Traditional Buildings Twenty-First Century Technologies-Not Such Strange Bedfellows

Mike Mutrie
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Common Terms

- **Embodied Energy**: The sum total of the energy necessary - from the raw material extraction, to transport, manufacturing, assembly, installation as well as the capital and other costs of a specific material - to produce a service or product and finally its disassembly, deconstruction and/or decompostion [Wikipedia]
- **Operating Energy**: The energy required to maintain (operate) the building. [*Operating Energy Reduction in Heritage Buildings*]
- **Building Envelope**: The building envelope consists of those parts of the building that separate the controlled indoor environment from the uncontrolled outdoor environment. The building envelope includes the foundation, walls, windows and doors, and ceilings. [Athena Institute and Morrison Hershfield. "Service life Considerations in Relation to *Green Building Rating Systems*: An Exploratory Study."]
- **ecoENERGY**: Natural Resources Canada's (NRCan's) ecoENERGY Retrofit program provides financial support to homeowners, small and medium-sized businesses, public institutions and industrial facilities to help them implement energy saving projects that reduce energy-related greenhouse gases (GHGs) and air pollution, thereby contributing to a cleaner environment for all Canadians. ecoENERGY Retrofit was launched April 1, 2007 and is scheduled to end March 31, 2011. [oee.nrcan.gc.ca]
- **Energy Efficiency**: Refers to how effectively energy is being used for a given purpose. Providing a similar or better level of service with less energy consumption on a per unit basis is considered an improvement in energy efficiency. [*Operating Energy Reduction in Heritage Buildings*]
- **Thermal Efficiency**: In its most generic sense, thermal efficiency is a ratio of output energy versus input energy. For example, the heat generated by a furnace is the output energy and the fuel consumed generating this heat is the input energy. It is a concept use to compare heating system options.
- **EnerGuide for Houses**: EnerGuide for Houses is a rating system that measures the operating energy efficiency of both new and existing homes. It rates homes on a scale from 0 to 100. A rating of 0 corresponds to major air leakage, no insulation, and very high operating energy costs; a rating of 100 corresponds to an airtight, highly insulate that produces its own energy. It is important to note that the EnerGuide scale is not linear, as a jump from 80 to 85 requires a 50% reduction in energy use.
- **Natural Resources Canada (NRCan)**: Champions innovation and expertise in earth sciences, forestry, energy and minerals and metals to ensure the responsible and sustainable development of

our nation's natural resources. NRCan developed both HOT 2000 and RETScreen, two freeware programs that focus on improving energy efficiency in buildings. [oee.nrcan.gc.ca]

- **Canada Mortage and Housing Corporation (CMHC)**: CMHC works to enhance Canada's housing finance options, assist Canadians who cannot afford housing in the private market, improve building standards and housing construction, and provide policymakers with the information and analysis they need to sustain a vibrant housing market in Canada. In addition the CMHC publishes a wide base of articles for homeowners regarding renovation and energy efficiency. [cmhc.ca]
- **Renewable Energy Technologies**: This term has become somewhat ambigious and has become more of a marketing term than a classification. In the context of this report, a renewable energy technology refers to any device that produces energy using a fuel source that can be reproduced. Typical examples are solar energy, wind, tidal and hydro power.

Background and Purpose

Act in Haste, Regret at Leisure

"The village presents a somewhat naked appearance this week, a removal squad having gone round on Monday and taken all the iron railings etc. Scheduled under the Government's scheme for requisitioning such articles for use in the munitions industry. The two Methodist Chapels are among buildings thus denuded." (Luton News, England, 5th November, 1942).

Increasing awareness of climate change is putting a pressure on everyone to reflect on how they can make a difference. Unfortunately this pressure is causing some to take a mentality that the world will spontaneously combust tomorrow if we all don't start bicycling everywhere and throw a wind turbine up in our yard today. This isn't the first time we have reacted first and thought later. During the Second World War railings were removed across Britain to supply the munitions industry. The transformation of the urban and rural landscape was unparalleled saved for the effects of the Blitz itself. The effort was largely futile due to the unusable material properties of cast iron. In an effort to maintain public morale, centuries of urban artistry were quietly and unceremoniously dumped in the North Sea.

Back in the 1970s, the OPEC oil embargo led to a massive change in the North American automotive industry. Large cars with V-8 engines and a curb weight similar to some ocean going vessels were replaced overnight with a fleet of small vehicles. Cars such as the Pontiac Acadian were thrown together to meet public demand for more fuel efficient vehicles with little or no concern for long term reliability. Victims of an ill-considered, hasty decision prompted by the North American fuel shortage problem, these cars proved to be unreliable and the majority ended up in the scrap yard only a few years after purchase.

The moral of these stories is that problems need to be recognized and solutions need to be thought out. We need to recognize that humans have an effect on the climate and older buildings are energy inefficient. Although some older buildings are energy hogs, they can be improved! The quick and tempting answer seems to be tearing down the older building and replacing it with a brand new “green” building. The problem with this is while energy may be saved on heating the place, the embodied energy consumed in this action is massive. First there is the energy used in demolition, in both the action and carting the scrap to the junkyard. Then there is the energy consumed in new construction; air compressors and cement mixers need diesel too! So in the end, replacing the existing building that could have been upgraded with a new energy efficient one actually hurts the planet much more than retrofitting the old building instead! In addition to the environmental costs, someone has to pay for the demolition and construction, an investment that will probably not be recuperated in energy savings in any reasonable payback period.

These traditionally-constructed buildings include everything from the Emily Carr House, an Italianate villa constructed in Victoria in 1864, to a modest mail-order catalogue home in the interior, to a mid-rise commercial building in downtown Vancouver. It is true that some of these older buildings are energy inefficient, but they can be improved without radically altering the building envelope or tearing them down. This Heritage Branch report is designed to provide a choice for homeowners interested in preserving the durability, character and economic value of their property, all while saving some money (and the planet) in the process.

Easy to Retrofit Traditional Buildings

The green building industry has grown immensely in the last few decades. One portion of the green building economy focuses on products and services that retrofit onto existing buildings and improve energy efficiency. Increasing demand for a better environment is helping make these technologies more common and, therefore, less expensive. The good news is that these retrofit products can easily be applied to improve the energy efficiency of traditional buildings. With that in mind, this guide focuses on the two most common ways to upgrade the energy performance of a traditional building: maintaining the building envelope to reduce heat loss and supplementing the heating system with alternative technologies.

Methods

Software Description

Ideally, this report would come about as a result of an expensive experiment conducted on multiple buildings across the province over a decade or so where all technologies mentioned in this report would be fully tested through all seasons to determine if they are economically viable or not. The problem with this is its cost would be multiple times higher than the entire operating budget of the BC Heritage Branch! As such, it was decided that all of the technologies mentioned herein would be tested on virtual software models of a real home using two software packages published by Natural Resources Canada: HOT 2000 and RETScreen.

HOT 2000 is a tool that is used by architects and builders to virtually determine the EnerGUIDE rating of a new construction project. Its primary focus is on building envelope and heating/cooling systems. While HOT 2000 is intended for newer buildings, it can still be used as an effective tool for existing buildings because it can model how much energy can be saved by adding insulation to any one room in the house or improving the furnace. It is used by private consultants as a basis for deciding how an existing building may be improved. In the simulations conducted in this report, the viability of various options are evaluated by looking at the reduction of energy use over a year and the reduction of the annual energy bill. This reduction is compared against the initial and operating costs to determine the payback period. Its contra is primarily its inflexibility in accurately modeling renewable energy technologies (RETS).

HOT 2000 analysis was augmented by the use ofRETScreen, a program that evaluates the viability of renewable energy technologies (RETS). It is effective because it can accurately model payback periods and environmental impacts of various projects in easy to understand visual concepts (for example, greenhouse gas savings are dimensionalized as “cars and light trucks not used”). It is highly effective when evaluating multiple projects and decisions can be reached on an economic and environmental basis. The viability of various options are evaluated by considering the payback period and the net present value after a set period.

Testing Method

Using HOT 2000 and RETScreen, a virtual model of a Victoria home was created for testing. The home is a 2 storey arts and crafts style home built in 1913. Like most coastal British Columbia homes, the walls are uninsulated and finished internally with lath and plaster in most locations. Space heating is provided by a central natural gas furnace and domestic water heating is provided by a conventional natural gas water heater. This home was then “moved” to multiple different locations across the province with diverse climates to test the viability of various options across environmental conditions that reflect the many different climates found in the province.

ecoENERGY Evaluation

In addition to the simulations performed by the BC Heritage Branch, a certified energy advisor was brought in to perform a building envelope analysis on the test home using HOT 2000 and provide expert recommendations based on this analysis. The energy advisor provided both expert feedback on what upgrades are most effective in increasing the building's energy efficiency and a professionally completed HOT 2000 building envelope report.

Climate Locations

The province of British Columbia has a diverse array of climates from the temperate coastal region to the boreal forests of Fort St. John. This diversity has an effect on the approach to retrofitting for energy efficiency as some options are more suited for certain climates. For example, an air source heat pump is ideal in the coastal regions but inappropriate for the colder northern regions. To simulate the diverse climates found across the province, the freeware packages HOT 2000 and RETScreen were used to “move” the test home across multiple different climate zones. The diversity in climates impact relevant data such as annual rainfall, degree heating days, air temperature, daily solar radiation and earth temperature. Eight locations were chosen to reflect the broadest climate diversity.

1. Victoria
2. Tofino
3. Cranbrook
4. Kamloops
5. Fort St. John
6. Abbotsford
7. Terrace
8. Fort Nelson

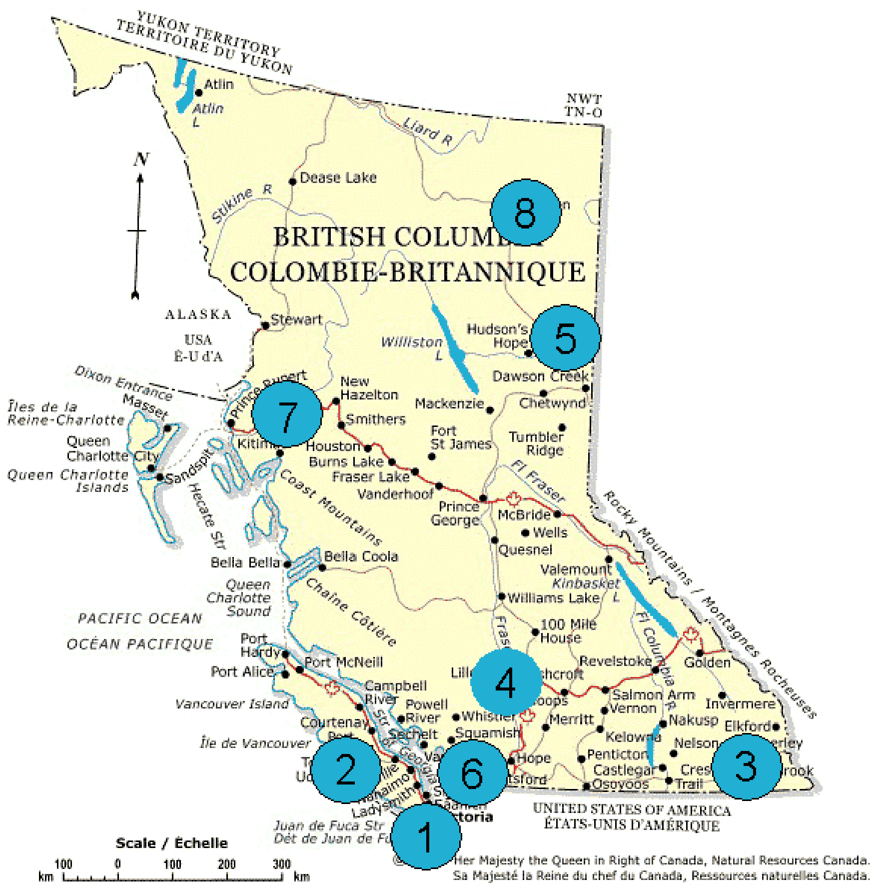

Figure 1: Location Reference for Test Sites

Ranking System Explanation

In the following pages of this report you will find several tables similar to the template below.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria					
Tofino					

Table 1: Sample Evaluation Table

These tables are used to evaluate every upgrade in this report. Each upgrade is graded out of five in various categories for each of the chosen climate locations. Included below is a brief description of each of the categories the upgrade will be evaluated upon.

Installation Cost

Installation cost is a measure of the initial cost to fully integrate the upgrade into the home.

Ranking	Explanation
$	under $2,500
$$	$2,500 to $5,000
$$$	$5,000 to $7,500
$$$$	$7,500 to $10,000
$$$$$	over $10,000

Table 2: Installation Cost

Appropriateness for Climate

This refers to how suitable the upgrade is for the climate zone. For example, an air source heat pump is not recommended in climates with harsh winters such as Fort Nelson and Fort St. John but is ideal in Victoria or Tofino. Similarly, a ground source heat pump gets high ratings in the colder climates because of the good performance over winter, but lower ratings in moderate climates like Victoria because an air source heat pump is a cheaper option.

Ranking	Explanation
*	Avoid installing the upgrade completely
**	Weakest choice of multiple satisfactory upgrades
***	One of multiple satisfactory upgrades
****	Preferred choice of multiple satisfactory upgrades
*****	Ideal climate zone for upgrade

Table 3: Appropriateness for Climate

Grants Available

This represents the cash value in the form of a grant from ecoENERGY.

Payback Period

The payback period is a measure of how long an upgrade will pay off its initial and operating costs in the form of energy savings. A 1-star rating represents a period of over 12 years while a 5-star rating represents a period of under 2 years.

Ranking	Explanation
*	over 10 years
**	8 to 10 years
***	5 to 8 years
****	3 to 5 years
*****	under 3 years

Table 4: Payback Period

Ease of Installation

This category is a measure of how difficulty in completely installing the upgrade. When evaluating the installation process, it is important to know your limits and how "handy" you are. Remember that it usually costs more to have a professional fix a fumbled installation than it does to have the professional do it right the first time.

Ranking	Explanation
*	Hiring a professional contractor is a necessity
**	Most of the work can be done by a competent handyman
***	All of the work can be done by a competent handyman
****	Most do-it-yourselfer's can perform this installation
*****	Simple tasks requiring few or no inexpensive common tools

Table 5: Ease of Installation

Why Don't Older Buildings Have the Problems of Modern Buildings?

There are several problems with modern construction that have never been an issue with traditional construction. The most common problems is now refered to as "sick building syndrome." Sick building syndrome refers to a condition where occupants of a building reported common symptoms of nausea, fatigue, dehydration and even local outbreaks of influenza and the common cold. The problem stems from the occupants breathing recirculated air and not getting enough fresh air. Older buildings allow both air and moisture to "breathe" through the building envelope, so occupants have enough access to fresh air. Modern building philosophy can be summed up by the motto "build tight, ventilate right." This means that the building envelope is intended to be both air and vapour sealed, and all air exchange is done mechanically by the HVAC system. This means that modern building is more susceptible to moisture trapping and rot if either the seal wears out or (all too often) the building envelope is constructed incorrectly.

Retrofit Warning: Modern Building Philosophy Applied to Existing Building Envelopes

The most important difference in philosophy between traditional and modern building construction is how the building envelope addresses air and moisture flow. Traditional building envelopes allow both air and moisture to “breathe” through it while modern building envelopes prevent the passage of both air and moisture. This is a very important difference to consider when retrofitting the building envelope of an older building with modern upgrades and products.

The major theme that is repeated through this guide is the importance of considering the full cost of any investment, which may involve more than just money. Ill-considered and hasty decisions on improving energy efficiency can often do more harm than good to the environment, the home and especially the pocketbook!

Evaluation of Upgrades for Traditional Buildings in British Columbia

Insulation Upgrades

One of the biggest causes of heat loss through a building envelope is inadequate insulation. In the context of this report, insulation refers to any material that resists heat flow through it and extends beyond walls to windows, doors and even heating systems. Described below are three standards of insulation that the building was subjected to. Multiple standards were required because they each represent different levels of intervention. The most difficult standard for an existing building to achieve is the 2006 British Columbia Building Code. This code presents insulation values that are meant for new construction, and would require a drastic renovation in an existing building. An intermediate amount of intervention was suggested by a 2004 CMHC report that was created with the intention of focusing on existing building construction, but still required some renovation. The standard requiring the least intervention is the 1976 ERMCan report. This report was drafted at the time for existing buildings and was based on insulation technology available at the time.

As the principle aim of this guidance is to examine existing buildings of a wide range of ages, multiple insulation standards were needed to handle this range. For example, a post WWII "Victory" house may be less likely to possess a character interior than say a nineteenth-century Victorian Home with an elaborate character interior so there is a possibility to completely replace all of the insulation and bring the site up to modern building code standards, whereas a 19th century Victorian Home with a significant interior will prohibit changes to any of the walls or floors.

Retrofit Warning: Insulation

The various standards mentioned below provide general guidance and do not reflect changes to be made to every home. In reality, the test home used cannot be insulated from the inside with conventional batt insulation as the walls are original lath and plaster and most of the ceilings are of cathedral construction. The standards below are purely for blind testing assuming any change could be made to the home to demonstrate the effect of adding insulation to the building envelope. As this report is meant for both existing buildings and heritage buildings, the character of the interior will determine the extent of building envelope intervention.

- ### *1976 Energy, Mines and Resources Canada Recommendations*

The first range of insulation values is taken from *Keeping the Heat in: How to Re-insulate Your Home to Save Energy and Money (And be More Comfortable Too)* which was published by Energy, Mines and Resources

Canada in 1976. The values listed in the table below represent the recommended minimum value of insulation.

Building Assembly	Value Required [RSI (R-)]
Ceiling	4.9 (R-28)
"Cathedral" Ceiling	3.5 (R-20)
Basement Walls (less than 50% of the wall above ground)	1.4 (R-8)
Basement Walls (more than 50% of the wall above ground)	2.1 (R-12)
Heated Crawl Space	1.4 (R-8)
Concrete slab on the ground, unheated	1.4 (R-8)
Concrete slab on the ground containing heating ducts, pipes, etc.	1.8 (R-10)
Walls	2.1 (R-12)
Floors over unheated garages, unheated crawl spaces, and overhangs to the outside	3.5 (R-20)

Table 6: 1976 EMRCan Thermal Insulation Recommendations

- ***2006 British Columbia Building Code***

The 2006 British Columbia Building Code regulates the constructionof new buildings and significant altercations to existing buildings and represents a standard that most traditionally constructed buildings would have a difficult time achieving. The relevant data is in Table 9.25.21 which is reproduced below.

Building Assembly	Value Required [RSI (R-)]	
	Less than 4500 Celsius Degree Days	More than 4500 Celsuis Degree Days
Attic Spaces	7.0 (R-40)	7.7 (R-44)
Roof Joist Assemblies (Cathedral/Flat Roofs	4.9 (R-28)	4.9 (R-28)
Frame Walls (including frame crawl space w	3.5 (R-20)	3.85 (R-22)
Framed Suspended Floors	4.9 (R-28)	4.9 (R-28)
Concrete Suspended Floors	2.1 (R-12)	2.1 (R-12)
Foundation Walls (to 2ft below grade)	2.1 (R-12)	2.1 (R-12)
Unheated Concrete Slabs on ground or abo	1.8 (R-10)	2.1 (R-12)
Radiant Heating Slabs on Ground	2.1 (R-12)	2.1 (R-12)
Radiant Heated Suspended Floor Assembly	2.1 (R-12)	2.1 (R-12)

Table 7: 2006 BCBC Insulation Upgrades

- ***2004 CMHC Renovating for Energy Upgrades Series***

As mentioned previously, it is difficult for an older building to conform to the standards set by the 2006 British Columbia Building Code so a more realistic set of values for the test home to conform to was needed. The CMHC has published several guides focusing on energy upgrades for existing buildings. Data was extracted from two volumes of the series, titled *Pre-World War II Homes* and *Post-War 1 ½ Storey Homes*. The thermal insulation values are shown below:

Building Assembly	Value Required [RSI (R-)]
Basement Walls	2.1 (R-12)
Floor Header	2.1 (R-12)
Exterior Walls	1.4 - 3.5 (R-8 - R-20)
Ceiling:	
Natural Gas or Oil Space Heating	7.0 (R-40)
Electric Space Heating	9.0 (R-52)
Coastal British Columbia	5.6 (R-32)

Table 8: 2004 CMHC Thermal Insulation Recommendations

Heating System Upgrades

Why Consider Heating System Upgrades?

There are two main ways to improve energy efficiency in a building. The first is to reduce the heat lost through the building envelope by means of insulation and reducing the amount of air leakage. The second is to reduce the amount of energy needed to heat the building by improving the heating system. Improving the heating system is especially important when considering traditionally constructed buildings because of its low aesthetic impact and the energy savings that can be realized. For example, the ecoENERGY evaluation of the test home revealed that installing a new gas furnace would save approximately 77.5 Million BTUs (73.5 kJ), or installing an air source heat pump with an electric backup furnace would save approximately 132.8 Million BTUs (123.8 kJ) annually, which is tantamount to performing all of the insulation upgrades!

Heat Recovery Ventilator (HRV) Addition

A Heat Recovery Ventilator (HRV) is a heat exchanger that warms inlet air to the furnace with the warm furnace exhaust air. The HRV was developed to bring fresh outside air into modern buildings that have been built airtight to maintain the comfort of the occupants. They are not a heating device, just an energy efficient way to deliver fresh air. While meant for modern buildings, they will work on any building equipped with a ducted furnace system.

In an older building, however, natural ventilation is already present and is typically, sufficient to provide fresh air to maintain occupant comfort. **Indeed, installing an HRV in a building with natural ventilation can *increase* the energy bill because it requires the furnace fan to run continuously rather than intermittently!**

Space Heating System Upgrade

A common trend seen in the residential market is the upgrade of the furnace while the space heating system is being augmented by other devices like a heat pump or an HRV because all of the work can be done by a single HVAC installation firm. Upgrading the furnace is a viable option in homes where older existing systems include components such as a cast-iron radiators or an oil-fueled furnace which is very inefficient and expensive due to rising fuel prices. Federal grants from Natural Resources Canada can be as high as $600 for replacing an old space heating appliance with a modern energy efficient one. The table below is based on a high efficiency gas furnace.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria	$$$	***	500	**	*
Tofino	$$$	***	500	**	*
Cranbrook	$$$	***	500	**	*
Kamloops	$$$	***	500	**	*
Fort St. John	$$$$	***	500	**	*
Abbotsford	$$$	***	500	**	*
Terrace	$$$$	***	500	**	*
Fort Nelson	$$$$	***	500	**	*

Table 9: Gas Furnace (AFUE = 92.0%) Evaluation

Domestic Hot Water (DHW) Heating System

Tankless Hot Water Heater

Tankless hot water heaters or "flash" heaters are a modern invention that utilize a heat exchanger rather than a boiler to heat domestic hot water. Water is heated as it flows through the device, which does not retain any water internally except for what is in the heat exchanger coil - this makes the tankless water heater much more efficient than a conventional boiler hot water tank. Tankless hot water tanks are gaining popularity and are poised to soon outsell conventional water heaters. The drawback of tankless systems is that they can be expensive to retrofit as they are meant to be installed on new buildings during construction. A drain water recovery system cannot be used with a tankless system as there is nowhere to store the recovered energy.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria	$$	****	250	***	**
Tofino	$$	****	250	***	**
Cranbrook	$$	****	250	***	**
Kamloops	$$	****	250	***	**
Fort St. John	$$	****	250	***	**
Abbotsford	$$	****	250	***	**
Terrace	$$	****	250	***	**
Fort Nelson	$$	****	250	***	**

Table 10: Tankless Water Heater Evaluation

Adding Insulation

The simplest and cheapest way to decrease the energy consumption of a conventional hot water heater is to add insulation to the both the tank and the pipe run from the tank. An insulation kit should be purchased at any hardware store and installed by the homeowner. It is important to note the type of hot water tank (electric, natural gas) as the installation procedures are different. This upgrade is most effective when the hot water tank is in an uninsulated area or outdoors.

Drain Water Heat Recovery

More commonly known as “grey water heat recovery”, a drain water heat recovery (DWHR) system works by extracting heat from warm drain waste water from processes like showering to preheat the cold water entering the domestic hot water heating system as shown in the figure below. It is important to note that a DWHR cannot be used if the water heating system is a tankless water heater because there is nowhere to store the hot water that comes from the DWHR.

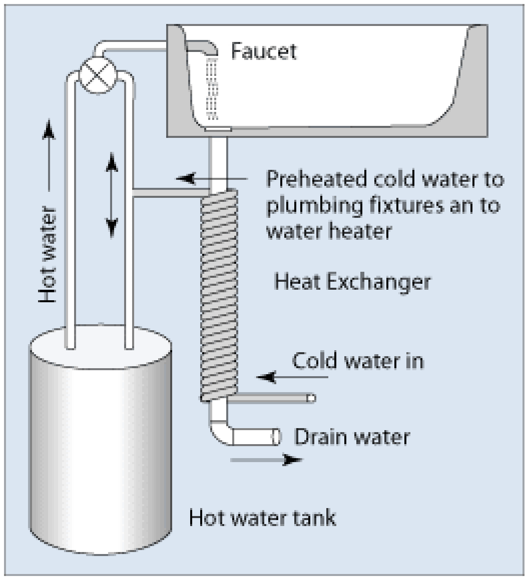

Figure 2: Drain Water Heat Recovery System Operation

Installing a Drain Water Recovery System

As shown in the figure above, the drain water heat recovery system has no moving parts and coils around the existing drain stack. There are currently about five manufacturers of DWHR systems, and the systems can be installed through a manufacturer recommended installer or any certified plumber. Even homeowners proficient with plumbing are recommended to purchase a DWHR system rather than building one since Canadian Standards Association (CSA) certified DWHR systems usually come with a manufacturers warranty and CSA certified systems are eligible for a grant from Natural Resources Canada of up to $130. Although the systems are intended for long-term installation in the home, should they need to be removed they are recyclable as they are manufactured completely from copper.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria	$	****	75-130	****	***
Tofino	$	****	75-130	****	***
Cranbrook	$	****	75-130	****	***
Kamloops	$	****	75-130	****	***
Fort St. John	$	****	75-130	****	***
Abbotsford	$	****	75-130	****	***
Terrace	$	****	75-130	****	***
Fort Nelson	$	****	75-130	****	***

Table 11: Drain Water Heat Recovery Evaluation

Warning Regarding Drain Water Heat Recovery Systems

In modern homes, the drain stack material is usually Acrylonitrile Butadiene Styrene (ABS). This material is easy to manipulate in both cutting and gluing. In older homes the drain stack material is cast-iron. Cast-iron is substantially heavier than ABS and as such structural integrity needs to be considered when replacing a section of cast iron with a weaker copper coil DHWR system. A plumbing permit is normally required to carry out this work.

Augmenting the Energy System of Traditional Buildings for Improved Performance

Generation

A Note on Generation Systems

The relatively modern concepts of "selling" power back to the grid and being completely off grid has given riste to multitude of renewable energy technologies (RETs) that produce electrical power from a renewable fuel source. Technologies like geothermal power generation in Iceland, wind power generation in Pincher Creek, Alberta and hydroelectric power generation in various areas throughout British Columbia are recent examples of the use of this new technology.

Many of the aforementioned technologies are only practical on a large scale, or in areas completely off grid. As the principle focus of this report is single-family residences (SFRs) and multiple urban residential buildings (MURBs) including large commercial building rehabilitations in downtowns, some of these technologies require too much capital to be viable on this scale. The most common small scale RET is photovoltaic power production:

Photovoltaic System

A photovoltaic (PV) solar panel converts thermonuclear (solar) energy from the sun's radiation to a more usable form of electrical energy. The most common PV solar panel application is supplying electricity to "off-grid" buildings, such as seasonal use cabins and boats. However, there is a growing market for PV installations in residential applications, where the system is used to suppliment electricity acquired from the traditional grid.

Heating and Cooling System

Heat Pumps

Heat pump technology is the fastest growing method of alternative heating currently available. Because a heat pump only transports heat and does not generate any, it is much more efficient than conventional heat methods. Consider that a modern combustion fuel source furnace can have an efficiency as high as 95%: an electric furnace has an efficiency of 100% whereas a heat pump can have an efficiency of up to 400%. Below are descriptions of the two main types of heat pumps commercially available. All modern heat pumps are equipped with reversing valves, meaning they can function in both the heating and cooling season by either adding or extracting hot air from the space conditioning processes.

Ground Source Heat Pump

A ground source heat pump, geoexchange system, or earth energy system (EES) works by extracting heat from a relatively constant temperature source deep below the ground. A liquid refrigerant is pumped through buried tubes where it is heated by the surrounding earth and then it is used for both domestic hot water and space heating purposes. Ground source heat pumps have an advantage over air source heat pumps as more heat can typically be extracted during the heating season, although they are much more expensive due to the nature of installation.

Open Loop versus Closed Loop?

This is a question of economics, environmental impact and location but may be answered by site geography. An open loop system works by extracting heat from an aquifer or some other underground water source and then pumping that water into a buried earth drain after its heat is transferred to the house as seen in the figure.

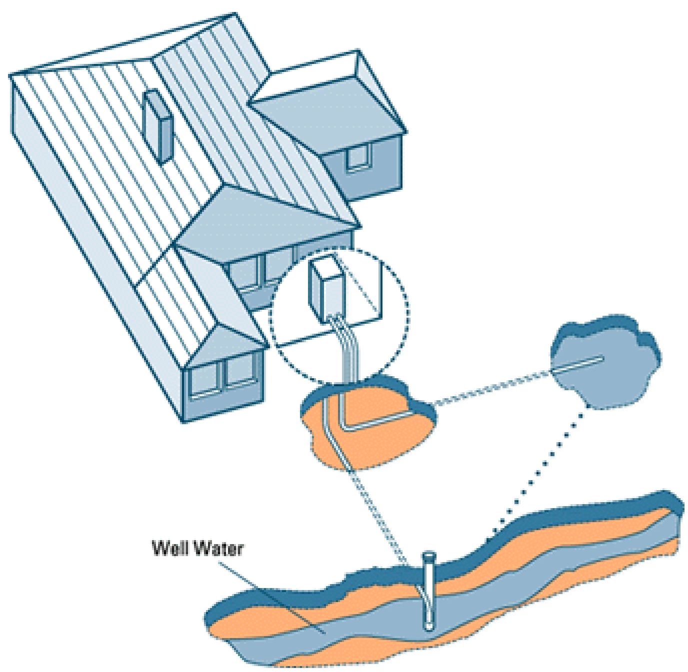

Figure 3: Open Loop Earth Energy System

Economically, an open loop system is much cheaper than a closed loop system, and in appropriate regions it is much more popular. An appropriate region for an open loop is anywhere source water can be extracted at 8 - 12 gallons/minute (30 - 45 litres/minute).
Currently under study is the possible environmental impact of an open loop system as it transports the water elsewhere and may have an affect on the local water table at the aquifer site and effect the flora and fauna that relies on that aquifer.

Horizontal Loop, Vertical Loop and Water Loop Systems

If the site requires a closed loop EES, there are several configurations that may be suitable dependent upon the siting of the building:

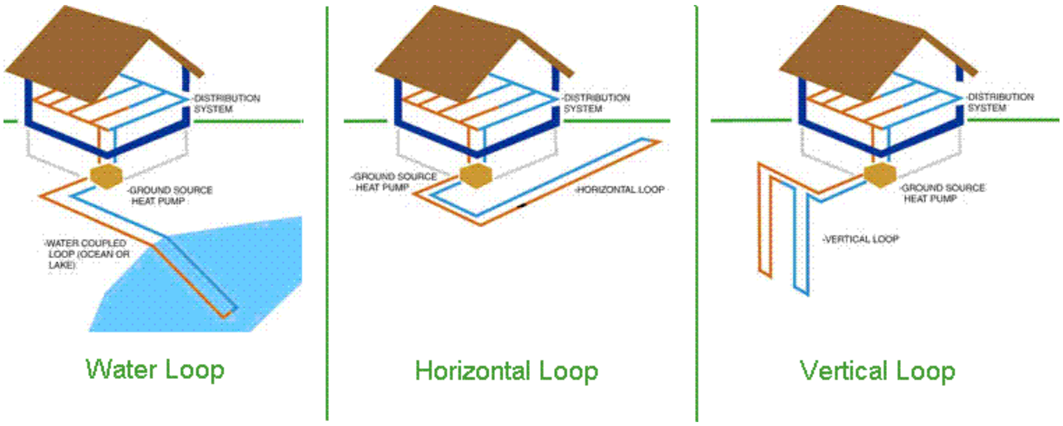

Figure 4: Types of Closed Loop Systems

The least expensive option is the water loop system. Rather than run the refrigerant tubing underground, it is laid on the bed of a body of water. This method is cheaper because the pipe does not have to be fully buried but requires an exposed body of water to be present near the building site such as a lake or ocean.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria	$$$$	*****	3,500	***	**
Tofino	$$$$	*****	3,500	***	**
Cranbrook	$$$$	*****	3,500	***	**
Kamloops	$$$$	*****	3,500	***	**
Fort St. John	$$$$	*****	3,500	***	**
Abbotsford	$$$$	*****	3,500	***	**
Terrace	$$$$	*****	3,500	***	**
Fort Nelson	$$$$	*****	3,500	***	**

Table 12: Water Loop EES Evaluation

In a horizontal loop EES, the refrigerant tubing is laid in a shallow (~2 meter) trench dug into the ground. Rather than laying the pipe linearly in the trench, it is 'slinkied' to minimize space. This method is cheaper than vertical looping because it does not require the same depths (2 meters rather than 30 or more) and can be done with an excavator rather than a specialized drilling machine. It requires a large site to install as the trenches are generally long and would be prohibitive to dense urban areas. A geothermal contractor can specify the proper system based on the siting.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria	$$$$$	***	3,500	***	*
Tofino	$$$$$	***	3,500	***	*
Cranbrook	$$$$$	*****	3,500	***	*
Kamloops	$$$$$	*****	3,500	***	*
Fort St. John	$$$$$	*****	3,500	***	*
Abbotsford	$$$$$	***	3,500	***	*
Terrace	$$$$$	*****	3,500	***	*
Fort Nelson	$$$$$	*****	3,500	***	*

Table 13: Horizontal EES Evaluation

In a vertical loop EES, the refrigerant tubing is buried in drilled holes in the earth, typically 30 meters deep. It requires the least amount of space to install, and provides the most consistent heating/cooling, but is more expensive than any other EES option. This expense considerably increases the payback period, so it is typically used in areas where the site is small and there is no exposed water source, or in industrial processes because it has the highest heating/cooling capacity per site surface area.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria	$$$$$	***	3,500	**	*
Tofino	$$$$$	***	3,500	**	*
Cranbrook	$$$$$	*****	3,500	***	*
Kamloops	$$$$$	*****	3,500	**	*
Fort St. John	$$$$$	*****	3,500	***	*
Abbotsford	$$$$$	***	3,500	**	*
Terrace	$$$$$	*****	3,500	***	*
Fort Nelson	$$$$$	*****	3,500	***	*

Table 14: Vertical EES Evaluation

Desuperheater

A desuperheater is an addition to a ground source heat pump space heating loop that takes excess heat used in space heating and sends it to heat the domestic hot water. It is only active when the space heating/cooling loop is active. If possible, the installation of the desuperheater is recommended as it will increase the economic attractiveness of an EES.

Air Source Heat Pump

An air source heat pump uses the outside air to transfer or extract heat from an internal coolant pumped throughout the system. In the heating season, refrigerant is pumped through a compressor which raises both the temperature and pressure to the point where the refrigerant becomes a superheated vapour at a high temperature and pressure. This refrigerant vapour transfers heat to an incoming airflow, which then is distributed through the home. During the cooling season, the heat pump cycle reverses whereby the air in the home transfers heat to the refrigerant, which then transports the heat outdoors. Both heating and cooling actions are illustrated in the figures below:

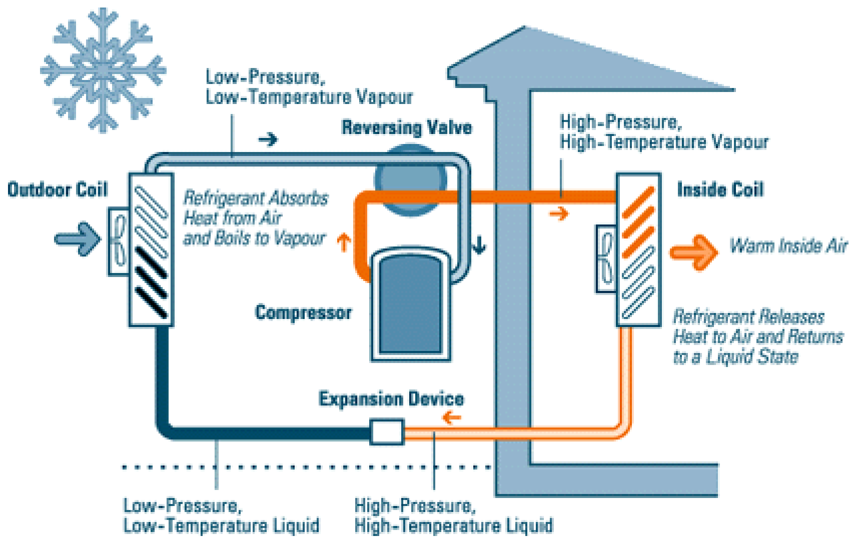

Figure 5: Heating Season

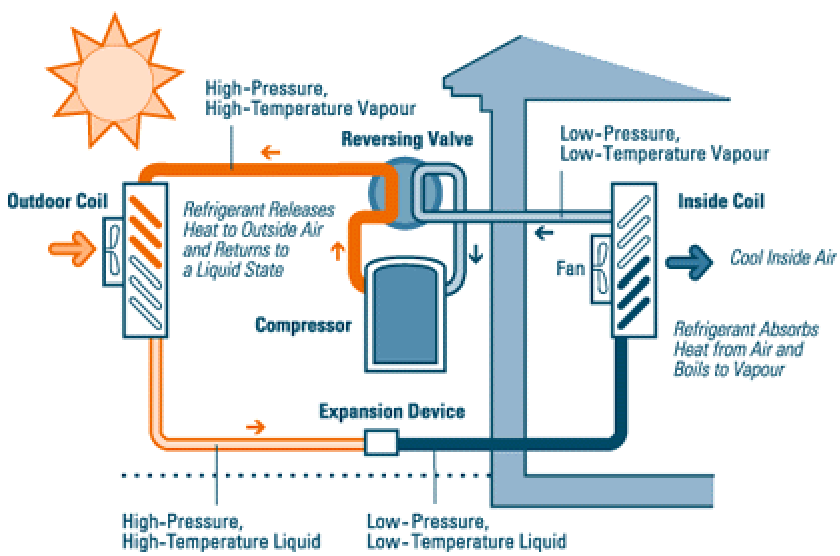

Figure 6: Cooling Season

Heat Pumps as an Add On

Figures 5 and 6 above show homes where all of the home heating needs are supplied by the air source heat pump system. In the retrofit market, there are also add on heat pump systems which supplement the existing furnace system as shown in the figure below.

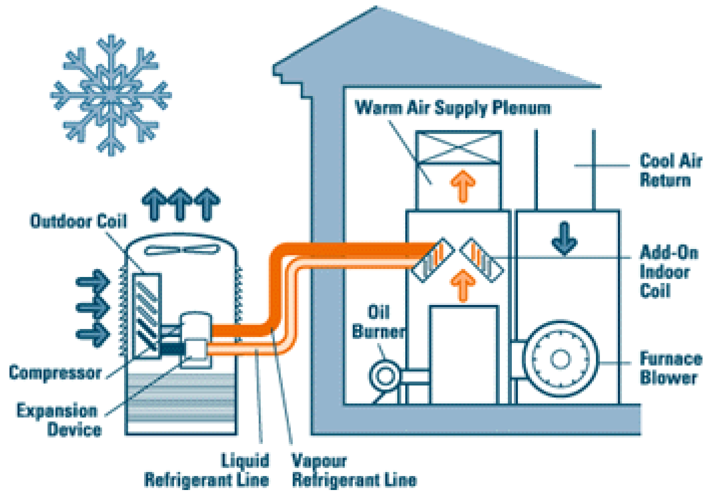

Figure 7: Add On Heat Pump System

Warning on Air Source Heat Pumps

The United States Department of Energy suggests that:

> *"Although air source heat pumps can be used in all parts of the United States, they do not generally perform well over extended periods of sub-freezing temperatures."*

While air source heat pumps are considerably less expensive than geothermal heating, they have several disadvantages in climates with cold winters. Major concerns include the dwindling thermal efficiency of the heat pump in relation to sub-freezing temperatures and the frequent need for a defrost cycle, which sends a cold breeze into the home every time this happens. In the context of this analysis, air source heat pumps would be most viable in coastal British Columbia, where they would have the shortest payback period in the mild climate.

Location	Installation Cost	Appropriateness for Climate	Grants Available [$]	Payback Period	Ease of Installation
Victoria	$$$$	*****	400	***	*
Tofino	$$$$	*****	400	***	*
Cranbrook	$$$$	**	400	*	*
Kamloops	$$$$	****	400	**	*
Fort St. John	$$$$	*	400	*	*
Abbotsford	$$$$	*****	400	***	*
Terrace	$$$$	**	400	**	*
Fort Nelson	$$$$	*	400	*	*

Table 15: Air Source Heat Pump Evaluation

Mini-Split Heat Pumps

Mini-split or Ductless heat pumps are a new technology that allow for the space heating and cooling of zones from a master heat pump. The master air source heat pump supplies up to three radiators around the home. The major advantage of this system is that it does not need a duct system like a conventional air source heat pump which makes it an attractive option for retrofitting on older homes. The major downfall of this system is that it is a very new technology and it is hard to find contractors capable of installing it. At the time of the drafting of this guidance, no installer of mini-split systems could be found in British Columbia.

The Future of Air Source Heat Pumps

There are two emerging technologies in the air source heat pump field that may improve on the non-viable nature in sub-freezing climates: cold climate heat pumps and all climate heat pumps. Both of these new technologies focus on the heating season and are specifically designed to utilize colder outdoor temperatures and to control frosting on the unit. However, at the time of this article, neither of these technologies is commercially available in Canada at this time and are excluded from analysis.

Water Heating Solar Panels

The common notion is that solar panels are used to create electricity from the sun's energy, but they can also heat water! The two typical water heating applications for these solar panels are pool heating and domestic hot water (DHW) heating. These types of panels are divided into two categories based on application: glazed and unglazed. Unglazed solar panels are for the heating of water in a pool system and they work by letting water heat up by trickling through an array of black polyethylene tubes that are heated by the sun. These panels are considerably less expensive in manufacture than glazed panels, but lack any insulation and therefore can only be run in the pool heating season. Glazed panel systems are for DHW heating applications and work by pumping water through tubes warmed by the sun's radiation. The glazed systems are considerably more expensive than the unglazed systems because they are designed to run at a higher temperature and for a longer season. The aesthetic impact of panels will be reduced in the future, as solar panel manufacturers are cottoning on to the market for integrating panels more smoothly with the building envelope. One British Columbia company is now producing a panel that mimics a rooflight - since rooflights on rear and side-facing elevations rarely compromise the character of traditional buildings these products are of interest to the rehabilitation industry.

Window Upgrades

Current BC Heritage Branch Suggestions

A report prepared for the Heritage Branch by Dian Ross; *Operating Energy Reduction in Heritage Buildings* proposed that the majority of heat loss through a window comes from air leakage through the envelope and the most cost-effective method of improving energy efficiency of windows was to eliminate unwanted airflow. In addition, the report made several recommendations to upgrade the energy performance of traditional windows. These upgrades were especially sensitive to maintaining the aesthetic integrity of heritage buildings. The main upgrade recommended involved the addition of a storm window sash. This product is designed to cut down air leakage through the window and create an intermediate climatizing zone between the indoor and outdoor temperatures, increasing the existing window's R-value. The most immediate difference noticed with the upgrade is an increase in occupant comfort near the window. This comfort increase is primarily because the window is no longer drafty and it does not collect as much condensation on its surface.

ecoENERGY Energy Efficiency Evaluation Report

If you have made the decision to have your home evaluated by a Certified Energy Advisor there are important considerations regarding the findings. The upgrades suggested in the findings may not consider the complications around a traditional building envelope. It is important to ask questions about the aesthetic impacts of each recommendation to ensure that you get energy savings without sacrificing any of the charm of a traditional building.