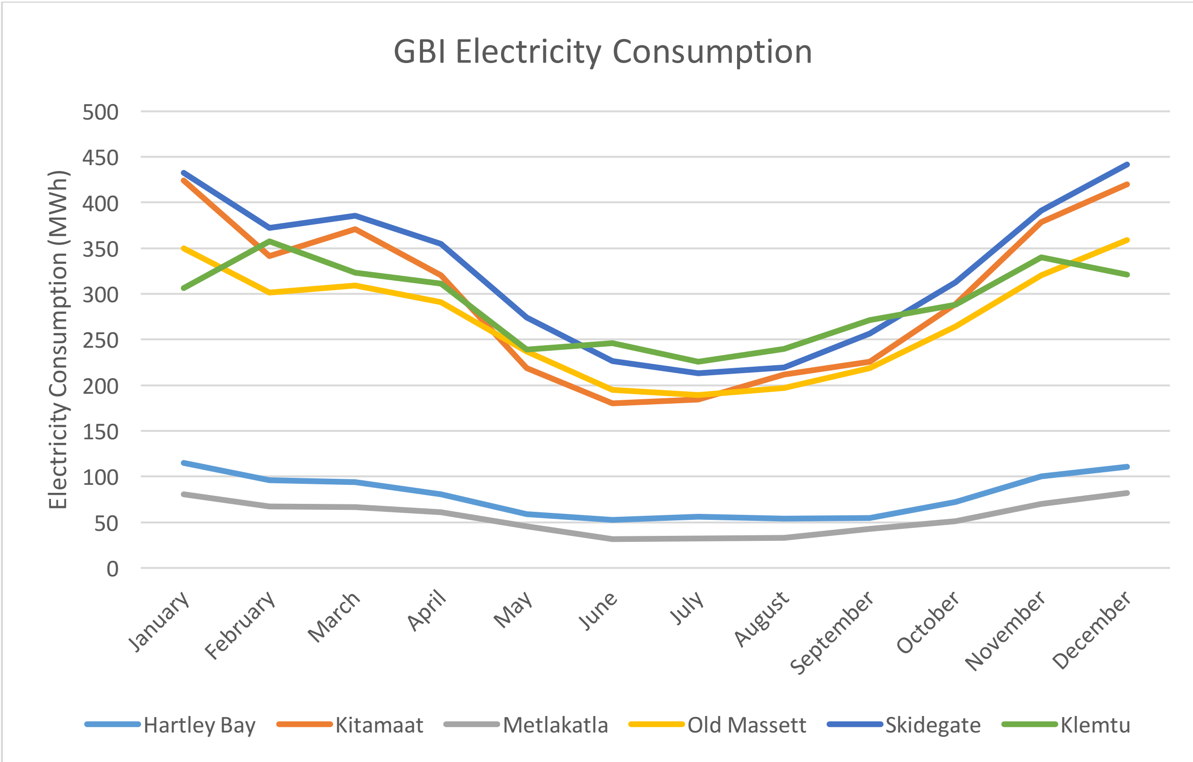
Baseline Energy Consumption

Community	Service Provider	Electricity Supply	Annual Power Demand
Metlakatla	BC Hydro	BC Grid	663 MWh/yr
Hartley Bay	BC Hydro	Diesel, Transitioning to Hydro	1344 MWh/yr
Klemtu	Self-Supply	Hydro, Diesel Backup	3469 MWh/yr 1700 kW
Bella Bella	BC Hydro	Hydro, Diesel Backup	11746 MWh/yr 2400 kW
Bella Coola	BC Hydro	Diesel, Supplemental Hydro	17715 MWh/yr 3800 kW
Rivers Inlet	Self- Supply	Diesel, Transitioning to Hydro	No data
Old Massett	BC Hydro	Diesel	24275 MWh/yr
Skidegate	BC Hydro and IPP Supply	Diesel and Hydro	5772+ MWh/yr (Diesel Only)

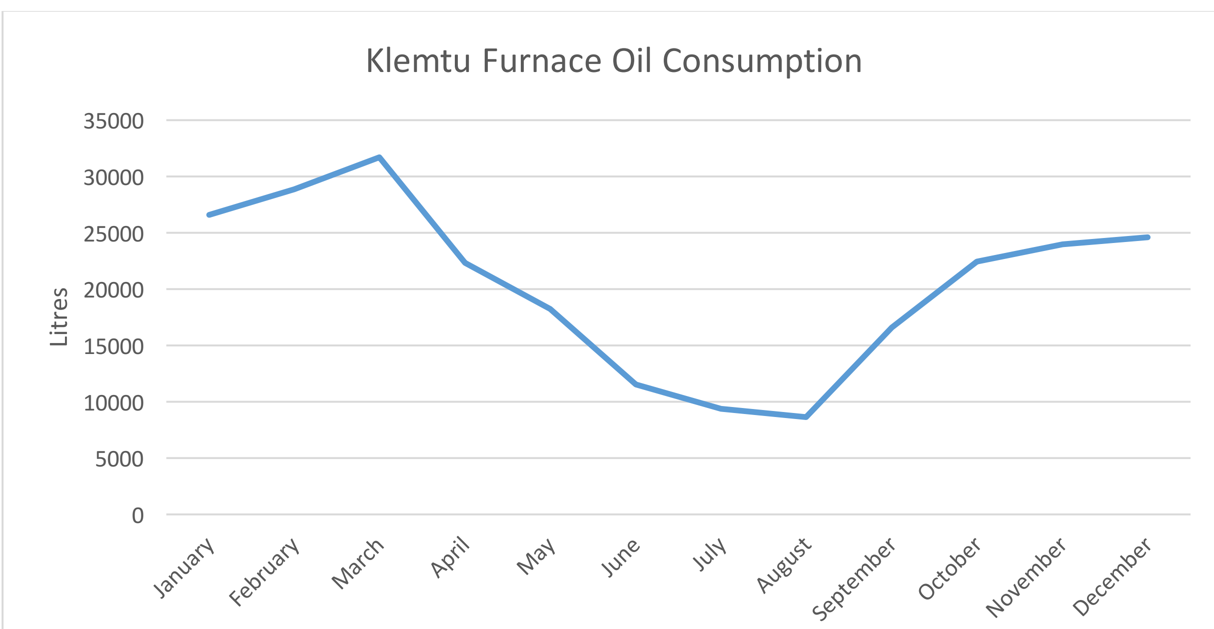
The existing building energy performance in the Kitasoo and Nuxalk communities (Klemtu and Bella Coola) has been estimated using utility consumption data. The average electricity consumption ranged from **7 kWh/ft^2/yr in Klemtu to 7.6 kWh/ft^2/yr in Bella Coola**. This compares with an average for BC homes of around 8.1 kWh/ft^2/yr. Several factors may contribute to lower electricity usage in these communities including the more temperate climate of coastal BC as compared to the Interior. [14]

The annual electricity consumption in the GBI communities is also highly seasonally dependent, and illustrates the reliance on electric heating sources such as space heaters and baseboard heaters. The seasonal variations for six communities are shown below. In the larger communities of Kitamaat, Old Massett, Skidegate and Klemtu, very similar seasonal demands are observed, with peak consumption occurring in the months of December and January.

In the smaller communities of Hartley Bay and Metlakatla, the same trend can be observed, but on a smaller scale.



The existing consumption of fossil fuels for heating was also investigated for the two communities, with an average of **0.11 GJ/ft^{2}yr in Klemtu**, primarily in the form of heating oil for space heating, and **0.10 GJ/ft2/yr in Bella Coola**, in the form of heating oil and propane for space heating. The demand for heating oil is highly dependent on seasonal temperature variations as shown below:



Green Building Standards

There are a myriad of green building rating and certification programs available for new home construction in Canada. Some of these are highly prescriptive, while others allow for more freedom in material selection and design.

Some standards are focused only on energy efficiency, while others are much more holistic and may include requirements for the sustainability of building materials, urban and community design, or water usage, to name a few examples. This study will primarily focus on the energy efficiency aspects of building standards, and will separately consider the appropriateness of the standard on a cultural and community basis for Coastal First Nations communities.

Efficiency Standards in BC

There are several building standards that are unique to Canada, and a few that are unique to British Columbia. Standards may have slightly different names or requirements between jurisdictions. A few of the most popular building standards which contain energy efficiency requirements are summarized in this section.

EnerGuide

The EnerGuide program is an official Natural Resources Canada (NRCan) rating system that was originally designed to rate the energy efficiency of appliances as compared to other appliances in the same class. In 2006, the program was extended to include new home construction. The EnerGuide for New Houses program **rates the overall energy performance of a home on a scale of 0-100.**

Home Type	Typical EnerGuide Rating
Built to code	65-72
Some efficiency improvements	73-79
Built to energy efficient standard e.g. R-2000	80-90
Net-zero ready (requires little or no purchased energy)	91-100

[6]

Builders must work with an EnerGuide certified energy advisor in the design phase. The house is modeled in NRCan's HOT2000 software, and then built to specification. After construction is complete, the energy advisor returns to the house to verify the energy performance of the house by performing a blower door test and verifying the equipment installed in the house.

Advantages:

- **Numerical rating of homes allows for clear comparisons**

Disadvantages:

- **Rating system only, no methods, materials or suggested approach**

ENERGY STAR® for New Homes

The ENERGY STAR® for New Homes program is an extension of the international ENERGY STAR® brand and is administered by Natural Resources Canada. The New Homes program has existed since 2005 and contains prescriptive requirements for energy efficiency. A home constructed to the standard is typically **20% more energy efficient than a home built to national code,** with a minimum **EnerGuide rating of 81.**

The standard requires that windows and doors be certified for the ENERGY STAR® zone that the home is built in, and requires a certain level of electricity savings from certified ENERGY STAR® appliances. It also contains **minimum airtightness, insulation, and ventilation levels.** [45]

Advantages:

- **Clear targets for energy efficiency**

Disadvantages:

- **Relatively small performance gains as compared to code**

R-2000

Yet another program administered by Natural Resources Canada, R-2000 is a home performance standard that contains energy efficiency requirements, as well as **additional air quality, water use, and environmental performance requirements**. The program has existed since 1981 and has undergone several revisions. Homes constructed to the most recent R-2000 standard are typically around **30-50% more energy efficient than a home built to national code**.

R-2000 homes must be constructed by a licensed and trained R-2000 builder and are built to meet an energy budget which is defined by the climactic zone and characteristics of the home. A new R-2000 home would typically strive to achieve an **EnerGuide rating as high as 86.** [46]

Advantages:

- **Stringent energy efficiency standard**
- **Requirements for air quality etc.**

Disadvantages:

- **No prescriptive insulation requirement**
- **Only certifiable if licensed builder used**

Passive House (Passivhaus)

The Passive House standard was developed in Germany as *Passivhaus*, and is a very stringent energy efficiency standard. It sets requirements for space heating energy use, overall energy use and airtightness. A Passive House is built to minimize heat loss through the walls, windows and doors of a home. It is also built to be extremely airtight to reduce heat loss through air leakage. A house constructed to the Passive House standard is designed to have enough insulation that it **does not require a regular furnace or heating system,** but has only a very small heating element for use on the coldest winter days.

The Passive House standard does not specify how a house is to be built, but only provides an overall target for building performance. A Passive House built in Canada is typically **80% more energy efficient than a home built to national code,** and would often achieve an **EnerGuide rating of 90 or higher.** A Passive House is required to be certified by a Passive House accredited expert, but it need not be constructed by a licensed builder. [47]

Advantages:
- **Very stringent international energy efficiency standard**
- **Does not need to be built by licensed builder**

Disadvantages:
- **Difficult to achieve**
- **No suggested materials or methods, contains performance targets only**

Net Zero Ready (CHBA)

The Canadian Home Builders Association is in the process of developing a Net Zero Energy labelling program for new homes. It will contain two tiers of performance, the first being a Net Zero Ready label, which will certify a home that could offset all its annual purchased energy through on-site renewable energy. Such a home is typically **80% more efficient than code.**

The program will also have a second tier for labelling Net Zero homes, being those which have successfully offset all their purchased energy requirements and are therefore **100% more efficient than code.** The program is scheduled to launch its first full version in 2016.

Advantages:
- **Very stringent, made-in-Canada energy efficiency standard**

Disadvantages:
- **Still in development**
- **Net zero energy is difficult to achieve**

LEED Canada for Homes

The LEED program for new homes in Canada is part of the larger international LEED framework and was established in 2009 and is administered by the Canada Green Building Council. LEED is a green building standard that goes **beyond energy efficiency**, covering many aspects of home construction including the environmental impact of building materials, durability, support for alternative transportation such as transit and cycling, and much more.

The LEED certification process is based on **accumulated points**, with a large checklist of green building attributes that a home may or may not include. The total points scored determines the LEED rating of the house. These levels include Certified, Silver, Gold and Platinum. LEED is therefore not a standard based on a performance target like Passive House, but rather is an overall rating system with **thresholds for different levels of certification.** [64]

Advantages:

- **Covers many aspects beyond energy efficiency**
- **Internationally recognized program**

Disadvantages:

- **No specific performance targets**
- **Not all aspects are relevant to remote communities**

BUILT GREEN® BC

The Built Green program exists in several provinces in Canada and was established in 2003. It is **a direct competitor to LEED and is structured in a similar way**. Like LEED, there are several categories under which a Built Green home can accumulate points, including energy efficiency, ventilation, air quality, material use and water use. The levels of certification depend on points accumulated and include Bronze, Silver, Gold and Platinum.

The primary criteria for Built Green are resource use, energy efficiency, recycled content and indoor air quality. Buildings can also **accumulate points for achieving a higher EnerGuide rating.** [63]

Advantages:

- **Canadian equivalent to the LEED program**
- **Locally informed standard**

Disadvantages:

- **No specific performance targets**
- **Not all aspects are relevant to remote communities**

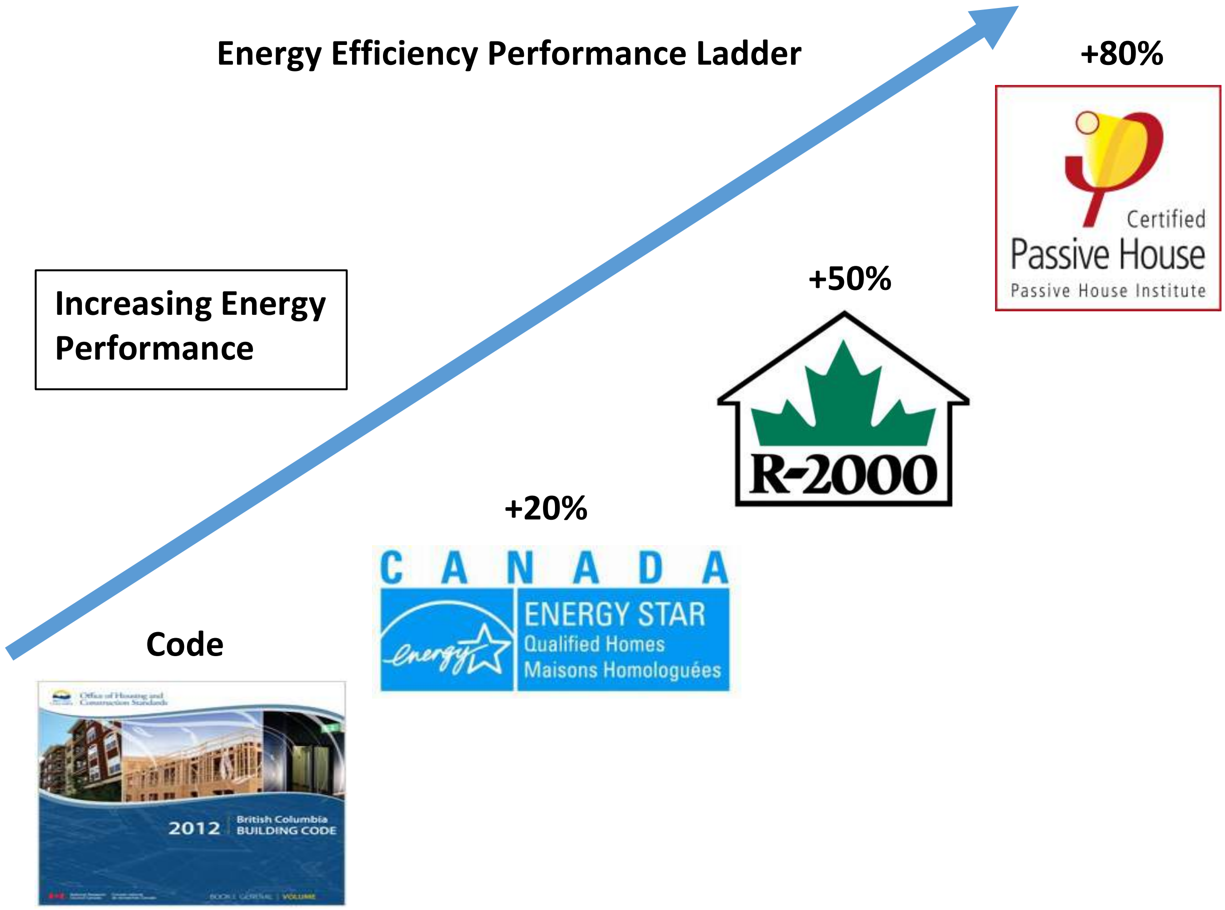
Power Smart New Homes

The Power Smart New Homes program was a BC Hydro certification and rebate program that was discontinued in 2015. Certification was based on a home's EnerGuide rating and had two tiers: Gold for EnerGuide 80 or higher, and Silver for EnerGuide 77 or higher. BC Hydro has since endorsed the ENERGY STAR® for New Homes program.

Benchmark Standards for Coastal BC

For the purposes of comparison, this study is most interested in green building standards that have a clear benchmark for energy efficiency. By selecting a number of standards for comparison, an "energy performance ladder" can be visualized, representing different levels of stringency in energy efficiency for new homes.

Because they are well-established standards with clear benchmarks, and a significant track record of certification in Canadian homes, the study will use ENERGY STAR® for New Homes, R-2000, and Passive House as the benchmark standards.



As the above diagram demonstrates, ENERGY STAR® for New Homes typically requires that homes use 20% less energy than a code house, R-2000 requires around 50% less energy use, and Passive House requires around 80% less energy use.

It is important to stress that **a more stringent standard is not necessarily the most appropriate choice**. Issues of economics, certification, and cultural appropriateness may influence the best choice of energy target for a new home in the Coastal First Nations communities.

For example, a Passive House certified house is extremely airtight, a requirement to meet its energy use targets. If a window is kept open in the home as a result of homeowner preference, the extra cost of making the home airtight is not reflected in energy bill savings. Similarly, an airtight house typically uses mechanical ventilation (by a Heat Recovery Ventilator or equivalent), which can lead to issues with indoor air being perceived as dry or stuffy.

In all cases, a home constructed to an energy efficiency standard must be operated as intended in the standard in order to achieve its performance target. If the operation of the home is different from that intended, the cost savings benefits of energy efficiency in the building design may not actually be realized.

The House as a System

Modern building science does not consider each component of a house as a separate, independent piece. Rather, the house is an interdependent system, where each component can affect the performance of the entire building [7].

In this context, concepts such as the **building envelope** emerge. The building envelope is a collection of pieces including walls, foundation, roof, windows and doors. Together they form the barrier between the conditioned space inside the home and the outside environment.

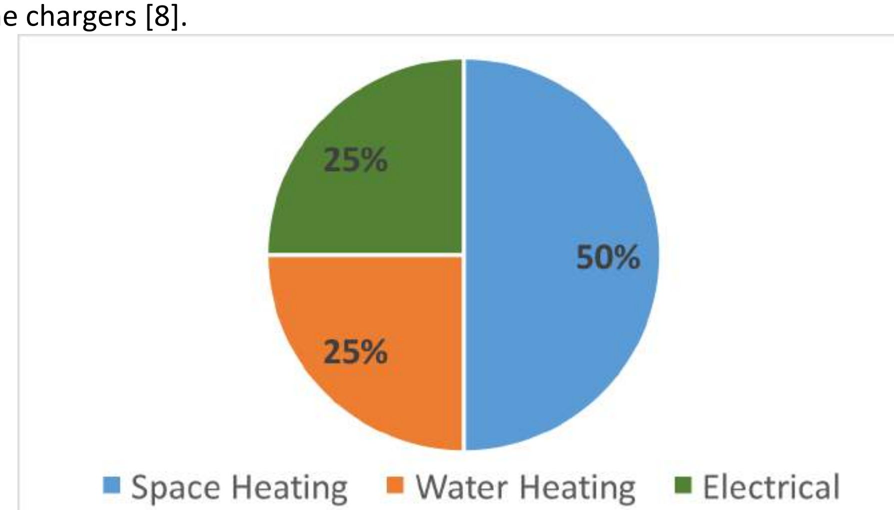
Similarly, the **mechanical systems** of the home depend on each other to provide an optimal environment for living. Mechanical systems in a home include the heating system, cooling system and ventilation system including fans and humidifiers or dehumidifiers.

It is important to consider the interdependence of building components when designing or retrofitting a home. For example, making the building envelope more airtight may lead to a decrease in heating loads, allowing a smaller furnace to be used. At the same time, a more airtight home may cause issues with air quality, leading to a need to increase ventilation. There are tradeoffs to be considered when improving or changing one aspect of the house system.

Home Energy Breakdown

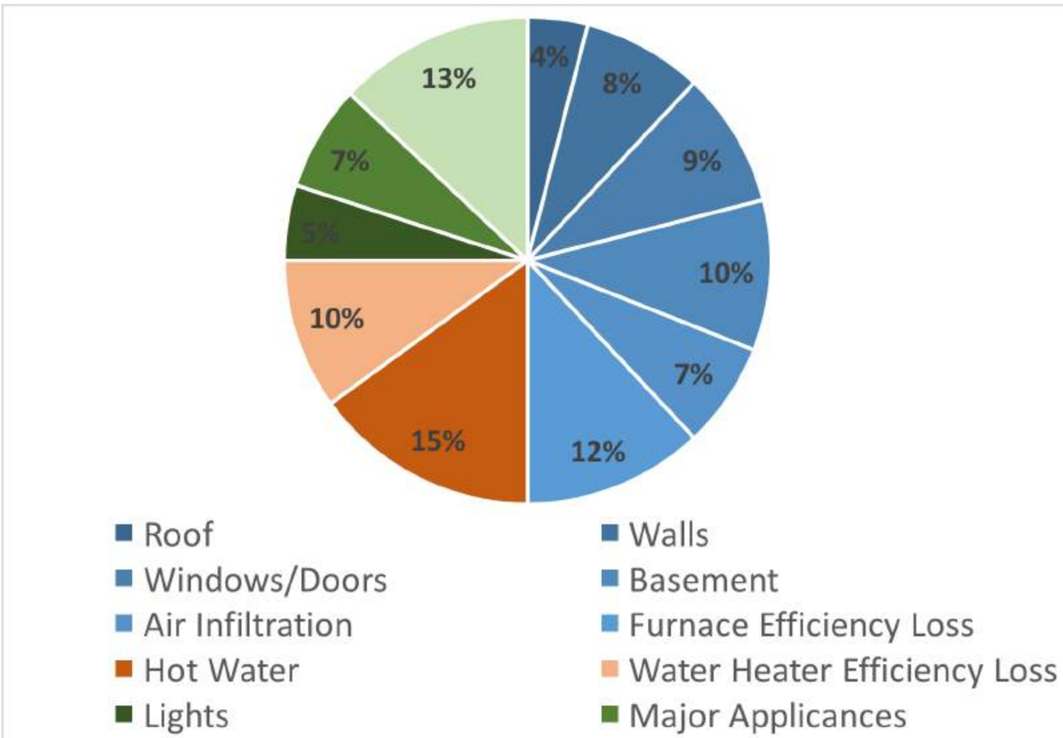
In order to provide for the needs of its occupants, a house requires energy inputs to several components. The single largest consumer of energy in a typical home in coastal BC is the space heating system, which provides thermal comfort for occupants and accounts for roughly 50% of all the energy used in the home.

The remaining 50% of home energy use is split evenly between water heating loads and electrical loads. Hot water is usually provided by a single appliance, whereas the electrical load is split between several appliances, which might include large appliances such as a stove, clothes washer and dryer, or dishwasher, and smaller appliances like televisions, computers or mobile phone chargers [8].



Breaking these larger systems down into their components, the interdependent nature of each component of the house is shown more clearly. Each component of the building envelope including the energy loss through the walls, roof, etc. contributes to the overall energy needs of the building.

It is also shown that a large amount of the energy used in the home is wasted energy from the **efficiency loss** of major appliances such as the furnace and water heater. As a result, choosing more energy efficient major appliances can lead to major improvements in the overall energy performance of the house.



[41]

Performance Targets

Good:	**Better:**	**Best:**
~20% more efficient than national building code, with an EnerGuide rating of at least 81.	~30-50% more efficient than national building code, with an EnerGuide rating around 86.	~80% more efficient than national building code, with an EnerGuide rating often 90 or higher.

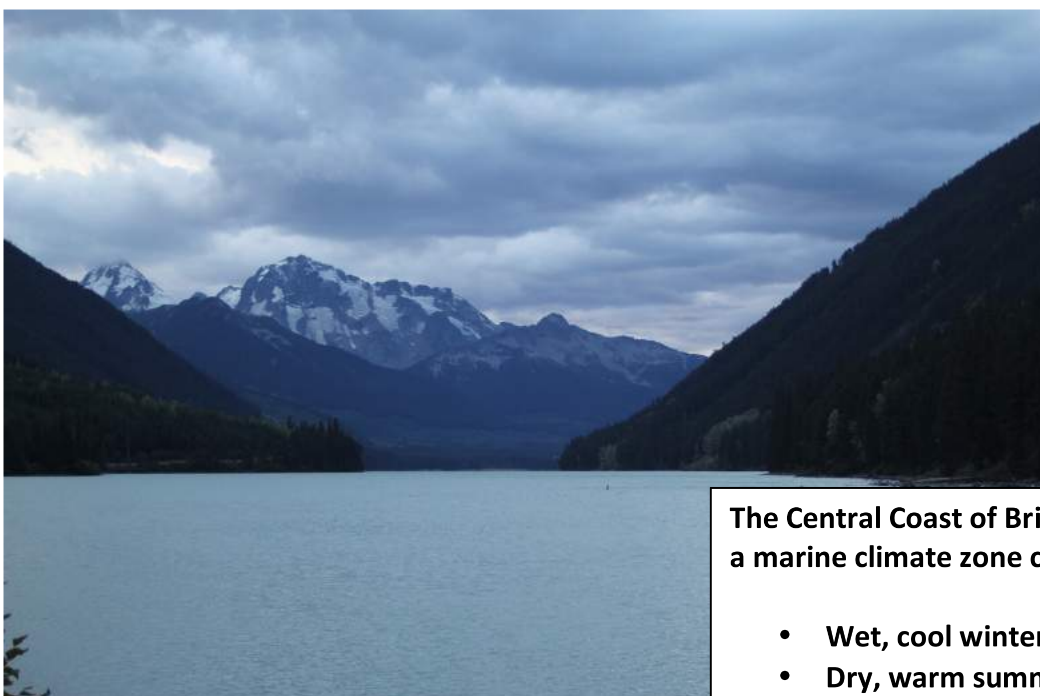
Climate

Background

The Great Bear Initiative communities are all located in the very wet marine environment of coastal British Columbia. Annual rainfall in this area is typically more than 1000mm, creating a temperate rainforest biome. Temperatures typically fall into a relatively narrow range around 0-20 degrees Celsius, and winds are sometimes very high [9].

In this marine climate zone, the most prevalent weather factors influencing building design are frequent and wind-driven precipitation, high winds, seismic activity, and forest fires during dry summers. As a result, some of the most important considerations in designing a livable home for the region include **mould reduction**, **storm water management**, **flood preparedness** and **weatherproofing** [10].

In terms of heating and cooling loads, the temperate environment of coastal BC has the lowest thermal comfort energy requirements of any zone in Canada. A common metric for defining heating load requirements is the heating degree-day (HDD), which uses measurements of outdoor air temperature throughout the year to estimate the amount of heating required. The communities of the Great Bear Initiative have a HDD index of around 3750, among the lowest in Canada.



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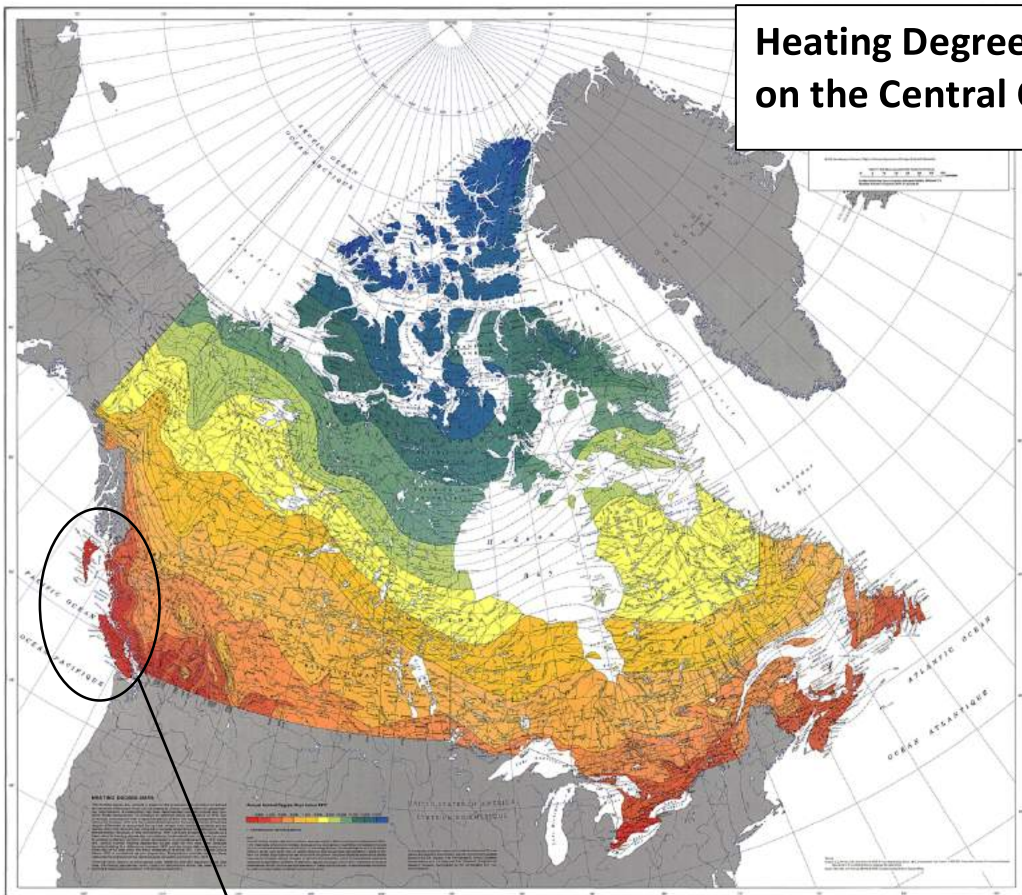
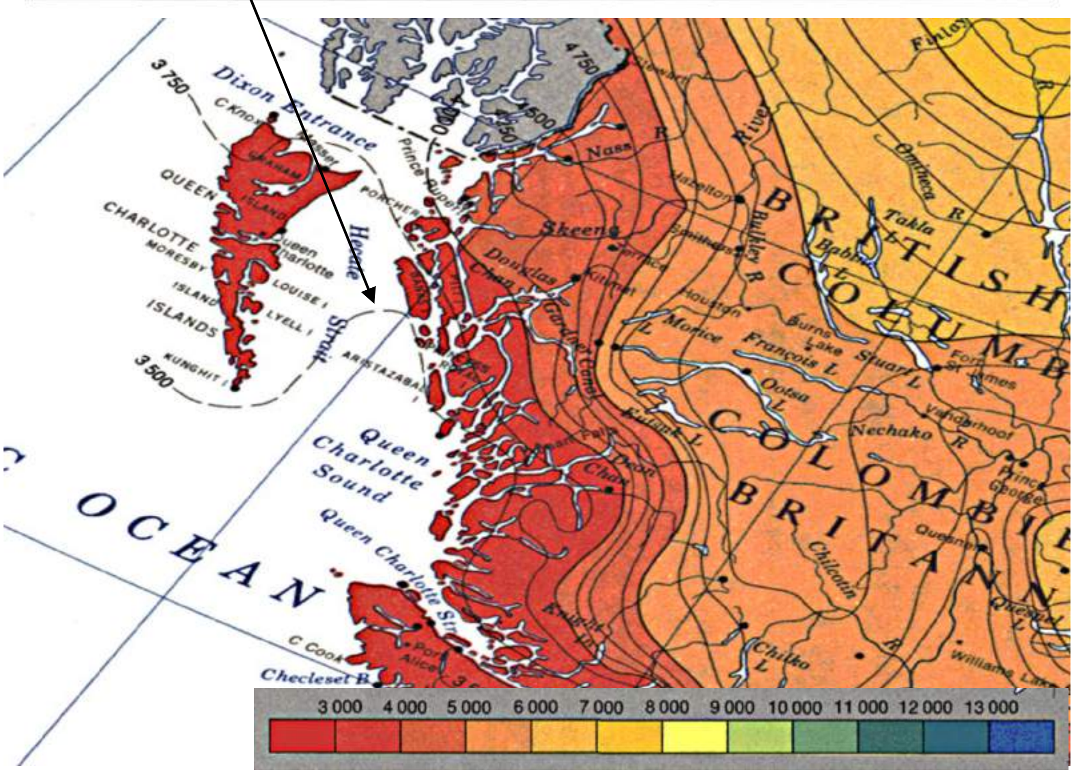
The Central Coast of British Columbia is a marine climate zone characterized by:

- **Wet, cool winters**
- **Dry, warm summers**
- **Frequent fog and cloud cover**
- **Frequent precipitation**
- **High winds**

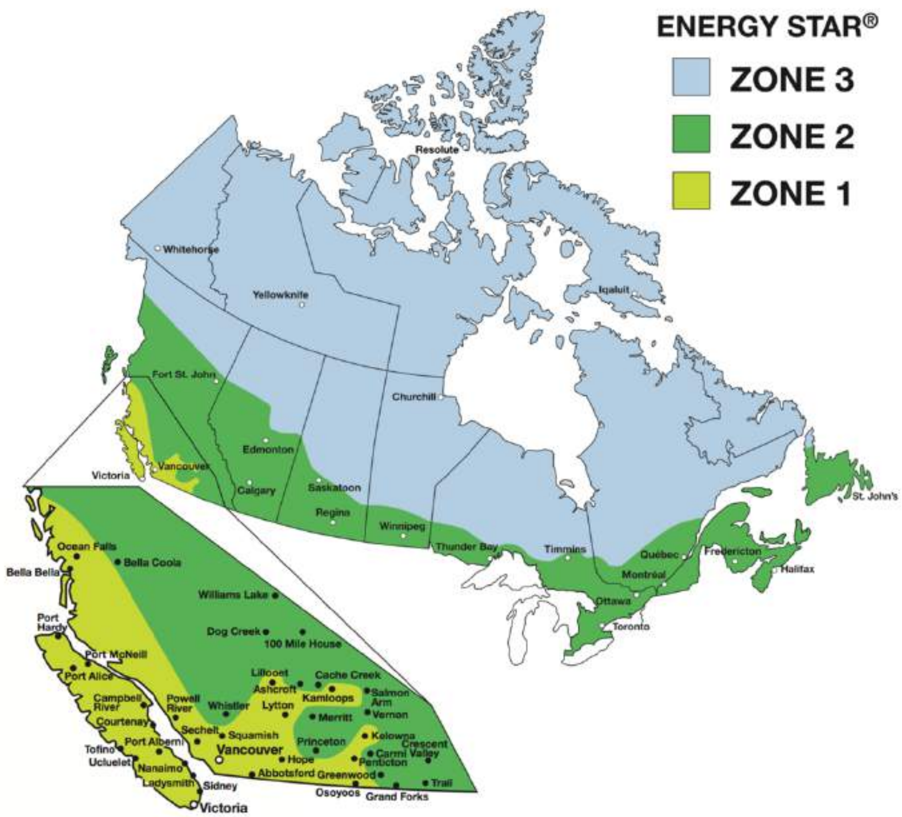
Heating Degree Days on the Central Coast





[11]

The North and Central Coast’s low heating load compared to other regions has implications for energy efficiency standards. For example, most of the Central Coast of BC is part of “Zone 2” of the ENERGY STAR standard, but is very close to meeting “Zone 1” requirements. This means that products such as windows and doors must meet relatively rigorous requirements relative to regional conditions in order to be considered compliant products for certification.

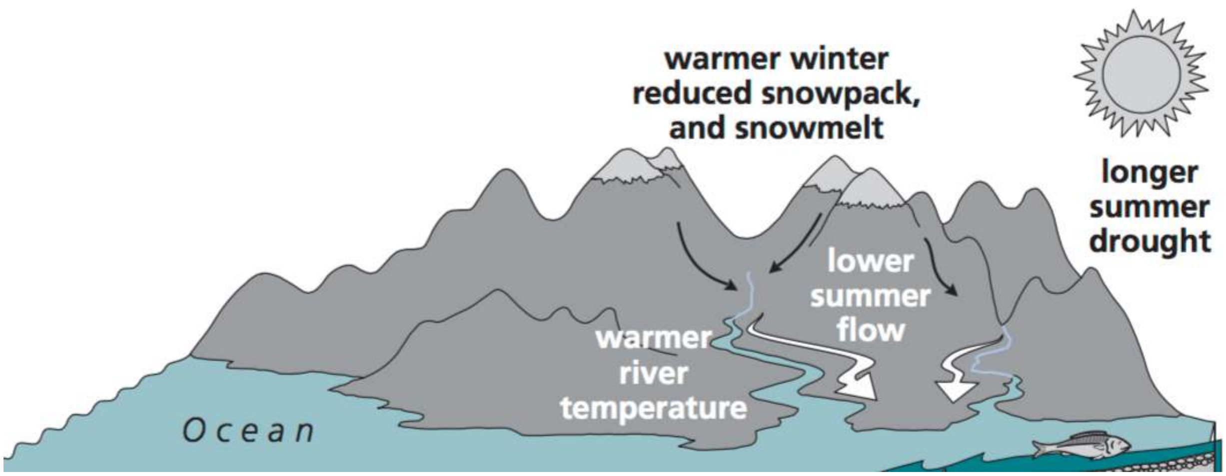


[12]

Community	Nation	ENERGY STAR Zone	Annual Heating Degree Days (HDD)
Metlakatla	Metlakatla	2	4000
Hartley Bay	Gitga’at	2	3750
Klemtu	Kitasoo	2	3500
Bella Bella	Heiltsuk	2	3500
Bella Coola	Nuxalk	2	4000
Rivers Inlet	Wuikinuxv	1/2	3500
Old Massett	Haida	2	3750
Skidegate	Haida	2	3750

Climate change will have a profound impact on the coastal regions of BC over the next 100 years. It is very likely that the frequency of heavy precipitation events will increase, causing more flooding and wind-driven rain events. It is also very likely that summers in the region will become warmer and drier, which coupled with decreasing winter snow packs will lead to an increase in drought events. This presents a problem for communities such as Klemtu, which rely on hydroelectric power rather than diesel.

Likely Effects of Climate Change on the BC Coast



[13]

The desire to move away from diesel-fired electricity in all of the GBI communities means that they could potentially be more exposed to supply shortages as water flows become more unpredictable. A further impact of climate change on coastal BC is rising sea levels, which may have an impact on all of the GBI communities as they are located in coastal areas [13].

Key Considerations for Coastal Homes

Mould

Mould reduction is a key issue for new homes in coastal BC. The most effective way of reducing mould growth is to increase ventilation, especially increasing the circulation of dry air. Ventilation caused by infiltration of moist outside air is far less effective, and can even encourage the growth of mould, as water vapour carried by infiltrating air is the largest single source of moisture inside the building [10].

Some other considerations for reducing mould growth include:

- Ensuring regular maintenance of eaves troughs and gutters
- Use of mould-resistant drywall
- Building a home without a basement
- Designing a more open floor plan to encourage air circulation

Mould is a common problem in the damp, humid climate of coastal BC.

The key to mould reduction is proper ventilation!

[0]

Climate Change

It is important that new home design in the GBI communities be done with climate change adaptation in mind. By the 2080s, communities in coastal BC will likely need to adapt to significant changes in climate including:

- A 9% decrease in summer precipitation
- A 10% increase in winter precipitation
- A 2.4°C increase in average temperature
- A 30% decrease in winter snowfall and 74% decrease in spring snowfall
- 878 fewer annual heating degree-days (HDDs) [15]

Extreme Wind

BC experiences violent wind storms that cause damage to homes and infrastructure, and sometimes cause significant power outages. The North and Central Coast is no exception, especially in communities that are not sheltered by inlets or nearby islands.

Buildings in this region would benefit from being strengthened as compared to the current building code in order to accommodate possible high winds, and could incorporate shutters and covers as appropriate to protect windows and doors.

Storms such as that experienced in 2015 in the Lower Mainland can cause widespread damage to homes.

New buildings could be sited and designed to be prepared for damage from trees and blowing debris.

[0]

Site Selection and Passive Solar Design

Site Selection

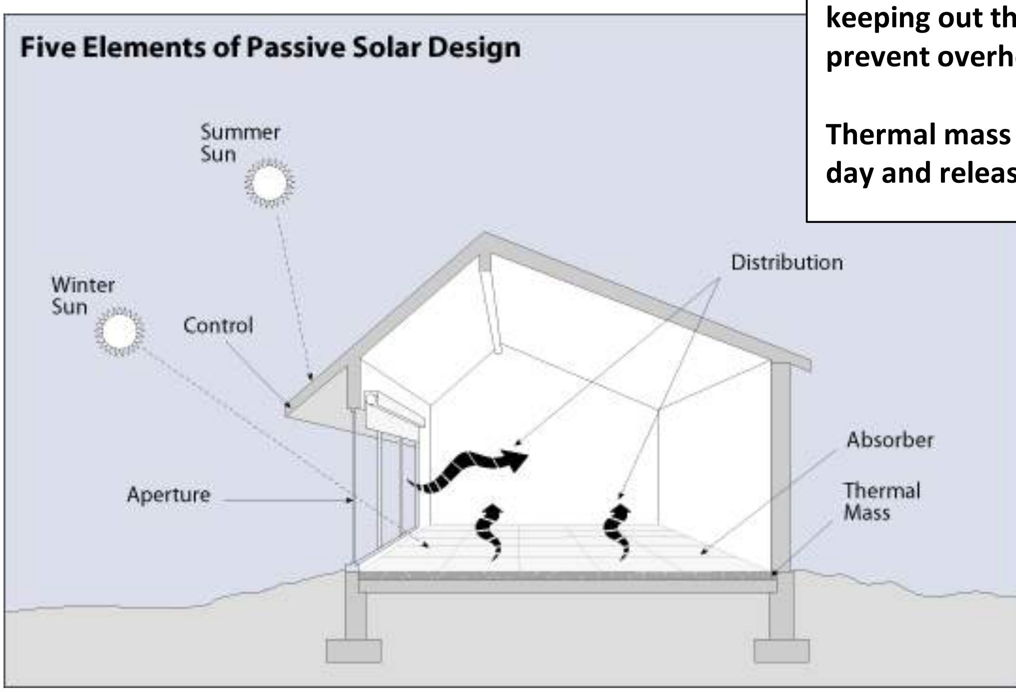
The first, and one of the most important considerations in new home construction is the selection of building site. The selection of site and initial design of the home will have a large impact on its longevity, livability and energy performance. Some key considerations in this process include:

- **Planning for south-facing orientation.** A home that is located in an area with significant south-facing exposure will be able to maximize solar gains and take advantage of passive solar building design.
- **Site suitability and preparation.** Buildings should be located in a well-drained area, with sufficient slope to allow for drainage, but not at such an extreme slope that it is vulnerable to soil erosion or landslides. This is a particular concern in coastal BC, which is typically mountainous and at risk for destructive landslides caused by heavy precipitation.
- **Setbacks and landscaping.** Buildings should be sufficiently set back from trees to meet fire suppression requirements, and to avoid damage in storms from breaking tree branches or falling trees.

Passive Solar Basics

Passive solar takes advantage of the winter sun to heat the home, while keeping out the summer sun to prevent overheating.

Thermal mass absorbs heat during the day and releases it again at night.



[16]

The key principle of passive solar design is to **take advantage of the natural variation in solar radiation** throughout the day and as the seasons change. This is achieved on a daily basis by capturing solar energy through energy-efficient windows during the day, and providing thermal mass in the building which can absorb some of this energy. At night, the thermal mass radiates this heat back into the air inside the building, keeping the temperature inside the house more stable.

On a seasonal basis, passive solar design uses carefully designed overhangs and shades, which work to shade the windows as much as possible from the midsummer sun, which allowing as much light as possible through the windows during midwinter. This serves to **reduce cooling loads during the summer, and reduce heating loads during the winter**.

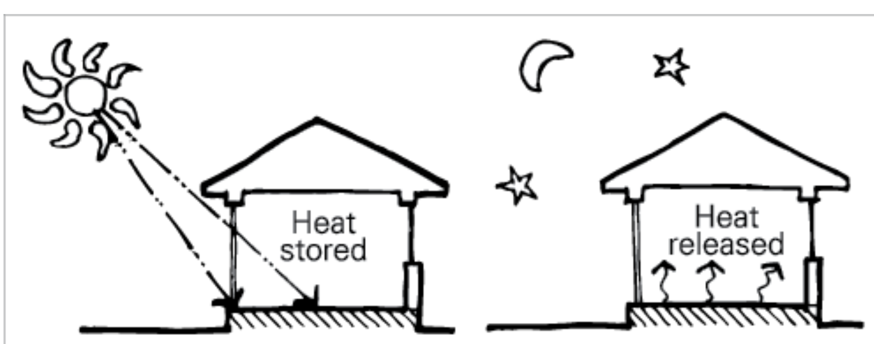
Passive solar design at its most fundamental level simply takes advantage of these basic principles, and combines them with the use of high performance windows that do not leak too much heat. This will ensure that heat lost through the windows at night does not outweigh the heat gained from the solar radiation during the day.

Thermal Mass

Thermal mass is an important concept in energy efficient home design. A thermal mass in a home typically takes the form of a thermal wall or thermal floor. When constructed from a material that has the ability to absorb and hold heat, such as concrete or brick, these structures can help **prevent the temperature inside a home from fluctuating** on a daily basis. Examples of thermal mass include concrete slab floors (including *slab-on-grade*), and masonry or brick walls.

A thermal mass is able to absorb heat from sunlight during the day. Because thermal mass materials have a high *heat capacity*, they can store a large amount of energy in this way. Later, during the night, these materials radiate their stored energy back into the surrounding air. A thermal mass can act like a "heat battery", keeping the home **cool during the day** by absorbing sunlight, and keeping the home **warm at night** by releasing this energy as heat.

In order to take advantage of thermal mass, these structures should be combined with passive solar design so that the thermal mass is exposed to sunlight for most of the day, especially during the colder winter months when the energy released by the thermal mass at night is most needed.



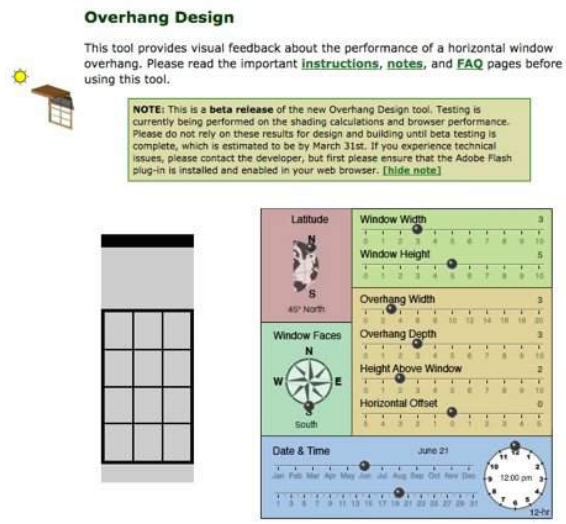
[17]

Key Considerations for Coastal Homes

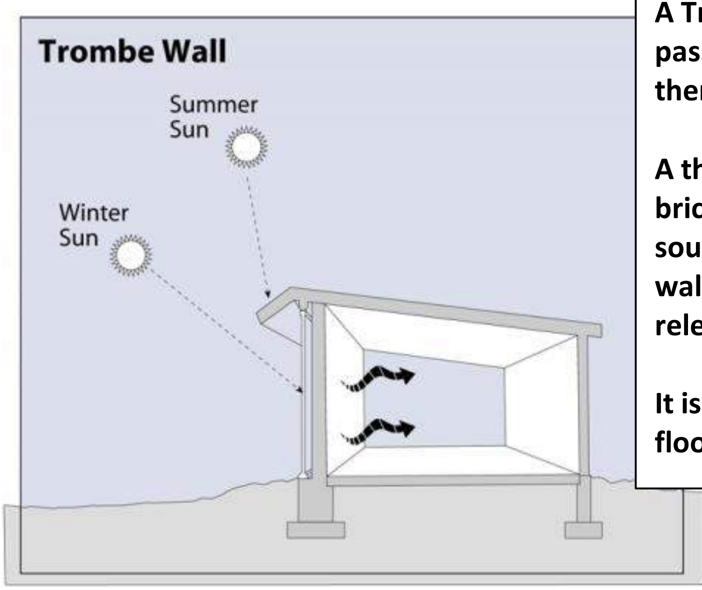
In an ideal situation, new homes in coastal BC should be designed to take advantage of passive solar principles, as these design modifications provide significant energy efficiency benefits at negligible additional cost. Where possible, homes should incorporate significant **south-facing windows**, with **overhangs properly designed to provide shade from summer sun** while **maximizing winter sun**. This reduces summer cooling loads as well as winter heating loads. The incorporation of thermal mass materials such as a concrete slab floor provides further efficiency gains, by allowing the house to store solar energy during the day and then release it at night. [16]

Sustainable by Design **(in Seattle, WA), provides a free online calculator for designing and optimizing window overhangs** [72]**.**

This design can also be done by an architect or building science professional.



For sites in which south-facing windows are not desirable but there is still significant winter sun exposure on the south-facing wall, other methods such as a Trombe wall can be utilized to capture and circulate heat from the winter sun. These alternate methods are often referred to as "indirect-gain" methods.



[16]

A Trombe wall is an indirect-gain passive solar technology that utilizes thermal mass in a unique way.

A thermal mass wall (constructed of brick or masonry) is placed behind a south-facing window, allowing the wall to heat up during the day and release this heat at night.

It is a good choice when a concrete floor is not a feasible design option.

Some key considerations for passive solar design in the coastal BC context include the following:

- Incorporate **south-facing windows** with a total area of between **9-12%** of the conditioned floor area.
- Where south-facing windows and walls are not possible, they should be within **40 degrees of true south**.
- Houses should also generally be **longer on the east-west axis** than the north-south axis.
- **Setbacks** to trees on site should be large enough to ensure sufficient sunlight and adequate fire preparedness.
- Incorporate the passive solar design principles of **overhangs, thermal mass and high-performance windows.**


[0]

A modern home built using passive solar principles.

Following passive solar design can **reduce heating loads by 10-20%** and **cooling loads by 10-40%!** [14, 18]

Performance Targets

Good: ENERGY STAR HOMES	Better: R-2000	Best: Certified Passive House Passive House Institute
Minimal use of passive solar principles. Energy savings may be from airtightness and efficient appliances only.	One or more elements of passive solar design is incorporated e.g. high performance windows.	Incorporates all the key elements of passive solar design: south-facing, large windows and overhangs, and thermal mass.

Technology Comparison

Technology	Implementation	Cost	Advantages	Disadvantages	Best Practice for CFN?
Passive Solar Design					
South-facing Orientation	Dependent on a suitable site (e.g. not possible on a north-facing hill)	Little or no additional cost	-Takes advantage of solar energy throughout the year	-May not be feasible in some communities that primarily face north	✓
High Performance Windows	Dependent on shipping from a few vendors	10% to 15% more for triple-glazed windows	-Much better energy performance	-High cost -Replacements must be shipped long distances	✓
Overhangs	Simple addition in design phase, more difficult to add later	Little additional cost	-Cooler in summer, warmer in winter -Lower energy costs	-Needs to be considered in design phase -May not be considered aesthetic	✓
Thermal Mass	Must be built in at time of construction. Requires large amounts of masonry or concrete	No additional cost when using slab on grade foundation, extra cost otherwise ($1000+)	-Improves temperature stability -Reduced energy costs	-Often requires that floors be made of concrete, which may be expensive in remote locations	✓
Trombe Wall	Requires careful design, construction of a thermally massive wall	$700-$1500 in additional concrete	-Creates thermal mass without a concrete floor	-Covers window space that could otherwise be used natural daylighting	✓

Meeting Community Needs

The principles of passive solar design have many advantages from the perspective of building performance and energy efficiency, but also have the benefit of improving the cultural and practical appropriateness of homes in the Coastal communities.

Passive solar design encourages open floor plans, which improve airflow and allow thermal mass floors and walls to absorb heat effectively. This discourages the growth of mould and mildew, improving the air quality inside homes.

Encouraging more open floor plans also increases the area in the home that can be used as a gathering space, and the use of large windows makes these spaces more connected with the surrounding environment. Natural daylight in open gathering spaces makes them much more inviting. Open gathering spaces can also be used to display local and family artwork.

[19]

This home combines passive solar design and an open concept. It provides highly livable and flexible space that feels connected with the forest environment outside.

Foundation and Frame

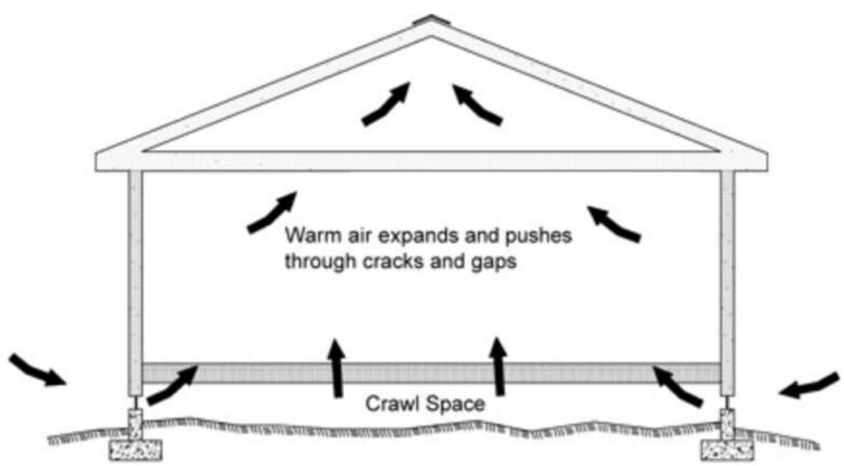
Foundations

The choice of foundation design is one of the most important design aspects in home construction. There are three main approaches to foundation design: basements, crawlspaces, and slab on grade.

[20]

Crawlspaces

Crawlspaces are unfinished foundations, above which the floor sits. They have the advantage of providing access to ductwork and piping, and allowing the floor to be constructed of a material that cannot site directly on the ground (e.g. wood). They require less excavation than a basement, and also very little concrete. However, crawlspaces are excellent environments for **mould growth**, and should be covered with a moisture barrier. Mould growing in a crawlspace can pose a particular problem because of the “stack effect”, in which warm air inside the house rises, drawing cool air up from the crawlspace, and mould spores along with it. Crawlspaces should be well-sealed if used due to the potential adverse health effects of this phenomenon [21].



[22]

Basements

Traditional home design often includes an excavated foundation. Some of the issues of crawlspaces exist in basements, including mould growth. However, basements **add to the useable area of the home**, particularly if they are eventually finished. Basements require significant excavation, and also use large amount of concrete. As a result, basements are the **most expensive** foundation option. Adding a basement to a home can increase the cost by as much as $30,000 [23].

Slab on Grade

In slab on grade construction, a single concrete slab is poured directly on ground that has been flattened, compacted and mixed with gravel to provide sufficient drainage. The concrete slab is polished and may be acid etched, and serves as the floor of the home. If site and soil conditions permit slab on grade construction, it is usually the **cheapest type of foundation**.

When well insulated with rigid foam under the concrete, slab on grade is also the **most energy efficient** type of foundation, since the slab acts as an effective thermal mass. The slab on grade design builds this thermal mass into the living space of the home, providing thermal stability and reducing heating and cooling loads. It is an excellent alternative to masonry walls, which also provide effective thermal mass but are more difficult to insulate than traditional wood frame walls [24].

A principal disadvantage of slab on grade construction is that all the mechanical equipment for the house must be placed in a **utility room** on the main floor, rather than in a basement. The slab also usually contains plumbing, electrical, and radiant heating components, which are embedded in the slab as it is poured. This makes it essentially impossible to alter or upgrade these components after the concrete has set.


[0]

A slab on grade foundation being prepared.

Framing

Stick-Build

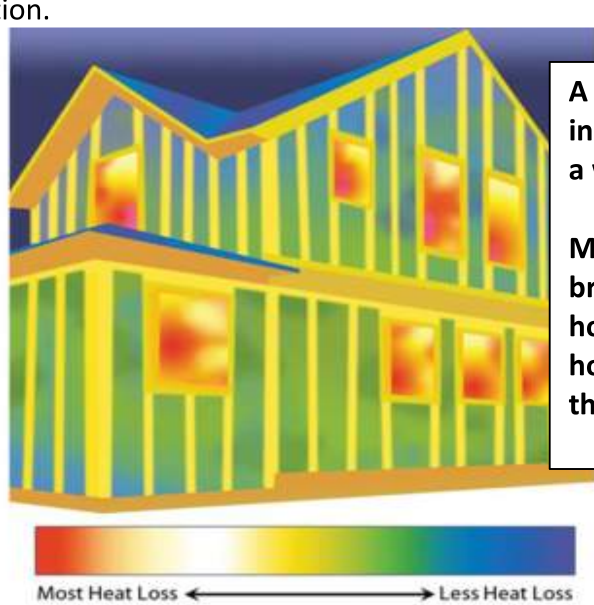
Stick-build is the most common method for house framing, where the house is constructed entirely on-site, rather than incorporating modular components that are prefabricated, or prefabricating the entire building and moving it to site. Stick-built also usually refers to the common practice of framing houses with wood beams or "sticks".

A typical stick-build framed house would usually incorporate studs with 16 inches of space between them: "16 inches on center"

[0]

Advanced Framing Techniques

Advanced framing is an alternative to a traditional stick-build frame, and incorporates new understanding of building science in order to increase efficiency. A popular advanced framing method is to construct 2x6 walls with 24 inches on center, rather than the usual 16 inches. This reduces the number of potential thermal bridges in walls and provides larger cavities for insulation.



A *thermal bridge* occurs when a poorly insulating material causes heat loss through a wall or other barrier.

Most commonly, wood studs form thermal bridges when they conduct heat out of the house. Despite being well-insulated, a home can lose a great deal of heat through the wood frame.

[25]

Advanced frames also often utilize double stud corners rather than triple stud, which is typically adequate for structural stability as the third stud is typically only used to mount drywall. Drywall clips can be used in corners to remove the need for a third stud [3]. All of this serves to reduce the amount of wood used in the frame, and therefore, reduce the amount of thermal bridges in the building envelope.

Another alternative to a traditional stick build frame is a double stud wall construction. This is typically achieved with 2x4 beams and offsets the studs between two separate wall assemblies in order to remove thermal bridges [26].

A double stud wall under construction. The space between the studs will later be filled with insulation.

[0]

Prefabricated Frame

Walls can also be constructed using prefabricated panels (sometimes called *structural insulated panels)*, which some developers prefer because they can be manufactured off-site and assembled quickly, reducing local installation costs. Some prefabricated panels are constructed with magnesium oxide boards, while other projects have utilized structural insulated panels constructed with EPS foam and plywood or oriented strand board (OSB) [28].

Prefabricated wall panels are built to contain **no thermal bridges**, and provide a continuous layer of insulation in the building envelope. There are some disadvantages of prefabricated panel construction, including the cost of shipping. In remote locations this factor can make prefabricated construction uneconomical.

Two types of prefabricated wall panel. The panel on the left is constructed using oriented strand board (OSB), which can occasionally swell if exposed to moisture.

The panel on the right is constructed using magnesium oxide (MgO), which is waterproof, mouldproof and fireproof but is more expensive.

Key Considerations for Coastal Homes

Foundations

There are several advantages to **slab on grade** construction in the coastal BC context. Basements and crawlspaces are prone to moisture infiltration and tend to be excellent environments for mould growth. When the slab is appropriately insulated, it can act as effective thermal mass and still remain comfortably warm as a floor material. A slab on grade construction may also be significantly more affordable than construction of a concrete foundation, even considering the extensive site preparation that must take place before pouring the slab [23].

A 2004 Seabird Island First Nation sustainable housing project utilized slab on grade construction, providing the homes with an effective thermal mass, as well as providing a medium for installing radiant heating [29].

Some advantages of building a foundation, rather than slab on grade include the additional living space provided, especially if the basement is eventually finished, and the ability to build on a significantly sloped site. This can provide more site options in a mountainous area like coastal BC. However, they are generally unsuitable for the GBI communities due to higher costs, large concrete requirement, and susceptibility to mould and mildew.

Crawlspaces are moist, mould-prone areas that do not add to the livable space of the home. If possible, they should be avoided, but if a crawlspace is built, a polyethylene ground cover should be installed to reduce moisture infiltration. They may be the only option in extremely remote communities where the cost of concrete is prohibitive to building a slab on grade. In this case great care should be taken in weatherproofing and ventilating the crawlspace properly [30]. An advantage of crawlspace construction is that plumbing and ductwork is much easier to access, maintain and upgrade than in a slab on grade, where these elements are usually embedded in the concrete and cannot be altered.

Framing

The framing option which typically strikes the **best balance** between energy efficiency and cost effectiveness is **double 2x4 wall** stick build construction. This type of wall is easy to insulate with an affordable material such as cellulose. This construction method uses a minimum of materials in order to **eliminate thermal bridging**, without the added cost of shipping and assembling prefabricated panels.

2x6 wall construction with 24” on center studs is a good alternative option. This type of construction minimizes lumber use through **advanced framing**. In order to reduce the effects of thermal bridging, **rigid foam insulation** should be applied on the exterior of the wall. However, this option sometimes incurs a **cost premium** depending on the local cost of labour, as it requires more time to construct.

Both advanced framing options are superior to a traditional frame with 16” on center studs, if structural concerns are adequately mitigated. Code requirements for **strength and rigidity** should be maintained, keeping the building resilient to storm and seismic activity [26, 35].

Prefabricated panels are another viable option for some communities, but the **cost of shipping** to remote locations must always be factored into cost estimates. Prefabricated panels can also be damaged in shipping or by moisture infiltration. Another disadvantage of prefabricated design is that the panels should not be excessively altered to allow ductwork, piping, etc. to pass through them. Homes designed to use prefabricated components are usually carefully designed to minimize alteration of the panels. There is at least one developer, AYO, pursuing home construction using prefabricated Magnesium Oxide (MgO) panels for the Yunesit’in First Nation in BC [27].

Performance Targets

Good:	**Better:**	**Best:**
Traditional basement or crawlspace foundation with some insulation on below grade walls	Basement or slab on grade foundation with some insulation under the foundation	Slab on grade construction is common and provides thermal mass. Insulation under foundation is extensive.
Conventional framing on 16” centers, with extra insulation added	More advanced framing such as 2x6 walls on 24” centers and two stud corners	Double 2x4 walls or 2x6 walls with exterior insulation, with thermal bridging nearly eliminated, or prefabricated wall panels

Technology Comparison

Technology	Implementation	Cost	Advantages	Disadvantages	Best Practice for CFN?
Foundation					
Slab on Grade	Requires extensive site preparation and precise concrete pour	Often the cheapest foundation option	-Affordable option -Reduces health issues -Energy efficient	-Ductwork, plumbing difficult to modify -Utility room on main floor	✓
Traditional Basement	Sometimes the only option for highly sloped sites	Increases cost by up to $30,000	-Adds additional living space -Utility room out of sight	-Expensive -Prone to mould and mildew	✗
Crawlspace	Requires site preparation but little concrete, good for very remote communities	Extra cost for some excavation	-Easy to access and modify ducts and plumbing -Low concrete use	-Very prone to mould growth -Does not add useful space	✓/✗
Frame					
Traditional Stick Build	Standard construction method	$10-$20/ft^2	-Simple, time-tested method -May require less specialized labour	-Relatively poor energy performance -Requires more material	✗
Advanced Framing	Uses similar materials and methods as traditional stick build	Somewhat less than traditional build	-Uses less material -Reduces thermal bridging -Allows more space for insulation	-Not possible in some areas due to code requirements	✓
Prefabricated Panels (Structural Insulated Panels)	Needs to be assembled correctly and precisely according to planned design	~20% higher cost per square foot; Up to ~30% savings overall (less labour)	-Eliminates most thermal bridges -Mould resistant -Continuous insulation layer	-Shipping costs can be prohibitive -Installation can be more complex	✓/✗

Meeting Community Needs

Building with slab on grade foundations has benefits from an energy efficiency perspective, but also improves the livability of the home. A foundation at grade does away with underground environments such as crawlspaces that are prone to mould growth.

This concrete slab floor is comfortably warm underfoot and eliminates basement drafts [19].

A slab on grade draws fresh air from the sides of the home and through planned ventilation systems, rather than drawing cold and potentially contaminated air up through the basement or crawlspace. This not only reduces the presence of mould in the home, but also reduces cold drafts that make many coastal BC homes uncomfortable in winter.

A slab on grade foundation also provides thermal mass for the floor, keeping it at a comfortable and relatively constant temperature. This can reduce problems with floors being cold underfoot.

Constructing a stick-built home using advanced framing techniques can reduce the amount of material used in construction, as well as providing higher energy performance. This reduces shipping and material costs, keeping costs affordable for remote communities.

When considering home design and framing, a single storey home will generally meet community needs better than a multi-storey home. In many communities with two storey homes, the living spaces on the second storey are the only ones that are regularly utilized, with the ground floor being neglected or used for storage. This is an inefficient use of space, and also presents issues when elders have issues using stairs, leading them to become effectively trapped in upper stories.

A single storey building is also much easier to construct and maintain, with all parts of the home being accessible from a short stepladder. This reduces the difficulty of maintenance, for example the cleaning of eaves and gutters.

Insulation

R-Values

The R-value of insulation is a measure of how well it blocks the flow of heat. A higher R-value corresponds with a higher insulation value. Ducts, for example, may be insulated with a thin layer of foam having an R-value of only 2. A well-insulated ceiling in a Passive House, by comparison, may have an R-value of nearly 100. These R-values are given in the commonly used Imperial units of $h \cdot ft^2 \cdot °F/Btu$, but are sometimes also expressed in Metric units!

Fiberglass

The most familiar type of insulation found in Canadian homes is fiberglass batting, which is designed to fit in the voids between studs in a traditional stick-build frame. It has the advantage of being affordable and available, but is difficult to install correctly. This often leads to insulation gaps in walls that cause heat loss.

Cellulose

Blown-in cellulose is becoming a popular alternative to fiberglass insulation. It is sourced from recycled materials and is treated to be water and mould-resistant. Cellulose insulation is blown in to wall cavities and attics using specialized equipment. Cellulose offers higher performance compared to fiberglass and can reduce insulation voids, but it can be more expensive.

Rigid Foam Insulation

[31]

Rigid foam insulation comes in three principal forms: extruded polystyrene (XPS), expanded polystyrene (EPS), and polyisocyanurate. There are advantages and disadvantages to each type of insulation.

EPS has the lowest R-value at about R4 per inch of insulation but is cost effective [32].

XPS performs somewhat better at R5 per inch, however it has historically been criticized for relying on blowing agents for its manufacture that are potent greenhouse gases (GHGs). Since 2010 alternative products have become available which do not use these environmentally damaging agents [10].

Polyisocyanurate has the highest performance per unit thickness of all rigid foam insulations, however its key disadvantage is that it loses performance rapidly as temperatures decrease, particularly as freezing temperatures are approached [33].

Key Considerations for Coastal Homes

Any concrete floor on unheated ground, and especially a slab on grade floor, should be insulated well to avoid heat loss through conduction and also to enable the concrete to act as an effective thermal mass. The most effective material for insulating underneath a slab is typically a rigid foam insulation such as extruded polystyrene (XPS) or expanded polystyrene (EPS) [34]. Polyisocyanurate foams are not typically appropriate for northern climates as they lose performance with decreasing temperature [33].

Many existing homes use R-values of 10 or 12 below the slab and/or around the perimeter of the foundation, which would typically equate to a single layer of 5-cm XPS insulation [35]. Depending on the targeted energy performance level of the home, the level of slab and perimeter insulation could be increased dramatically, up to and exceeding R30 in the case of Passive House certified applications.

Increasing the level of insulation adds cost, but also provides the benefit of improved thermal stability and comfort, especially in a slab on grade application where the floor should be kept warm enough to be comfortable underfoot. The entire perimeter of the slab or foundation should be well-drained and sloped to prevent water from pooling under the concrete [10].

Wall insulation is typically achieved with fiberglass batting, but blown-in cellulose can be used as well. Cellulose is sourced from recycled materials, making it a sustainable choice, and can provide higher R-values in the same space as compared to fiberglass [36]. It can also be blown into high-volume spaces such as attics, making highly insulated ceilings with R-values of 100 and above possible at marginal extra cost [35]. Cellulose carries a slight price premium but offers many advantages.

Insulated wood walls can be covered with rigid foam panels on the exterior surface, which increases the overall R-value of the wall assembly, but also acts as an effective moisture barrier, reducing the need for exterior sheeting. This method is a relatively cost-effective way to achieve R-values of around 30, but is potentially more expensive than a double-wall or prefabricated construction when targeting higher R-values of around 50 [35].

Performance Targets

Good:	Better:	Best:
Ceilings: R50 Exterior Walls: R17.5 Walls Below Grade: R17 Foundation/Slab: R11	Ceilings: R50 Exterior Walls: ~R28 Walls Below Grade: ~R20 Foundation/Slab: ~R20	Ceilings: R50-R90 Exterior Walls: R40-R60 Walls Below Grade: R30-R50 Foundation/Slab: R30-R50 [37]
Fiberglass batting insulation	Cellulose or foam panel insulation or extra insulation, minimizing thermal bridges	Prefabricated foam-filled modules, double wall with cellulose or single wall with EPS/XPS panels

Technology Comparison

Technology	Implementation	Cost	Advantages	Disadvantages	Best Practice for CFN?
Insulation					
Fiberglass Batting	Industry standard, but requires skill to install correctly	~$1/ft^2$, depending on thickness	-Standard insulation material -Readily available	-Prone to air gaps -Lower performance	✓
Blown-in Cellulose	Requires special equipment and preparation	May be comparable to fiberglass or up to 50% more	-Sustainable -Better performance than fiberglass	-Requires qualified person for installation	✓
Rigid Foam	Relatively easy to install	Up to 400% more than fiberglass	-Can be used as moisture or air barrier -Can be used to insulate foundations	-Expensive -Often needs to be combined with another type of insulation	✓
Spray Foam	Requires special equipment	Several times more than fiberglass	-Excellent for sealing air gaps	-Very expensive -Usually used in combination with other insulation	✓

Meeting Community Needs

A highly insulated home has advantages beyond energy savings and efficiency. More insulation leads to a more effective building envelope, which contributes to comfort in all areas of the home. Temperatures in a highly insulated home are more stable and warm, especially in areas that may be drafty or cold in many houses including bedrooms and entryways. Insulation can also help to keep a house cool during summer.

The choice of insulation material can also have an impact on the community. Most insulations are manufactured in major cities and industrial centers. However, an insulation like cellulose is derived from recycled wood products, and can be sourced locally here in BC. In the future, there could be a potential for less remote communities such as the Nuxalk or Haida Nations to produce their own cellulose insulation material from wood and paper waste products.

Weatherproofing and Airtightness

Barriers

There are three types of barriers typically used in home construction: vapour barriers, air barriers, and water resistive barriers or WRBs.

A **vapour barrier** such as polyethylene is installed on the warm (conditioned) side of an exterior wall and is intended to reduce the diffusion of water vapour, but not air, through the wall.

An **air barrier** is any assembly intended to stop the leakage of air through the wall. It may be a single membrane, spray-on sealant, or a combination of materials.

A **WRB** is installed on the outside (unconditioned) side of the exterior wall and is intended to stop liquid water in the form of rain from penetrating further into the wall assembly.

[38]

Any given material may provide one *or more* of these functions, for example, a WRB may also serve as an air barrier [39].

Weatherproofing

Sealing

Sealing around gaps in the building envelope is a critical step in the overall weatherproofing of a house. Sealants, including caulk and spray-on foam, can fill small gaps and improve the overall airtightness of the building envelope. This is especially critical around duct and pipe holes, which are often-overlooked areas.

Weather Stripping

Weather stripping can fill in some larger gaps, or can be used in areas where the building envelope opens. For example, weather stripping is an important part of a well-sealed door or window assembly. High quality weather stripping makes these areas more airtight, and also prevents the ingress of moisture and wind-driven rain.

Rainscreen

A rainscreen is an important detailing feature of exterior walls where an air gap is maintained between the exterior siding (or other finishing material) and the exterior WRB. The purpose of a rainscreen is to provide a cavity for ventilation and water drainage, so that if water infiltrates the exterior finish of a house it can drain without getting the WRB wet. Rainscreens are especially important in areas where high winds may drive rain through the exterior finish and potentially compromise the WRB.

Eavestroughs

Directing bulk flows of water away from the walls and foundation of a house is an important step in minimizing water infiltration. Eavestroughs and gutters should be designed not to direct water into the walls of a house, and should drain far enough away from the foundation to prevent pooling of water. Finally, even the best designed eavestroughs are ineffective without regular maintenance to keep them clear of debris.

[0]

When eavestroughs are not maintained, they can clog. This leads to water leakage in heavy storms that can cause water to pool around walls.

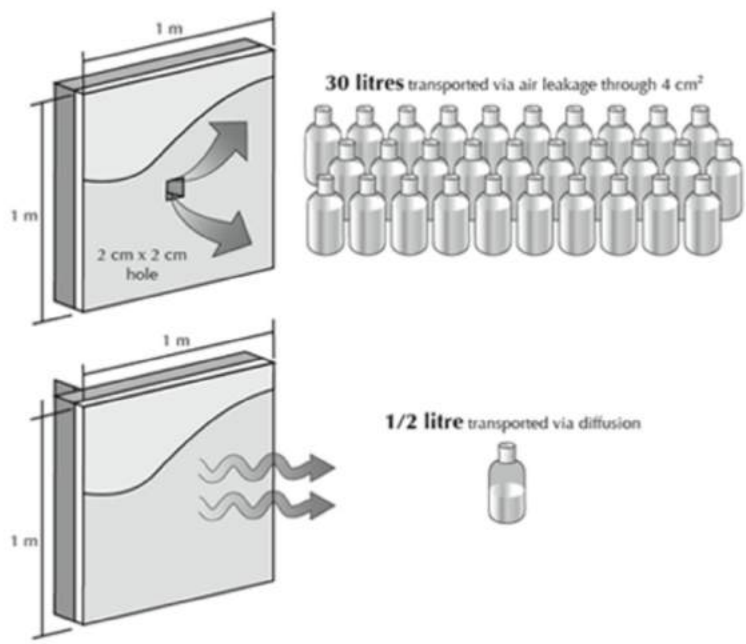
Key Considerations for Coastal Homes

Sealing and Weather Stripping

It is a common misconception that the majority of water infiltration is caused by diffusion of water vapour through the vapour barrier. US Department of Energy publications suggest that the vast majority of moisture infiltration in houses is caused by water vapour entering the building envelope via air leakage [30].

Water vapour is carried in air through gaps in the building envelope, especially around ducts, windows and doors, and where walls meet floors, roofs or foundations. As much as 30 times more water vapour enters a house through this pathway than through diffusion through the vapour barrier [10]. Therefore, it is of greater importance to ensure that air infiltration and leakage is minimized than to make the vapour barrier more impervious.

Air Leakage and Diffusion Over One Season



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Sealing air leaks around ducts, doors and other common locations of air infiltration has also been shown to lead to energy saving of as much as 10% in existing housing stock in the Kitasoo Nation [41].

Barriers

The vapour barrier used on the warm side of exterior walls in new home construction should be equivalent to 6-mm polyethylene sheeting [34]. Using a thicker or more impervious vapour barrier (10 or 15-mm) may not be necessary or cost-effective, as the majority of water vapour entering the building envelope is carried through air leaks, not through the vapour barrier [10].

Sealing leaks in the vapour barrier should be prioritized over using a more expensive vapour barrier.

The exterior walls should be covered on the outside with a water resistive barrier (WRB) such as Tyvek® HomeWrap, or with a foam insulation such as XPS that is impermeable [10]. Either of these methods can create an effective moisture barrier for the exterior walls, but rigid foam insulation has the benefit of increasing the overall R-value of the wall assembly. There are also combination products such as Tyvek® ThermaWrap, which is non-rigid and delivered in a roll similar to a membrane-type WRB, but is also insulated. ThermaWrap adds an R-value of 5 to the overall wall assembly [38].

Weatherproofing

Regardless of whether a membrane-type WRB or rigid foam insulation WRB is chosen, homes constructed for the coastal BC climate should include a rainscreen between the WRB and the siding or stucco (called *cladding*), which serves as the final exterior finish. Providing an air gap allows for wind-driven rain to drain out at the bottom of the wall rather than to directly contact the WRB. It is important to ensure that these rainscreens are well-drained at the bottom of the wall so as to not encourage pooling of water near the foundation [10].

The rainscreen can be achieved in several ways, however one effective method is to install furring strips on top of a standard WRB such as Tyvek® HomeWrap, and then to install cladding on top of this furring [42]. This method is already being used in new homes being constructed in the Nuxalk Nation [34].

Close attention to weatherproofing and limiting the ingress of air and water through the building envelope is the most important factor in the longevity of homes in marine climates. Provided that quality materials are used in construction, a house constructed in coastal BC that is highly weatherproof should last 50-80 years, which far exceeds the typical useful lifetime of existing homes in the region (which in Klemtu, for example, is as little as 15 years).

Performance Targets

Good: ENERGY STAR HOMES	**Better:** R-2000	**Best:** Certified Passive House Passive House Institute
Typical construction with 6-mm polyethylene vapour barrier and exterior WRB.	Home wrapped with high-quality WRB such as Tyvek® HomeWrap with furring to create rainscreen	Advanced WRB such as Tyvek® ThermaWrap or exterior foam insulation plus WRB and rainscreen
Weather stripping better than code requirements	Excellent weather stripping and caulking to minimize air infiltration	Air leaks almost eliminated, sealing, caulking and weather stripping throughout

Technology Comparison

Technology	Implementation	Cost	Advantages	Disadvantages	Best Practice for CFN?
Weather Resistive Barriers					
Flexible House Warp (e.g. HomeWrap)	Relatively standard and easy to install	~$0.15/ft^2	-Affordable and straightforward to install	-Does not insulate	✓
Insulated House Wrap (e.g. ThermaWrap)	Requires more care in installation to avoid damage	~$1.00/ft^2	-Acts as air and water barrier -Adds additional insulation to building envelope	-Very Expensive -May be difficult to source	✗
Rigid Foam	Requires precise installation to ensure no gaps	~0.50/ft^2	-Adds additional insulation	-Expensive	✓
Weatherproofing					
Barrier without rainscreen	Standard practice	No additional cost	-More affordable -Easier to install for some types of cladding	-May allow water to collect under cladding -Poor drainage	✗
Barrier with rainscreen	Requires the addition of furring underneath cladding	Flashing design, material and installation adds extra cost	-Much better deflection of water away from WRB -Adds to home longevity	-Extra cost -More time to install	✓
Enhanced vapour barrier	Same as for standard (6-mm poly) barrier	2 or more times as costly as 6-mm poly	-More impermeable to moisture -More durable	-More expensive -Benefits are limited	✗

Meeting Community Needs

Airtightness and weatherproofing are perhaps the most important issues to address in meeting community needs in the Coastal First Nations communities. A home built with an airtight building envelope dramatically reduces energy requirements and heating costs, but also addresses other key concerns.

An airtight building envelope does not allow outside air to infiltrate through walls, roofs and foundations. This is the single most important step to reducing mould and mildew growth in hidden areas where it is the most harmful to health. Less air leakage also results in a home that is less drafty and more comfortable.

Careful consideration should be made of when a home is “too airtight”, as this can lead to indoor air being perceived as stuffy or stale. Ideally, this issue should be addressed through the use of controlled ventilation of fresh air into the house rather than relying on opening windows and doors, as this allows cold and humid air to enter.

Weatherproofing is also a key consideration in the coastal BC climate. A properly weatherproofed home with rain screening, effective use of eaves and gutters, and coverings over key entryways can dramatically reduce the amount of water that enters the building. Reducing water leakage and pooling increases the lifespan of the house and further discourages the growth of mould and mildew.

Covered entryways can reduce the amount of water entering the home and make entering and exiting the building more comfortable.

[43]

Windows and Doors

U-Factors

U-factors are the *reciprocal* of R-values (U = 1/R), and are often used to describe the insulation value of windows and doors. A smaller U-factor means that less heat is transmitted through the window or door. U-factors for windows generally fall in the range from 0.5 to 3, in units of $W/m^2 \cdot K$. Note that Metric units are more common in Canada for U-factors, unlike R-values.

Windows

Window Insulation

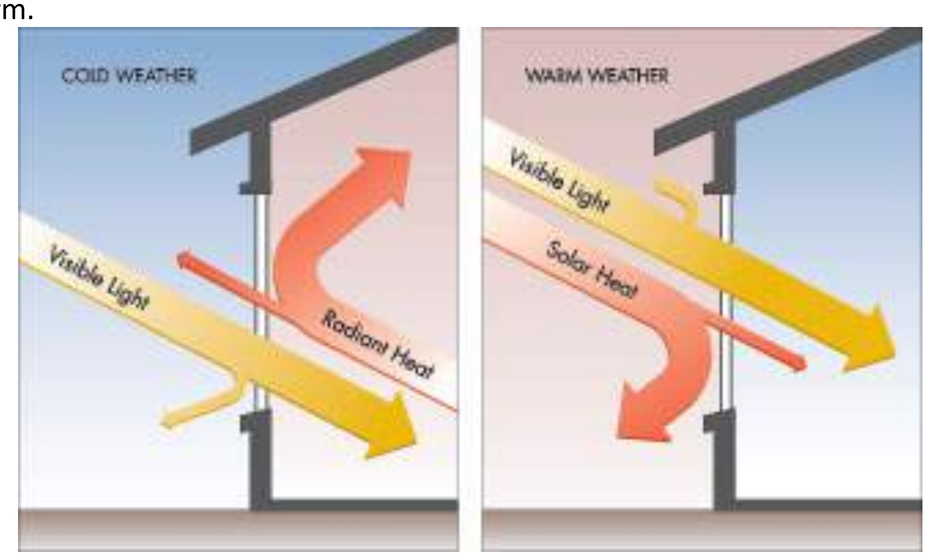
A window with a lower U-factor corresponds with less heat transfer and better performance. In addition to the U-factor, windows have other performance metrics. The solar heat gain coefficient (SHGC) is a measure of how much of the heat caused by sunlight is blocked by the window. A window may also have a special treatment called a *low-e* coating.

Panes

The insulating performance of a window (and ultimately its U-factor) is influenced by the number of panes the window is constructed from. Energy efficient windows are typically at least double-paned, with triple-paned windows becoming increasingly common. In a high performance window, the space between window panes is filled with a low heat transfer substance such as argon.

Low-e Glass

Many windows have a low-emissivity (low-e) coating, which is designed to serve two purposes. In warm weather, the low-e coating allows sunlight to pass through the window while reflecting solar heat back to the outside, keeping the house cool. In cold weather, the coating reflects radiant heat from the inside of the house, preventing this heat from escaping and keeping the house warm.



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Thermal Break

High-quality window frames are designed with a thermal break, meaning that the window frame is designed to not conduct heat between the inside and outside of the house. Since windows are usually the thinnest part of the building envelope and are not insulated in the way that walls are, a well-designed window frame is a complex structure that minimizes heat loss. [44]

Doors

Doors are an often-overlooked part of the building system, but there are a few things that can be done to minimize heat loss and air infiltration through them. In the design phase, it makes sense to place doors out of prevailing winds to avoid drafts and storm damage. Doors should also be selected to meet basic insulation standards (an ENERGY STAR® qualified door, for example, will have an appropriate insulation rating for the home's climate zone.) Finally, good weatherstripping is essential part of the door system and prevents both air and water from entering the inside of the house. Weatherstripping on doors requires regular inspection and maintenance in order to remain effective.

Doors can be constructed of wood, fiberglass or steel. Each material has advantages and disadvantages. Wood doors are more aesthetic, but are typically more expensive. Wood also does not insulate as well as other materials. Steel doors are usually the least expensive option, but may be less visually appealing. They insulate much better than wood doors. Fiberglass doors offer a compromise between wood and steel, as they appear similar to a wood door but have much superior insulation performance. [66]

Key Considerations for Coastal Homes

Windows

Windows in the coastal BC zone should meet ENERGY STAR® requirements at a minimum to ensure that energy efficiency gains in other areas are not lost due to poor-quality windows. The most efficient windows are triple-glazed and incorporate frames designed to minimize thermal bridging [3]. However, triple-glazed windows come with a cost premium and are available from fewer manufacturers. There are options for locally-sourced triple-glazed windows such as EuroLine Windows in Delta, BC. In the long run, the energy savings from installing triple-glazed windows may be worth the higher initial cost [35].

In an ideal case, windows installed in remote coastal communities should be of a small number of **standard sizes**. This allows for replacements to be kept on hand in a central location in the community, making the process much faster and cheaper. This is especially useful when triple-glazed panes are chosen, as the number of suppliers for these windows is limited and lead times may be unacceptably long if custom sizes need to be ordered.

Doors

Doors constructed of steel or fiberglass offer high performance and cost less than wood doors, making them an attractive choice for coastal BC homes. Wood doors also suffer the disadvantage of warping or rotting when exposed to moisture, a common problem in coastal BC. However, a wood door can be constructed of local materials such as cedar, which could be considered more sustainable.

Like windows, doors can be replaced much more easily and affordably if all types of doors (indoor and outdoor) in the community are the **same standard size,** and kept on hand.

Performance Targets

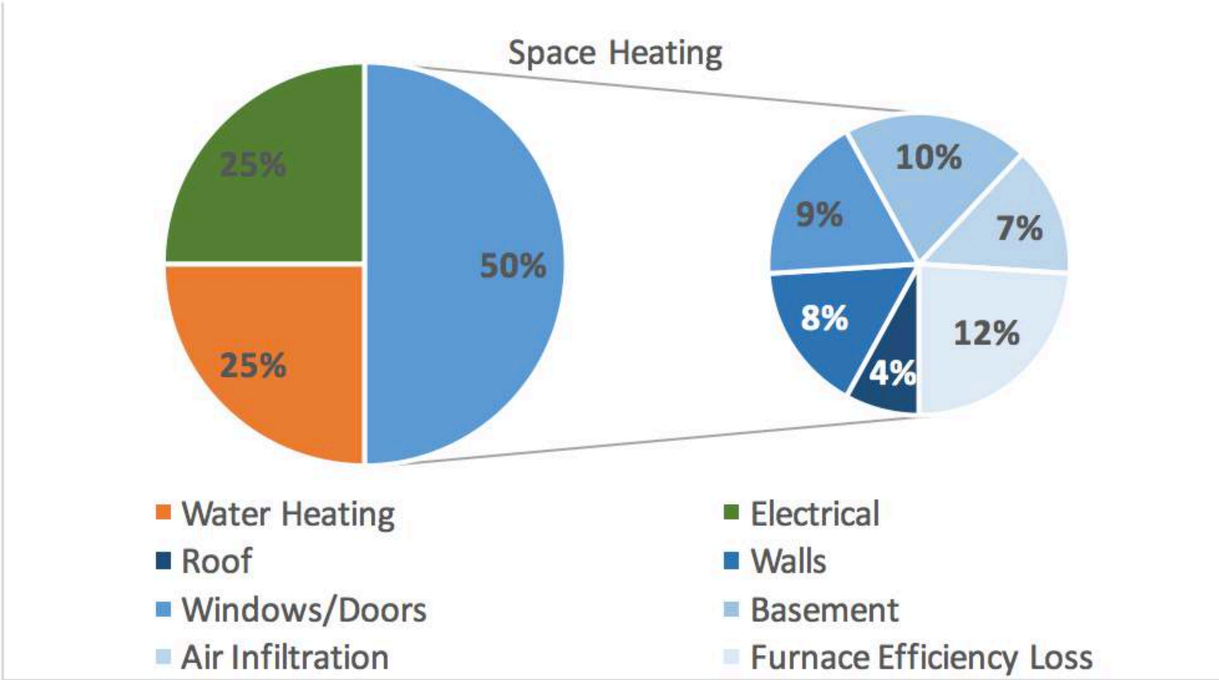
Good: ENERGY STAR HOMES	**Better:** R-2000	**Best:** Certified Passive House Passive House Institute
ENERGY STAR® certified windows and front door U<1.6 W/m^{2}K for windows (at least double-glazed) [45]	At least double-glazed, low-e coated, inert gas filled and with insulated spacer [46]	U<0.8 W/m^{2}K windows, typically triple-glazed and argon-filled with low-e coating [47]

Technology Comparison

Technology	**Implementation**	**Cost**	**Advantages**	**Disadvantages**	**Best Practice for CFN?**
Windows					
Double-glazed windows	Industry standard	No additional cost	-Affordable	-Poor energy performance	✗
Triple-glazed windows	No more difficult to install, but far fewer suppliers.	15% to 30% more expensive than double-glazed	-Far better energy performance -More durable	-More expensive -Harder to obtain	✓
Doors					
Wood	N/A	Highest cost; ~$500	-Visually appealing -Can be sourced locally	-Poor energy performance -Vulnerable to moisture	✗
Fiberglass	N/A	Moderate cost; ~$300	-Most energy efficient option -Long life	-More expensive than steel	✓
Steel	N/A	Lowest cost; ~$200	-Affordable -Energy efficient	-Not as visually appealing	✓

Heating and Cooling Sources

Space heating is, by far, the largest source of energy consumption in a coastal BC home.



Types of Heating and Cooling Sources

There are a number of different approaches to space heating and cooling utilized in existing homes in coastal BC. All of the available technologies have advantages and drawbacks, and the most appropriate choice of technology may vary from community to community and home to home. The goal of every system is to keep indoor temperatures stable at or around 21°C.

Forced Air Furnace

A forced air furnace relies on the distribution of warm air around the home by a central air handler. Air is usually heated by the combustion of natural gas or heating oil, or by an electric resistance element. Forced air heating systems are very common in many parts of Canada, especially in areas where natural gas distribution is available and affordable.

On the Central and North Coast of BC, forced air has some **major drawbacks**. Natural gas is not available in GBI communities, and diesel, propane, and electric furnaces are more expensive to operate compared to other heating options such as baseboard heaters. Forced air furnaces must be serviced and inspected once a year to ensure proper and safe operation. [0]

Forced air systems can be very efficient, transforming up to **90%** of the energy in heating oil into useful heat for the home. However, a furnace can never be more than 100% efficient, unlike advanced heating systems such as heat pumps [7].

Heat Pump

A heat pump is a device that moves heat from one location to another. Air conditioners, refrigerators and freezers all use heat pumps to move thermal energy out of a space, making it colder. A heat pump for space heating uses the same principles but operates in the reverse direction, moving thermal energy from the cooler outside air into the home.

A heat pump can use as much as 50% less electricity than a baseboard heater! [10]

The most important advantage of a heat pump is that it **moves heat** from one place to another, rather than creating this heat directly through combustion or electric resistance. A heat pump can therefore be <u>more</u> than 100% efficient when comparing input energy to output heat. In fact, modern heat pumps can provide 3 to 4 units of heat energy for every unit of input energy. Heat pumps **are by far the most energy efficient** home heating source available today.

Heat pumps can use **several mediums including air, water, or earth** to supply heat energy. The most common heat pump systems use energy in the outside air, or underground (geothermal) energy as a heat source. Heat pumps can also transfer their energy to inside air (like a furnace), or to water (for use in radiant heating).

Heat pumps suffer the disadvantage of being relatively expensive compared to other heat sources. However, in areas where fuel or electricity is expensive (such as remote communities in coastal BC), the **higher initial investment** of a heat pump will be paid off by **lower energy bills** much faster than in other areas. Heat pumps require regular maintenance, similarly to furnaces, and should be serviced at least once a year.

Electric Baseboard Heating

Electric baseboard heating is ubiquitous in many areas of British Columbia. It is an extremely simple form of space heating that utilizes electric current passing through a resistive element in order to produce heat. Baseboard heating has the advantage of being **very affordable to install**, as it is simple and requires no moving parts. **Maintenance of baseboard heaters is minimal**. [0]

Electric resistance heating converts all of its input energy to heat. It is therefore considered to be **100% efficient** as a heating source, making it more efficient than most furnaces. However, the relative costs of electricity, natural gas or heating oil must be compared to determine which choice is more cost effective. A baseboard heater cannot be more than 100% efficient, making it **inherently less efficient than a heat pump**. Baseboard heaters also **do not contribute to home ventilation** in the way that a forced air furnace or air-to-air heat pump does, because they do not move air around.

Wood or Pellet Stove

Efficient and affordable biomass stoves, using raw wood or wood pellets as fuel, are popular in some homes in British Columbia. Pellet stoves are a relatively new player in the market, and have many advantages over traditional wood stoves. They are easier to operate, and utilize hoppers that can be filled only once per day. [0]

Space Heaters

Electric space heaters are commonly used to supplement inadequate central heating in cold areas of a home. When sized and operated correctly, space heaters can be a relatively efficient way to complement an existing heating system, but there are many pitfalls with space heaters. They are sometimes used to supplement an already adequate central heating system which is not operating as it should due to poor maintenance, air leakage in the home, or improper operation. In these cases, space heaters add to the heating load and **could be avoided altogether** by addressing issues with the primary heating system. Space heaters also pose **safety issues** and can cause burns and fires if not used with care. [0]

Radiant Heating

Underfloor heating is often referred to as *radiant heating*, and takes two forms: **electric and hydronic.** Electric radiant heating is achieved by placing electric resistance elements under the floor, whereas hydronic heating relies on hot water flowing in pipes embedded in the floor.

In both cases, the floor is usually constructed of concrete. This is partly due to the ease with which the heating elements can be sealed into a poured concrete slab, but more importantly, concrete acts an an effective **thermal mass** that can absorb and slowly release the radiant heat, keeping temperatures inside the house consistent and comfortable.

 [0]

An advantage of hydronic heating systems is that they can **also be used for cooling,** by running cold water through the underfloor piping when desired.

Air Conditioners

Air conditioners are an effective and efficient means of space cooling, and operate in much the same way as heat pumps. For every unit of input energy, an air conditioner can remove 3 to 4 units of heat energy from a house. However, air conditioners are often improperly operated, leading to poor energy efficiency and performance. It is important that windows and doors be closed when operating an air conditioner, so that the heat removed from the space is not replaced by warm air entering the home.

Air conditioners also require regular maintenance, and condenser coils need to be kept clean to prevent failure. Air conditioner condensers also collect moisture, or *condensate*, which needs to be drained properly.

Key Considerations for Coastal Homes

Heat Pumps

Air source heat pumps are theoretically an excellent choice for the relatively mild climate of coastal BC. Air source heat pumps typically lose efficiency at temperatures below freezing, making them less cost effective than electric baseboard heating in some colder jurisdictions such as the Yukon [35]. However, in the Great Bear Initiative communities these sustained cold temperatures are not observed, and a heat pump is the most thermodynamically efficient heat source [48]. Developers of energy efficient housing for First Nations communities in BC often choose **air source heat pumps** as they are typically less expensive than ground source heat pumps [49].

Ground source heat pumps are theoretically more energy efficient than air source heat pumps, and the do not suffer the drawbacks of lost performance at lower outside temperatures. This is because the heat pump loops are installed several feet underground, where temperatures remain relatively constant throughout the year. However, ground source heat pumps are more expensive to install than air source heat pumps. The most appropriate choice of heat pump depends on local site characteristics and community budgets.

Heat pumps have benefits beyond the provision of thermal comfort as well. A heat pump, especially one with a multi-head or mini split design, provides additional ventilation to the home. The Skidegate Band Council is currently in the process of retrofitting 350 homes with heat pumps, and tenants have reported fewer issues with mold and increased thermal comfort as a result of the warm air circulation and ventilation that a heat pump provides. This was achieved at a cost of approximately $5200/unit [50].

Radiant Heat

In cases where an air-to-air heat pump is not an appropriate or economically feasible option, radiant floor heating has some advantages, and is currently utilized in new home construction in the Nuxalk Nation [51]. Radiant heating is relatively easy to install in new construction, especially when building with a slab on grade design. A heated slab can still serve as an effective thermal mass, and may be more comfortable underfoot than an unheated slab, depending on the amount of insulation under the slab [52].

A more energy-efficient option than electric or fossil fuel-fired hydronic radiant heating is, once again, to utilize a heat pump. In this case, an air-to-water heat pump can be used to preheat water which is then circulated in a radiant floor heating system under a concrete slab. Domestic hot water is provided by passing the preheated water from the heat pump through an electric hot water heater [23]. Such systems are usually relatively expensive to install.

Passive House Heating

Constructing to a stringent standard such as Passive House typically does away with the need for a central heating source altogether – with the necessary heat coming from a small heat pump or heating element. However, in order for this small heat source to provide adequate thermal comfort, a home built to Passive House standard must be operated and maintained as intended. This could be a potential issue in remote coastal communities where **maintenance is costly**.

Advanced Control Systems

Recent advances in home control systems can reduce energy consumption and **simplify operation**. Learning thermostats, such as the Nest, are advanced devices that interact with sensors in the home as well as an occupant's mobile phone. Such devices require a few hundred dollars of initial investment, but often pay off quickly in energy savings. These thermostats can also automatically control multiple heat sources, such as a forced air heat pump with electric baseboard heating as a backup. In this case the thermostat will only activate the backup heat source when necessary and keep it locked out when it is not.

A learning thermostat can determine when occupants are away from the home, and can also learn how the home is used. For example, a learning thermostat will **automatically adjust** the temperature to be cooler at night, and to warm the home before occupants wake up. A learning thermostat can also be adjusted remotely from a mobile device, and tracks energy usage over time, allowing energy consumption trends to be monitored.

Community Constraints

The most appropriate heating source for the GBI communities may vary from community to community, due to differences in energy supply and local constraints. For example, the community of Kitasoo relies on a hydroelectric plant for electricity that is operating at full capacity. Electricity demand from inefficient space heaters must be reduced before additional highly efficient electric air-source heat pumps are introduced into new homes. In cases like this, even **small increases in electrical efficiency may be highly beneficial** to the community.

By contrast, in the Nuxalk community of Bella Coola, the supply of electricity is not constrained as it is served by the BC Hydro grid. In this community, electric radiant heating is being used in combination with slab on grade foundations. This is a good choice in the context of this community, where electricity is relatively affordable and local capacity exists to install these heating systems. The end result is a system that **requires less maintenance**, and can be operated at relatively low cost and environmental impact.

In general, electric-driven appliances are more environmentally friendly than those which operate on fossil fuels, however this relationship is not as straightforward in remote communities that are not part of a centralized electricity grid. For example, the entire power grid of Haida Gwaii, as well as several remote Central Coast communities, are supplied by diesel generators. In these cases, it is not necessarily more environmentally advantageous to use electricity rather than fossil fuels in the home.

Utilizing electricity from diesel-fired generators has the advantage of keeping air pollution and fuel contamination impacts in a central location, rather than dispersing them throughout individual homes. In the future, as diesel generation is increasingly replaced by clean energy sources such as wind, solar and hydropower, **electric appliances and heating sources will become more preferable** in general.

Heating from other sources, such as wood pellet stoves, may also be appropriate for communities that have access to pellet fuels, especially those that may be in close proximity to wood processing facilities. This would enable communities to utilize local materials while still providing energy-efficient heating to homes. However, many communities have expressed a desire to not rely on biomass fuels for heating, as these sources require some **manual labour** to operate and therefore may not be appropriate for elders or disabled persons. The most appropriate heating source is highly dependent on the individual circumstances and desired of each community **and should be considered on a case-by-case basis.**

Performance Targets

Good:	**Better:**	**Best:**
Electric baseboard heating, forced air furnace or radiant floor heating	Air source heat pump with single or multiple heads and electric baseboard heating in bedrooms as necessary, or heat pump fed radiant heat	Very small heat pump or heating element integrated into HRV, used on very cold days
>100 kWh/m^2/yr heating load	~55 kWh/m^2/yr heating load [7]	<15 kWh/m^2/yr heating load [47]

Technology Comparison

Technology	**Implementation**	**Cost**	**Advantages**	**Disadvantages**	**Best Practice for CFN?**
Heating Sources					
Fossil Fuel Forced Air	Requires installation by qualified person	-~$4000 installed [73] -High fuel cost	-Improves home airflow	-Often uses fossil fuels -Complex installation -Requires maintenance	✗
Electric Air Source Heat Pump	Requires installation by qualified person	-~$5000 installed [50] -**Lower** operating cost	-Improves home airflow -Very energy efficient option	-More expensive -Requires maintenance	✓
Ground Source (Geothermal) Heat Pump	Requires excavation for installation of ground loops	-$10,000+ installed [74] -**Lowest** operating cost	-Most energy efficient option	-Most expensive -Requires maintenance	✓
Electric or Hydronic Radiant Heating	Requires installation by qualified person at time of construction	-$4000-$8000 installed [75] -**Higher** operating cost	-Makes floors comfortable -Easily combined with slab on grade foundation	-Must be installed during construction -More expensive	✓
Electric Baseboard Heating	Very easy to install, does not require any ductwork	-<$1000 [38] -**Highest** operating cost	-Affordable -Easy to install -Easy to maintain	-Uneven heating -No airflow improvement	✗

Wood or Pellet Stoves	Requires a source of biomass fuel, and adequate ventilation to ensure safety	-~$4000 installed [76] -Low cost option if fuel can be sourced affordably	-Uses locally sourced fuels	-Requires manual labour to operate	✓/✗
Electric Space Heaters	Used to supplement existing heating system, portable	-~$100 [38] -High operating costs	-Flexible	-Expensive -Dangerous	✗
Advanced Thermostats	Can be installed easily, may require Wi-Fi connection	-Small price premium (~$250)	-Dynamically adjusts heat -Saves energy -Remote operation	-Somewhat more expensive -Initial setup more complex	✓

Meeting Community Needs

Heating and cooling is a key component of comfort and should be carefully considered in the context of community needs. Heating sources such as baseboard heaters are affordable, but heat the home unevenly and may not warm the entire home. This sometimes leads to the use of space heaters, which consume extra energy and carry **safety risks** for occupants.

The use of a heating source such as a heat pump or forced air furnace warms the home more evenly and promotes good airflow. This makes the home more comfortable and also reduces mould growth. However, forced air and air source heat pump heating can sometimes reduce the humidity in a home, leading to indoor air feeling too dry.

Radiant underfloor heating has the advantage of making floors more comfortable underfoot, as the entire floor is kept warm. It also requires significantly less maintenance, which is an advantage for some occupants and particularly elders. By contrast, a heating source such as a wood pellet stove requires daily refilling and lifting of fuel bags, which may not be appropriate for many homes, **especially the homes of elders**.

Programmable learning thermostats can greatly simplify the operation of heating systems and can automate processes such as backup heating systems. This has the advantage of providing supplemental heat to the home when it is necessary on the coldest days, when temperatures drop below a preset level. Programmable thermostats could potentially allow for the displacement of plug-in electric space heaters which are currently used as backup heating sources. This has advantages for occupant **safety and comfort**, and makes the house easier to operate.

Ventilation

Natural Ventilation

Homes have historically relied on *natural ventilation* to provide adequate airflow. Natural ventilation allows air to enter the house through cracks, holes and openings in the building envelope. Another way of describing natural ventilation is that it uses **air leakage** as the primary source of fresh air inside the home. The main drivers of natural ventilation are the *stack effect*, which causes warm air to rise and draw in cool air from below, and the *wind effect*, in which air pressure from wind forces air through gaps in the building envelope.

There are several problems with natural ventilation in the context of modern home building. Natural ventilation is difficult to control, and may increase or decrease with changing outside conditions. A house that relies on natural ventilation is necessarily **leaky**, which means that it will have poor energy performance, requiring **more energy and money to operate.**

Modern homes are built to have tighter building envelopes, which reduces the flow of air from natural ventilation to the point where it does not provide adequate ventilation. In almost all new home applications, **mechanical ventilation is required**, both to ensure adequate fresh air for comfort and air quality, and to reduce the amount of energy required to heat and cool the home.

Mechanical Ventilation

Mechanical ventilation uses a controlled, artificial means to control airflow through the home. A mechanical ventilation system may be as simple as a fan exhausting air to the outside, or it may take a more complex form such as a heat recovery ventilator (HRV) or energy recovery ventilator (ERV) system.

A **heat recovery ventilator** is an effective form of mechanical ventilation that provides fresh air to the home, but also captures waste heat, **reducing heating bills.**

[40]

Modern homes meeting the BC building code are generally **required** to have a mechanical ventilation system that is designed for continuous operation. Previously, an exhaust-only ventilation fan was considered acceptable, and relied on air infiltration from leaky building envelope design to provide fresh air. As of the 2014 energy efficiency revisions to the 2012 Code, this is no longer considered an acceptable means of ventilation [53]. There are several ways to meet the new requirements:

- A principal exhaust ventilation fan, with fresh air provided from the inlet of a central forced air furnace. The exhaust fan and furnace are interlocked.
- A passive heat recovery ventilator (HRV) is installed, with a central forced air furnace blower fan providing continuous air pressure
- An active HRV is employed as a primary stand-alone ventilation device, with heating provided by a separate system (forced air, radiant heat, heat pump, baseboard heating or other)
- An exhaust fan and air distribution fan (air mixing fan) are installed separately from the heating system

The inclusion of an HRV unit significantly reduces the heating load by preheating incoming fresh air with the heat from stale exhaust air.

Key Considerations for Coastal Homes

Heat Recovery Ventilation

A home constructed in the damp coastal BC environment should not rely on infiltration of outside air for proper ventilation. As discussed above, outside air infiltrating into the building carries a large amount of water vapour, contributing to mould and other issues. Proper ventilation levels should be achieved through the use of a forced air or heat pump system, mechanical ventilation system, or ideally both [10].

HRVs are typically the most appropriate choice for coastal BC applications of mechanical ventilation as compared with ERVs. However, previous experience with HRVs have led to some issues with inside air becoming too dry for comfort. An ERV, usually considered for regions with low humidity, retains some of the humidity inside the house while still capturing the waste heat from exhaust air. Humidity in the home should generally be kept within the range of 30-40%.

The use of an ERV may lead to excessive humidity in winter, leading to issues with condensation and even mould. In these cases, it may be preferable to install an HRV that can be turned off, allowing windows to be opened for ventilation. This, however, has the downside of leading to higher energy consumption and moisture infiltration from outside air.

If a home is constructed to a very high-performance standard such as Passive House, care should be taken that minimum ventilation requirements are met to prevent inside air from becoming stale and “stuffy”. In the marine climate and in accordance with building codes, homes should aim to have 0.5 air changes per hour (ACPH) at a minimum [35].

Mould Control
Natural ventilation, exhaust-only ventilation and energy recovery (ERV) ventilation all share the problem of introducing **humid air** into the home. In the case where this air is drawn through the building envelope (such as in natural ventilation), humidity can be introduced where it is most harmful, i.e. in the walls, foundations and roof. The passage of humid air through these building components deposits large amounts of moisture, leading to ideal conditions for mould growth.

The building envelope is usually quite inaccessible. For example, insulation is usually hidden beneath drywall and finished surfaces. This can lead to mould growing without being noticed inside walls, ceilings, basements or crawlspaces, causing persistent air quality and health issues.

The best way to minimize mould growth is to minimize the flow of humid air through the building envelope. This is achieved in two ways: by making the house more airtight through the use of air barriers and extensive sealing, and by relying on mechanical rather than natural ventilation. In an ideal case, mechanical ventilation should be highly controlled, with fresh air entering the house through a contained ventilation system such as an HRV.

Ducts
Duct holes should all be sealed with spray foam where they pass from unconditioned to conditioned spaces. Ideally, ducts should be centrally routed and pass through conditioned spaces wherever possible. This method reduces energy losses from passing heated air through unheated spaces, and also reduces the need to insulate ducts. Moving ducts into conditioned spaces can result in energy saving of >1000 kWh/year. [10] Designing one central "utility wall" which houses all major ducts and utilities can further reduce energy losses [10, 23].

Performance Targets

Good: ENERGY STAR HOMES	**Better:** R-2000	**Best:** Certified Passive House Passive House Institute
2.5 Air Changes Per Hour [45]	1.5 Air Changes Per Hour [46]	0.6 Air Changes Per Hour [47]
60% HRV Efficiency	>60% HRV Efficiency	>75% HRV Efficiency
Duct take-offs and joints sealed and insulated where required	Ducts carrying conditioned air through unconditioned spaces are insulated	Ducts routed centrally or in utility walls, typically through conditioned spaces to minimize heat loss

Technology Comparison

Technology	Implementation	Cost	Advantages	Disadvantages	Best Practice for CFN?
Ventilation					
Natural Ventilation	Relies on gaps and leaks in the building envelope to provide ventilation	No extra cost	-No mechanical systems (fans) -No maintenance	-Very energy inefficient -Does not conform to modern code -Promotes mould growth -Makes homes cold and drafty	✘
Fan-only Mechanical Ventilation	Uses an exhaust fan combined with intake mixing fan or furnace fan interlock	<$1000 extra cost	-Provides additional airflow -Standard building approach	-Introduces humid and cold air -Not energy efficient	✓
Heat Recovery Ventilator (HRV)	Requires special installation and ductwork; captures heat from exhaust air	$1000-$2000 additional cost [38]	-Provides additional airflow -Discourages mould growth -Energy efficient	-Expensive -Can make air dry -Regular maintenance is essential	✓
Energy Recovery Ventilator (ERV)	Captures heat and humidity from exhaust air	Similar to HRV	-Provides additional airflow -Keeps the home humid in cold weather Energy efficient	-May cause excess humidity summer -Expensive -Regular maintenance is essential	✘

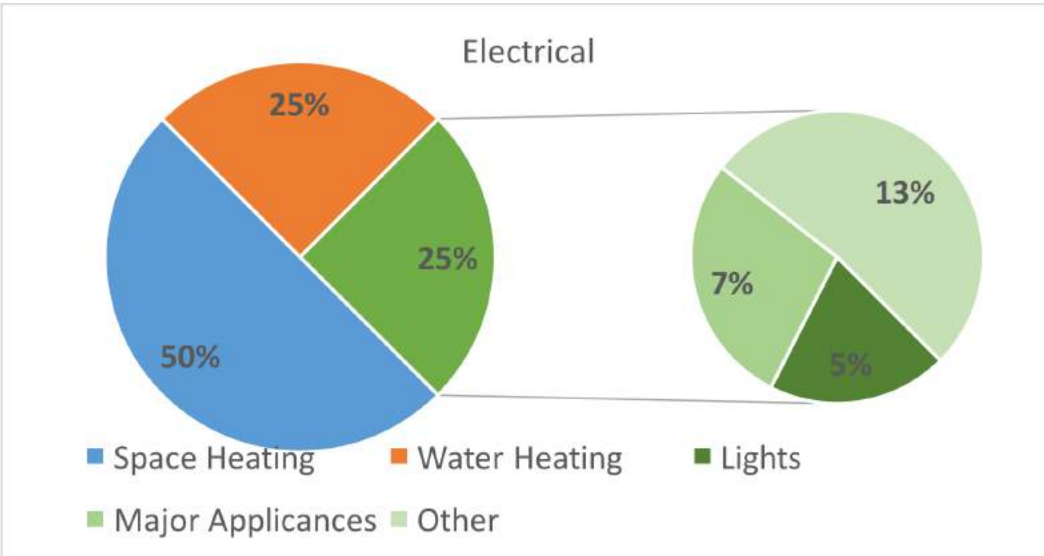
Meeting Community Needs

Ventilation can have a significant impact on the comfort of a home. Uncontrolled natural ventilation can lead to cold and drafty interiors, yet mechanical ventilation has some drawbacks as well. A mechanical ventilation system that captures heat such as a HRV saves energy, but can dehumidify a home, leading to air that feels too dry. Mechanical ventilation that uses outdoor air but does not capture heat can address this issue, but leads to higher heating costs. A careful balance must be struck that meets both the comfort and affordability needs of the community.

Mechanical ventilation increases the airflow in the home, which reduces issues with mould and mildew. It also helps to reduce condensation from steam on windows and walls, which can make activities such as cooking and canning more comfortable.

Water Heating and Electrical Loads

Water heating and electrical loads together account for around 50% of home energy use. In coastal BC, this energy demand is split more or less equally between water heating loads and electrical loads including lighting, major appliances, and minor appliances including computers, TVs and cellular phone chargers. Water heating can be provided either using electricity or using fossil fuels such as natural gas.



Lighting

Lighting is a relatively small part of a home's overall energy consumption. In most homes, lighting accounts for only 5% of the total home energy flow. Nevertheless, modern technologies allow much of this energy consumption to be eliminated, while reducing the maintenance required for changing bulbs over the lifetime of the house.

LED

Light emitting diode (LED) lighting is quickly becoming the industry standard in new construction, and the LED market is growing by as much as 25% every year [54]. LEDs have a vastly longer lifespan than any other type of home lighting source, and also consume far less energy. Though they have a higher initial cost, over the lifetime of the house LEDs are now the cheapest type of lighting due to energy savings. [0]

CFL

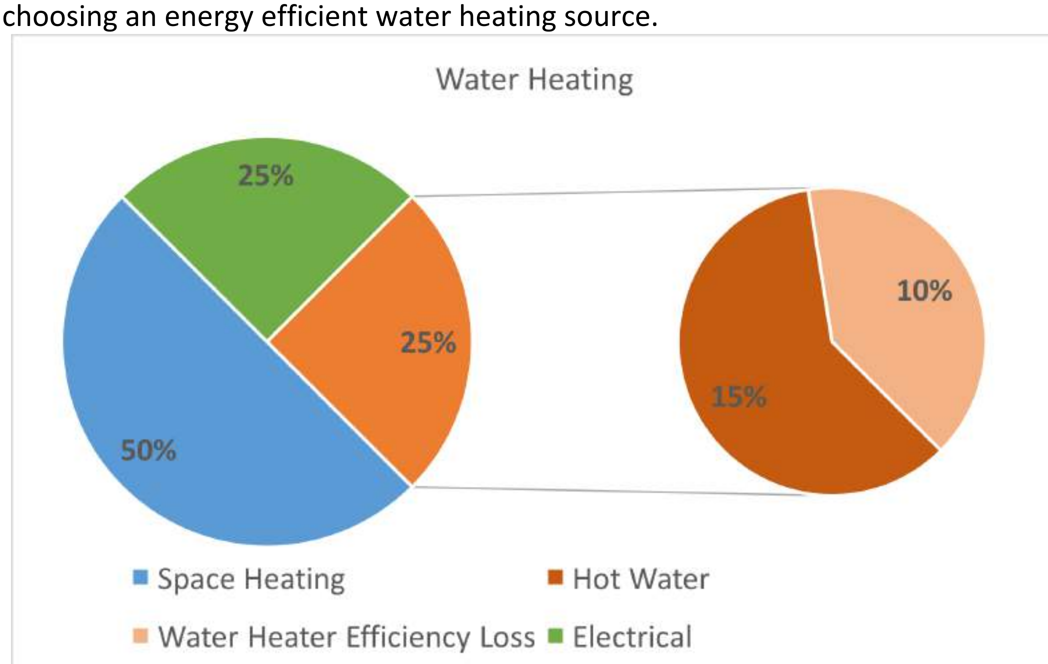
Compact fluorescent lamps (CFLs) started to become popular in the late 1990s as an alternative to incandescent bulbs. They are cheaper and more available than LED bulbs, but use slightly more energy. CFLs have some other disadvantages as compared to LEDs. They do not turn on instantly like incandescent or LED bulbs, requiring a fraction of a second to warm up first. CFLs also contain mercury which can be released if the bulb is broken. As a result, they should not be disposed of with regular household garbage. [0]

Incandescent

Incandescent bulbs are very inefficient at converting electricity into light. Around 98% of the energy used in an incandescent bulb is released as heat. As a result, an incandescent bulb consumes far more energy than a CFL or LED bulb. In well-insulated houses, however, the waste heat from an incandescent bulb can actually serve to warm the inside air, reducing the demand on space heating sources. This fact is often overlooked when comparing the overall energy efficiency of lighting sources, but does not necessarily mean that incandescent bulbs are superior to other technologies. [0]

Water Heating

Water heating is the largest contributor to home energy use after space heating, and accounts for around 25% of energy consumption. There are major opportunities to improve home energy use by choosing an energy efficient water heating source.



Storage-Type Water Heaters

Storage water heaters include a tank for storing hot water, and are the most familiar and common type of water heater seen in homes. They have the advantage of keeping hot water available at all times, which can be delivered instantly to a faucet or fixture. They are also the **most affordable** type of water heater. Storage water heaters can run on natural gas or electricity [55]. [0]

On-Demand Water Heaters

On-demand (*tankless*) water heaters do not have a storage tank, but heat water as it is required as it passes through the heater. Tankless water heaters use **much less energy** because they heat water only when it is required and do not need to keep a large volume of water hot. However, the lack of water storage means that there can be a **delay** between turning on a hot water tap and hot water arriving, as the heater needs some time to turn on and begin heating water.

Tankless water heaters can also run on electricity or natural gas, though electric tankless heaters can require a large amount of power and are not always practical. Tankless water heaters are also **more expensive** than storage-type water heaters [55].

Solar Thermal and Heat Pump Water Heaters

Several innovative energy efficiency technologies can reduce the amount of energy used for water heating in a house. In a ***solar thermal*** hot water system, cold water is passed through a solar collector, often on the roof of the house, where it absorbs heat energy from the sun. This preheated water is then further heated in a storage-type or on-demand system. Solar thermal preheating can reduce the energy required for water heating by over 50%.

Air source-to-water or ground source-to-water **heat pumps** can also be used to preheat domestic hot water. In the same way that a heat pump can efficiently transfer energy to the air used to heat a home, it can also transfer this energy to water. In some cases, a water heat pump can be combined with radiant heating and a small water heater, completely meeting the space heating and water heating requirements of the home [28].

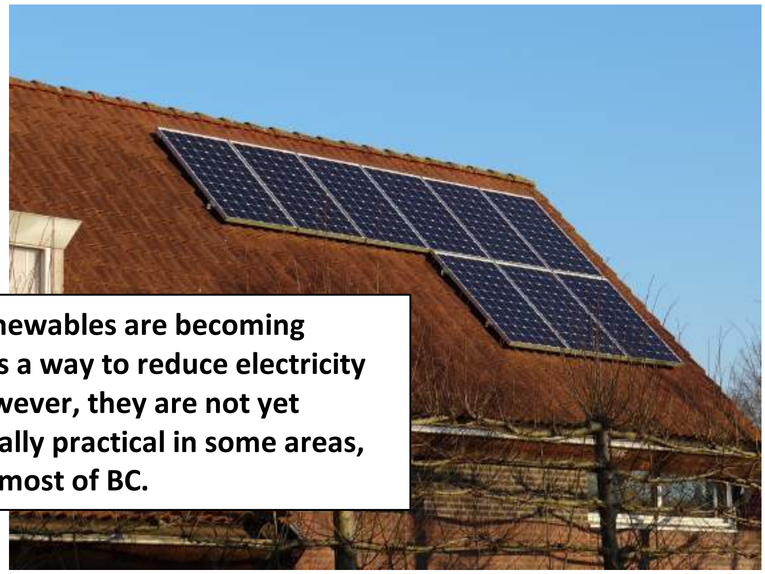
Appliances

A good way to simplify the choice of energy efficient appliances is to look for those that are certified under the ENERGY STAR® program. These appliances are identified as being in the top 15% to 30% of products in their class for energy consumption. Major appliances including washers, dryers and dishwashers consume more energy than small appliances, so making energy efficient choices for these appliances is more beneficial.

ENERGY STAR HIGH EFFICIENCY HAUTE EFFICACITÉ

Onsite Renewables

Although not a major focus of this study, the addition of onsite renewable electricity generation (e.g. from solar PV panels or a small wind turbine) can reduce or offset the electrical energy demand of a home. These systems are growing in popularity as prices decline and interest in reducing reliance on grid electricity grows. However, certain climates are not suited to such systems and the economics of installing a solar PV or wind system can be unfavourable.



Onsite renewables are becoming popular as a way to reduce electricity costs. However, they are not yet economically practical in some areas, including most of BC.

[0]

Key Considerations for Coastal Homes

Lighting

LED lighting is increasingly accepted as the new standard in interior lighting. Newer LED fixtures are more cost effective and have longer lifetimes than previous generations of fixtures, and are favoured by many energy efficient home builders [27]. While CFL bulbs have been used for years as a good replacement for incandescent bulbs, major manufacturers such as GE are now phasing out the manufacture of these bulbs in order to focus on LED products [56]. CFL bulbs are also not recommended as they **contain mercury,** a major issue for communities such as Wuikinuxv that manage their own waste disposal.

While LED fixtures carry a higher initial cost, they are cheaper to operate and need replacement far less frequently. Over the lifetime of the home, LED lighting is the **most cost-effective** as well as the most advanced and environmentally friendly choice.

Water Heating

Although tankless water heaters are up to 25% more energy efficient than storage water heaters, they are **not necessarily an economical option**. Tankless water heaters can cost several times more than a traditional water heater, meaning that the energy savings may not pay off for many years. In some cases, the investment may not pay off at all if it takes longer to pay off the extra cost than the expected lifespan of the water heater [55].

A CMHC study on tankless water heaters showed that the combination of increased energy efficiency and decreased waste energy reduced hot water energy consumption by almost half in many Canadian homes. However, many homeowners experienced issues with the delay between turning on a tap and receiving hot water, and the higher cost of the tankless units was a common complaint. The availability of "endless" hot water in a tankless system also caused some households to ***increase* their hot water consumption** as compared to a storage heater [57]. This could create issues in communities that will experience greater pressure on water sources in the future due to climate change.

A simpler and more cost-effective way to reduce water heating loads without compromising performance is to install a **drain water heat recovery system**. These are typically installed on shower drains and can reclaim **around 40%** of the otherwise wasted water heating energy [35]. Other methods for reducing water heating loads include using a central manifold for hot water distribution, and insulating hot water lines to at least R4 [10].

A **drain water heat recovery** system absorbs heat from hot water running down a shower drain and uses it to preheat water entering the heater.

It can reduce home energy use by 10%, or water heating energy by 40%! [38]

Solar thermal systems can take advantage of energy from the sun when a collection system is installed on rooftops. However, solar preheat systems suffer from the same disadvantages as solar PV systems in the coastal BC climate. The high latitudes and relative lack of sunny days in this region make solar systems **expensive to install and operate**, as they carry a high initial cost and take many years to pay back in energy savings.

Air-to-water and ground-to-water heat pumps suffer from the same disadvantage as solar thermal systems; they are very expensive to install and the cost savings take many years to pay off at current electricity prices. This type of heat pump presents a promising **vision for the future** of home heating, as they can be used for both water heating and hydronic space heating. They can therefore extract the energy needed for both space heating and water heating in a very energy-efficient manner, while using electricity as an energy source.

Onsite Renewables

Unfortunately, both solar PV and small-scale wind suffer from major drawbacks in Coastal BC [67]. Small wind turbines are usually quite expensive to install, and require careful maintenance in order to reach their expected design life of around 20 years [68]. They also require a good site with relatively strong winds throughout the year. The Central and North coast of BC is often windy, but these winds tend to be intermittent and many communities are relatively sheltered from steady ocean winds. Furthermore, at typical BC electricity prices, the payback period of a small wind turbine is longer than the 20-year lifespan of the equipment. This means that a small wind turbine in BC **may never pay off its initial cost in energy savings** [69].

Although solar PV panel prices have dropped dramatically in recent years, a similar problem exists with solar PV installations on BC homes. The high latitudes and relatively cloudy climate of BC lead to low levels of solar radiation, particularly in winter. The relative lack of sunlight in coastal BC means that energy yields from solar installations are low. Solar PV typically has a higher return on investment than small-scale wind, however, at BC electricity prices a rooftop solar PV system still takes 20-25 years for energy savings to pay off the initial investment. Solar PV panels have a useful lifespan of around 25 years [70].

Due to the long payback periods and lack of return on investment, **onsite renewables are not currently recommended** for a cost-optimized house system in coastal BC. However, steps can be taken to make homes ready for onsite renewables in the future when efficiencies and prices improve. For example, a central utility wall can be designed such that a conduit space exists running from the roof down to the main electrical panel. Such a design would reduce the cost of installing a solar PV system in the future.

Performance Targets

Good: ENERGY STAR HOMES	**Better:** R-2000	**Best:** Certified Passive House, Passive House Institute
ENERGY STAR® certified appliances or lighting leading to at least 400kWh/year of electricity savings.	Extensive use of efficient appliances including ENERGY STAR® certified products.	Total electricity use excluding space heating not to exceed 105 kWh/m^2/year
Mix of incandescent and CFL lighting is possible	Typically mostly CFL lighting with some LED	Moving towards all-LED lighting
Water Use: 4.8 L/flush, 9.5L/min shower, 8.3 L/min faucet [45]	Water Use: 4.8 L/flush, 7.6 L/min shower, 5.7 L/min faucet [46]	As good or better water use than R-2000 standard. Drain heat recovery may be incorporated.

Technology Comparison

Technology	Implementation	Cost	Advantages	Disadvantages	Best Practice for CFN?
Lighting					
Incandescent	Standard methods. Bulbs difficult to find.	Lowest bulb cost, highest operating cost. **5-year cost ~$44/bulb** [77]	-Natural light spectrum -Inexpensive	-Very inefficient -Increasingly difficult to obtain -Short bulb life	✘
CFL	Standard methods	Bulbs cheaper than LED, operating cost slightly higher. **5-year cost ~$10/bulb** [77]	-Affordable and readily available -More energy efficient than incandescent	-Less natural colour spectrum -Contains mercury -Time delay when turning on	✘
LED	Standard methods	Highest bulb cost, lowest operating cost. **5-year cost ~$9.50/bulb** [77]	-Extremely long bulb life -Newer fixtures less likely to fail	-Higher initial cost	✓
Water Heating					
Storage Water Heater	Simple installation, gas units require pipefitting	$700-$1000 [38]	-Hot water instantly available -Affordable	-Less energy efficient	✓
On-Demand Water Heater	Requires installation of several units, or one larger unit for while house. Electric units may require special wiring	$1000-$3000; some energy cost savings compared to storage [38]	-Energy savings -Hot water can last "indefinitely"	-Takes a short amount of time to turn on -Gas models are expensive -Energy savings may take years to pay off	✘
Drain Water Heat Recovery	Captures up to 40% of wasted heat from shower drain, easy installation	$500-$1000; significant energy cost savings [38]	-Energy savings -Easy to implement	-High initial cost	✓

Solar Thermal Water Heating	Requires installation of collector tubing on a sunlight-exposed rooftop	$5000-$6000	-Energy savings -Can be combined with radiant heating	-Must be combined with another heating source -Expensive	✗
Air-to-Water Heat Pump Water Heating	Requires specialized installation and regular maintenance	$5,000-$30,000 installed [38]	-Energy savings -Can be combined with radiant heating	-Very expensive -Requires more maintenance	✗
Appliances					
ENERGY STAR® certified major appliances	No special requirements	$50-$200 per appliance, payback period usually <3 years [71]	-Energy savings	-Slightly more expensive	✓
Onsite Renewables					
Solar PV or Small Wind	Requires complex installation	$3000-$10,000 for solar PV, $20,000+ for wind; payback period 20-25 years [69]	-Energy savings -Reduced grid reliance	-Expensive -Payback period often longer than life of technology	✗

Meeting Community Needs

Lighting is an important component of making a home feel livable and usable. Daylighting, which maximizes the use of natural sunlight, can lead to spaces appearing open and comfortable. Exposure to natural light also has positive health impacts, including improving the quality of sleep [58].

An example of natural daylighting from large windows in a Clayoquot Sound First Nations home [4].

Artificial lighting is also a necessary component of a modern house, and can be provided by a mix of incandescent, CFL, or LED lighting. CFL lighting, like other types of fluorescent lighting, is sometimes perceived as being harsh, whereas incandescent and LED lighting can appear more similar to natural light. This is because the colour spectrum of fluorescent light is concentrated in a few “spikes” of colour, whereas incandescent light and modern LED fixtures produce a “smoother” colour spectrum.

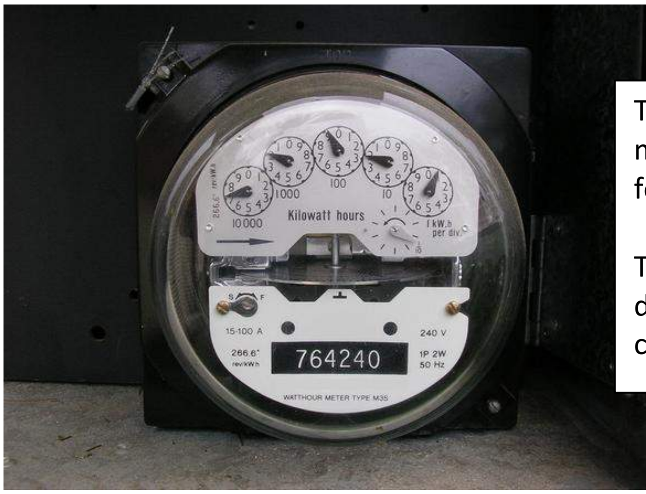
Other appliances primarily reduce electricity and water consumption, and provide benefits in energy savings as well as reducing water use and electricity generation impacts on the local environment.

The use of onsite renewables such as solar PV panels and small wind turbines remains uneconomical for most applications in coastal BC communities. Where the initial cost of solar panels can be subsidized, especially through donation, there is an opportunity to take advantage of electricity savings from these systems. The addition of donated solar panels to the Klemtu School is an example of a successful implementation of onsite renewables for a larger community building.

Cost Analysis

Energy Savings

Building an energy efficient house may cost more than building to the code standard. Depending on the level of energy performance desired, this upfront cost premium may be modest (a few dollars per square foot), or substantial (over $100 per square foot). However, this higher initial cost is balanced over the long term by energy savings, leading to lower utility bills and operating costs.



The time that an energy efficiency measure or component takes to pay for itself is called the **payback period.**

The payback period is calculated by dividing the extra cost by the annual cost savings.

Each component of a house that is more expensive as a result of being more energy efficient (for example, triple-glazed windows) will take a certain amount of time to pay for itself. This information alone is more useful for home retrofits than new construction. However, careful modeling of a new home can combine the effects of each component of the *house as a system*, leading to an estimate of energy savings for the entire home.

[0]

Depending on local conditions, the exact design of the house, and the materials chosen, an energy efficient home may take as little as five years, or many times longer to pay off in energy savings. However, over the lifetime of the house, energy efficiency built into new homes almost always leads to **overall cost savings.**

Case Studies

There have been a number of energy efficient home projects undertaken in First Nations communities in British Columbia, and many more in BC and around the world. The case studies below illustrate a few of these projects and their relative performance.

Project	Region	Performance	Cost	Notes
RDH Energy Efficient Northern Housing	Whitehorse, YT	EnerGuide 85	*Additional Cost*: $2.70/ft^2$ or $6500	In jurisdictions where fuel is expensive, a cost-optimized approach to energy efficiency would incur $6500 in additional costs, yet results in annual savings of $1200. This investment pays off in less than six years [35].
EcoSage Project	Penticton, BC	EnerGuide 88	*Total Cost:* $166/ft^2$ or $250,000	The Penticton Indian Band and FortisBC constructed eight energy efficient homes using passive solar principles and heat pumps [59].
BC Passive Housing	Nelson, BC and Whistler, BC	Passive House (>EnerGuide 88)	*Total Cost:* $180/ft^2$	Previous experience in certified Passive Houses in BC has included the Lost Lake and Rainbow projects in Whistler, and private houses in Vancouver and Nelson [60].
Saskatchewan Passive Housing	Saskatoon, SK	Passive House (>EnerGuide 88)	*Total Cost:* $195/ft^2$	First Passive House in Saskatchewan constructed in 2016, utilizing double 2x4 walls, cellulose insulation and electric heating in a cold and demanding climate [61].
Vancouver Coastal Health Housing	Bella Bella, BC	Passive House (>EnerGuide 88)	*Total Cost:* $175/ft^2$ built, $300/ft^2$ with transportation	Prefabricated Passive Housing units built for VCH by Britco. The final cost was nearly doubled by the need to transport modules by barge [60].

Skeena and Hastings Project	Vancouver, BC	Passive House (>EnerGuide 88)	Unknown	Eighth Avenue Developers is currently building Canada's largest Passive House certified building, an 85-unit residential complex in the heart of Vancouver [78].
AYO Smart Home	UBC and Yunesit'in Nation, BC	Passive House (>EnerGuide 88)	*Total Cost:* $130/ft^2$ (unfinished)	Prefabricated panel construction and a number of energy efficiency features were incorporated into a demonstration house at UBC for application in First Nations communities [27].
Seattle Net-Zero House	Seattle, WA	Net-Zero (EnerGuide 100)	*Total Cost:* $165/ft^2$ (US$125)	Net-zero house built in Seattle using prefabricated wall panels, air-to-water heat pump with radiant heating, and solar PV [28].
Nuxalk Nation	Bella Coola, BC	Not Tested	*Total Cost:* $108/ft^2$ or $103,000	Homes constructed under the supervision of Richard Hall in the Nuxalk Nation incorporate slab on grade foundations with radiant heating, mould resistant materials and rainscreen system at an affordable price [34].
Kwadacha Nation Housing	Fort Ware, BC	Not Tested	*Total Cost:* $215/ft^2$ or $300,000	Energy efficient homes constructed in a very remote community with diesel generation. Wood biomass heating saves on energy costs [62].

Cost Effectiveness

There have been numerous successful projects building energy efficient homes for First Nations in BC, but many have come at a cost premium when compared to traditional construction. Given a limited budget, which in some Great Bear Initiative communities has been identified as approximately $200,000, careful consideration must be given to choosing the most cost-effective efficiency measures.

The AYO Smart Home pilot project at UBC is an example of a home designed with First Nations to balance energy efficiency and cost effectiveness.

Building a home to Passive House standards will ensure that energy bills will be relatively low (assuming the building is operated properly), but usually comes at a much higher initial cost. In practice, the case studies shown above demonstrate that it remains difficult to build to an extremely demanding standard such as Passive House in the remote communities of the Central and North coast of BC for $200,000 or less.

Solutions which work well in other jurisdictions do not necessarily translate well to the context of remote communities in coastal BC. Materials such as prefabricated modules or, to a lesser extent, prefabricated wall panels, allow for houses to be constructed to the Passive House standard for around $175/ft^2. There are even examples of net-zero homes being constructed for as little as US $125/ft^2. However, experience has shown that this is not a cost-effective means of delivery to remote communities, where the cost of shipping and construction labour can increase final costs to $300/ft^2 or more [28, 60].

In contrast, homes which are not necessarily designed to maximize energy efficiency, but which incorporate sound building science and high performance, are being built in coastal BC First Nations (Nuxalk) for as little as $103,000 per unit or $108/ft^2. This demonstrates that a balance can be struck between maximizing energy efficiency and minimizing cost, leading to a building which performs well from an energy standpoint but is also highly practical and constructible in remote coastal communities [34].

Many factors not directly related to the purchase cost of materials influence the cost effectiveness of home construction in coastal BC. In remote GBI communities, the costliest components of construction can be the transport of materials and skilled labour to the site. Many building materials need to be barged or ferried in from highway access points, which adds cost and complexity to a project. Using local materials such as local cedar or gravel can help alleviate these shipping costs in some cases, provided the capacity exists in the community to extract and utilize these resources.

Perhaps a larger issue in remote communities is the availability of local skilled labourers and tradespeople. In Klemtu, for example, there is a single ticketed plumber and three construction labourers available, but further resources such as electricians need to be flown in to the community at considerable cost. By contrast, in Bella Coola there is a larger pool of skilled labour, road access, and a functional gravel batch plant. These resources enable a significantly higher local capacity to build new housing, and costs are reduced as a consequence.

Purchasing materials in bulk and building multiple homes at one time also creates economies of scale that favour lower prices in larger communities, or those undergoing major housing expansion or replacement such as Wuikinuxv.

In designing for energy efficiency and sustainability, building performance standards are often considered as benchmarks. In remote communities however, the logistics of achieving a building performance standard can be complicated. Standards require certification and verification, for example, airtightness is usually evaluated by performing a blower door test, a process that requires a skilled and certified person to perform.

Certification to a building standard also typically requires independent verification by a representative of the standard, and builders may need to be certified and trained in the standard as well (for example, in the case of R-2000). These factors can significantly increase project cost and extend far beyond the resources available in the community. For this reason, certification may not always be appropriate for remote communities even when energy efficiency and sustainability targets are being met.

A final consideration in cost effectiveness is that funding for new home construction in Coastal First Nations communities may include contributions from outside entities such as Aboriginal and Northern Development Canada, or from insurance companies in the case of loss or damage. This may determine, or at least limit, the funds available to pursue higher performance targets. In some cases, requirements or deadlines set by external funders may also influence the designed performance of the home.

Performance Targets

Good: ENERGY STAR HOMES	**Better:** R-2000	**Best:** Certified Passive House, Passive House Institute
$150/ft^2 or less	$150-160/ft^2 [59]	Historical projects in Canada: $175-195/ft^2 [60]

Best Practices Summary

Performance Targets Summary

Good:	Better:	Best:
The House as a System		
~20% more efficient than national building code, with an EnerGuide rating of at least 81.	~30-50% more efficient than national building code, with an EnerGuide rating around 86.	~80% more efficient than national building code, with an EnerGuide rating often 90 or higher.
Site Selection and Passive Solar Design		
Minimal use of passive solar principles. Energy savings may be from airtightness and efficient appliances only.	One or more elements of passive solar design is incorporated e.g. high performance windows.	Incorporates all the key elements of passive solar design: south-facing, large windows and overhangs, and thermal mass.
Foundation and Frame		
Traditional basement or crawlspace foundation with some insulation on below grade walls	Basement or slab on grade foundation with some insulation under the foundation	Slab on grade construction to provide thermal mass. Insulation under foundation is extensive.
Conventional framing on 16” centers, with extra insulation added	More advanced framing such as 2x6 walls on 24” centers and two stud corners	Double 2x4 walls or 2x6 walls with exterior insulation, with thermal bridging nearly eliminated, or prefabricated wall panels
Insulation		
Ceilings: R50 Exterior Walls: R17.5 Walls Below Grade: R17 Foundation/Slab: R11	Ceilings: R50 Exterior Walls: ~R28 Walls Below Grade: ~R20 Foundation/Slab: ~R20	Ceilings: R50-R90 Exterior Walls: R40-R60 Walls Below Grade: R30-R50 Foundation/Slab: R30-R50
Fiberglass batting insulation	Cellulose or foam panel insulation or extra insulation, minimizing thermal bridges	Prefabricated modules, double wall with cellulose or single wall with EPS/XPS
Weatherproofing and Airtightness		
Typical construction with 6-mm polyethylene vapour barrier and exterior WRB.	Home wrapped with high-quality WRB such as Tyvek HomeWrap with furring to create rainscreen	Advanced WRB such as Tyvek ThermaWrap or exterior foam insulation plus WRB and rainscreen

Weather stripping better than code requirements	Excellent weather stripping and caulking to minimize air infiltration	Air leaks almost eliminated, sealing, caulking and weather stripping throughout
Windows and Doors		
ENERGY STAR certified windows and front door U<1.6 W/m^{2}K for windows (at least double-glazed)	At least double-glazed, low-e coated, inert gas filled and with insulated spacer	U<0.8 W/m^{2}K windows, typically triple-glazed and argon-filled with low-e coating
Heating and Cooling Sources		
Electric baseboard heating, forced air furnace or radiant floor heating	Air source heat pump with single or multiple heads and electric baseboard heating in bedrooms as necessary, or heat pump fed radiant heat	Very small heat pump or heating element integrated into HRV, used on very cold days
>100 kWh/m^2/yr heating load	~55 kWh/m^2/yr heating load	<15 kWh/m^2/yr heating load
Natural and Mechanical Ventilation		
2.5 Air Changes Per Hour	1.5 Air Changes Per Hour	0.6 Air Changes Per Hour
60% HRV Efficiency	>60% HRV Efficiency	>75% HRV Efficiency
Duct take-offs and joints sealed and insulated where required	Ducts carrying conditioned air through unconditioned spaces are insulated	Ducts routed centrally or in utility walls, typically through conditioned spaces to minimize heat loss
Water Heating and Electrical Loads		
ENERGY STAR® certified appliances or lighting leading to at least 400kWh/year of electricity savings.	Extensive use of efficient appliances including ENERGY STAR® certified products.	Total electricity use excluding space heating not to exceed 105 kWh/m^2/year
Mix of incandescent and CFL lighting is possible	Typically mostly CFL lighting with some LED	Moving towards all-LED lighting
Water Use: 4.8 L/flush, 9.5L/min shower, 8.3 L/min faucet	Water Use: 4.8 L/flush, 7.6 L/min shower, 5.7 L/min faucet	As good or better water use than R-2000 standard. Drain heat recovery may be incorporated.
Cost Analysis		
\$150/ft^2 or less	\$150-160/ft^2	Historical projects in Canada: \$175-195/ft^2

Technology Summary

Category	Recommendation	Implementation	Cost Analysis
Passive Solar Design	-Incorporate all aspects of passive solar design wherever the building site allows	-Passive solar must be considered in the design phase -Sourcing concrete and high-performance windows may be an issue	-Does not add significant cost unless concrete is at a premium
Foundation	-Build slab on grade foundations wherever site conditions permit	-Sites must be suitable and well-prepared -Plumbing and ductwork must be well-planned -Requires good source of concrete	-May be the most affordable option, depending on cost of concrete
Frame	-Use advanced framing techniques in stick-build construction when labour is available	-Code and structural requirements must be checked	-Should lead to cost savings compared to traditional stick-build
Insulation	-Use cellulose insulation where available for walls and roofs -Rigid foam for foundations -Spray foam to seal gaps	-Cellulose requires special equipment and qualified person to install -Traditional fiberglass may be only option where this is not feasible	-Rigid foam and spray foam insulations are costly, use only as much as necessary
WRB	-Use a flexible house wrap, combined with exterior rigid foam if possible	-House wraps are standard on most houses and already in use e.g. in Nuxalk	-Flexible house wrap is affordable option -Adding foam insulation is costly
Weatherproofing	-Create a rainscreen underneath exterior finish -Design effective eaves, gutters and covered entryways	-Requires expertise in furring and attaching cladding -Nuxalk is excellent resource	-Weatherproofing adds marginal extra cost, dramatically increases lifespan of building
Windows	-Use triple-glazed windows with thermal break wherever possible	-Triple-glazed windows may be difficult to source and replace	-Cost premium for high-performance windows balanced by energy savings
Doors	-Use steel or fiberglass doors	-Usually no difference in implementation	-Steel and fiberglass doors are more

	where possible		affordable and perform better than wooden doors
Space Heating	Highly community specific: -Use air source heat pumps where possible -Radiant underfloor heating as a good alternative with concrete floors -Pellet stoves where fuel is available	-Mini split heat pumps can provide heat to several rooms -Heat pumps require proper maintenance -Radiant heating can be easily combined with slab on grade foundation, requires less maintenance -Pellet stoves require some manual labour	-Heat pumps more expensive than baseboard, but have lower operating cost -Similar cost to forced air furnace
Space Cooling	-Use of air conditioners if required -Hydronic underfloor heating systems can also be used for cooling	-Cooling is rarely necessary in coastal BC climate	-Cooling system adds extra cost
Ventilation	-Include mechanical ventilation in new homes -Use HRVs where possible	-HRVs require regular maintenance and proper operation, as well as qualified installation -Fan-only ventilation as alternative where HRVs are infeasible	-HRV carries cost premium
Lighting	-Use LED lighting in new home construction	-Usually no difference in implementation -Less maintenance	-Up-front costs will be higher, but pays off over time
Water Heating	-Use storage water heater -Heat pump water heater as stretch goal	-Storage water heater is standard practice -Heat pumps would require specialized installation	-On-demand heaters may not be worth extra cost -Storage heaters still most economical
Appliances	-Use ENERGY STAR® certified appliances where possible	-Usually no difference in implementation	-Extra cost quickly pays off in energy savings
Onsite Renewables	-Not currently recommended	-Solar PV or wind requires extensive planning and specialized equipment	-Cost savings unlikely to pay off in project lifetime

Community Needs Summary

Existing Housing Issue	Solutions for New Housing
Issue #1: Water Leakage and Pooling	• Rainscreening • Covered entryways and steel doors • Effective gutters and eavestroughs • Weatherproof building envelope • Sealed ducts and other openings • Graded site and well-drained foundation • Sufficient ventilation
Issue #2: Mould	• Elimination of basement or crawlspace • Airtight building envelope • Mechanical ventilation • Heat pump or forced air heating • Mould-resistant drywall, insulation and paint
Issue #3: Cold and Drafty Spaces	• Airtight building envelope • Slab on grade foundation • Heat recovery ventilation • Heat pump or forced air heating
Issue #4: Inadequate Gathering Space	• Passive solar design • Open floor plans • Flexible common areas
Issue #5: Food Preparation and Storage	• Larger kitchens and pantries • Outdoor preparation facilities for fish and game • Adequate ventilation for cooking areas • Canning rooms or smokehouses if desired
Issue #6: Energy Efficiency and Sustainability	• Passive solar design – triple glazed windows • Advanced framing techniques • Extensive use of insulation • Airtight building envelope • Sealed ducts and other openings • Heat pump space heating + advanced controls • LED lighting and energy efficient appliances • Use of recycled or sustainable materials • Heat recovery ventilation
Issue #7: Affordability	• Use of affordable insulation materials • Minimizing shipping to remote communities • Passive solar design • Airtight building envelope • Sealed ducts and other openings
Issue #8: Local Capacity and Materials	• Use of locally available material when possible • Use of local labour and expertise when possible

Conclusion and Recommendations

This project has attempted to identify some solutions to key issues in new home construction for the GBI communities. The technologies and methods identified in the study draw on technical considerations as well as economic, social and cultural needs.

The true applicability of these solutions to the GBI communities can only be measured through implementation. As in any other context or region, the true test of a home's performance is in the wellbeing of its inhabitants and the environmental impact of the home. Solutions which appear suitable on paper may encounter unexpected issues in reality.

The recommended next step for the GBI communities and Pinna Sustainability is to use the best practices recommendations of this study as a guideline for the design and construction of an actual home on the Central Coast. This is currently planned as part of the Klemtu Housing Pilot project, which will aim to construct a culturally appropriate and energy efficient home in the Kitasoo nation during the summer of 2016.

The Klemtu Housing Pilot project should include an electricity metering campaign, establishing an energy consumption profile for the building. This can then be compared to the baseline energy consumption of the existing building stock, leading to an evaluation of the overall energy performance of the home.

The learnings for the construction and operation of this pilot house could be used to inform future research and refinement of these best practices, establishing a community-tested guideline that can be applied to future home construction at scale. Modification of these guidelines should be made as necessary when constructing homes in different communities, in order to address the unique needs of each community and Nation.

Finally, the economic feasibility and constructability of energy efficient and culturally appropriate homes can be improved over time, as local expertise is developed and new housing practices are implemented at a larger scale. This process could organically refine the building process in communities both in the GBI and beyond, streamlining new home construction to meet an appropriate mix of performance, resiliency and affordability.

It has been an honour and privilege working with the Coastal First Nations, Pinna Sustainability and BC Hydro, and I think all the project participants for their time and effort. I would also like to extend special thanks to Gillian Aubie Vines for her support and input in the role of project mentor.

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Appendix A: Industry Expert Design Meeting Agenda

Date: Thursday March 31, 2016, 9am-11am

Location: Suite 1660 – 409 Granville Street

Participants

Confirmed:

- Gillian Aubie Vines – Kitasoo Energy Facilitator
- Dylan Heerema – UBC Building Science
- Allan Dobie – Retired CHMC, Architect
- David Wong – Architect
- Neil Griggs – Builders Without Borders
- Eileen Keenan – Builders without Borders
- Michael Keenan – Builders without Borders
- Luke Smeaton – Lighthouse
- Martina Sotherland – Energy Consultant
- Doug Spani – Spani Developments
- Karen Tam Wu – Pembina Institute
- Kathy Skelley – CHMC
- Ervan Selak – INAC
- Monte Paulsen – Energy Consultant
- John Bass – UBC Architecture
- Wilma Leung – BC Housing

Calling in:

- Darren Edgar – Kitasoo Band Manager
- Jamie Pond – Kitasoo Housing Manager
- Heather Davies – Ministry of Energy and Mines
- Jason Jackson – Hakai Energy Solutions
- Tabitha Eneas– Penticton Indian Band's Passive Housing Project

Purpose

- To gather expertise in advance of the Kitasoo Community Meeting
- Ideas to inform design

Agenda

- Introductions
- Design Criteria
- Short presentation on current thinking for the home - David Wong
- Context on Building in Klemtu
- Q and A on context
- Recommendations from participants
- Assessing cost benefit of recommendations
- Debrief / discussion.

Outcomes

- Cost savings measures
- Agreement on solutions that meet design criteria

Preliminary Design Criteria

Climate Appropriate – Klemtu experienced driving rain in all directions, and has an average annual temperature range from 2˚C to 17˚C. There are approximately 3500 HDD, a number projected to reducing to 2600 HDD by 2080s. With climate change, we can expect increasingly dry summers over time.

Specific considerations include:

- Mitigate mould:
  - Limiting water ingress (air leaks, rain screen, eaves troughs, awnings/ mudrooms near entry)
- Water conservation / water recycling

Culturally Appropriate – Homes in Klemtu need to accommodate multigenerational living, and specific food storage and preparation practices such as canning, freezing, and smoking. Occupants cannot be expected to significantly change existing personal behaviours.

Specific considerations include:

- Basic amenities on ground floor
- Elder bedroom on main floor
- Larger kitchens
- Freezer capacity (3?)
- Outside fish/game prep area?
- Large room attached to kitchen for family gatherings
- Privacy for teenagers

Livable / Comfortable Occupants currently use space heaters to keep each room warm, which is highly inefficient. New homes must be comfortably warm to reduce this practice.

Specific considerations include:

- Target interior temperature - 21˚C
- Target humidity - 30%-40%
- Adequate air flow for mould prevention and optimized health
- Consistent temperature
- High indoor air quality
  - At least 0.6 up to 1.5 air changes per hour - for discussion
  - VOCs and toxicity

Energy Efficient – Klemtu is electrified with hydro-electricity, though the system is nearly at capacity. Electrical efficiency is mandatory to ensure there is enough electricity to supply new homes.

Specific considerations include:

- Low electricity and ultra-low fossil fuel use while meeting above design criteria
- Ready for onsite renewables
- Passive solar design as appropriate:
    - South-facing
    - High performance windows
    - Thermal mass

Durable – Homes in Klemtu have not been designed to meet the climatic and cultural needs of community members, and have a useful life of roughly 15 years. The people of Klemtu have constrained resources to maintain homes. Occupants are not accustomed to maintaining their own homes.

Specific considerations include:

- Last 50-80 years with minimal maintenance
- Easy to maintain
- Low maintenance person / hours
- Inexpensive to maintain
- No / low need for technical knowledge

Local Resources – There are some local resources that can reduce costs.

Specific considerations include:

- Ticketed plumber lives in town
- Ticketed electrician – still needs to fly in
- 3 construction labourers
- Crushed rock plant?
- Low local capacity to build homes