
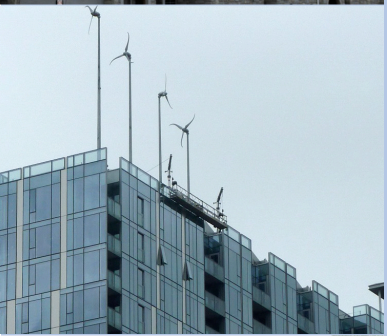



# Cost Assessment of Selection of Energy Efficiency Strategies for Buildings in British Columbia

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Sustainable Energy Solutions

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# Cost Assessment for Selection of Energy Efficiency Strategies for Several Building Types in Select Locations of BC

**The purpose of this study is to evaluate and assess costs associated with new construction that employs energy efficiency strategies which result in a 30% improvement over BC Building Code, as applied to four building types in two model BC geographic locations.**

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# Executive Summary

Light House has been engaged by Pembina Institute on behalf of a number of BC municipalities to assess the cost implications of energy efficiency and renewables strategies that go beyond minimum BC Building Code requirements. This study assesses new construction strategies that can result in a 30 percent improvement over current building code for multi-family residential and non-residential buildings that are admissible under Part 3 of the Building Code and for single family homes and low rise buildings that fall under Part 9 of the BC Building Code.

Light House has used ASHRAE 90.1 (2004) for Part 3 buildings, which is current BC Building Code. In the case of Part 9 buildings, Light House has revised an existing building model that uses Energuide 80 as a baseline in order to minimize the budget required for energy modelling. Energuide 80 is the baseline in City of Vancouver and is 3 points higher than BC Building Code (which is roughly equivalent to Energuide 77)[1]. The study then goes on to provide an estimate of the incremental cost for employing these strategies.

Table 1: Summary of building types included in the Pembina Institute analysis

| | | |
|---|---|---|
| **Existing Building Retrofits** | | |
| Part 9 | Single Family Homes | City of Vancouver Study (see www.greenbuildingleaders.ca) |
| Part 3 | 17 Building Types | City of Vancouver Study (research underway, report expected late 2010) |
| **New Construction** | | |
| Part 9 | Single Family Homes | **Included in this study: City of Vancouver Cost Assessment revised and re-evaluated for Interior BC climatic region** |
| Part 3 | 3 Building Types: medium hotel, medium commercial, mid-rise residential | **Included in this study: Model developed in collaboration with Recollective Consulting** |
| **Renewable Technologies** | | |
| Summary of performance and incremental cost | For several different technologies | BC Sustainable Energy Association study (delivered to Pembina) and other reports. |

[1] It is important to note that the Energuide scale is not linear. Each point is more difficult to attain than the previous.

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# Section I: Part 9 Buildings

The purpose of this section of the study assesses new construction strategies that can result in a 30 percent improvement over current building code for single family homes and low rise buildings that fall under Part 9 of the BC Building Code. Projects that are built in the City of Vancouver are subject to the enhanced performance levels dictated by the Vancouver Building Bylaw.

For this study, we have completed an assessment for model homes located in the City of Vancouver and an assessment for an Interior BC climate. The City of Vancouver Building Bylaw sets energy performance standards for new homes at approximately Energuide 80 under its Green Homes program[2]. By comparison, the BC Building Code's energy performance standard is closer to Energuide 77.

The model homes are buildings based on construction specifications usual to a two-storey south facing single-detached wood frame 2,600 square foot home built in 2008 in one of two climatic regions: Lower Mainland (represented by City of Vancouver) and Interior BC (represented by Terrace). The City of Vancouver model square footage represents the modal average size of a home in the City of Vancouver, and an HRV unit was incorporated to reflect the recent changes in the City's Green Homes Program (close to Energuide 80). The Interior BC model is of a similar size but built to meet BC Building Code specifications (close to Energuide 77).

While objective of the analysis for the City of Vancouver model was to investigate various strategies to achieve Energuide 85, it was determined valuable to model various options for the Interior BC that built on regional construction techniques and climate impacts. As a result, various Energuide levels are derived. The Interior BC bundles include for both natural gas and electric baseboard solutions.

Light House tested two bundles of strategies for this study:

- Bundle A – Envelope upgrades (windows, walls and air-tightness)
- Bundle B – Mechanical upgrades (high efficiency boilers and an air source heat pump[3])

Using the HOT 2000 software, this study evaluates the energy performance and greenhouse gas emissions reductions for each bundle.

## Summary of Bundles

The following tables outline the different features in each bundle for each climatic region. In the Interior BC region two models were developed to reflect whether a home relies on natural gas or electricity.

[2] This study references a June 2009 Light House study for the City of Vancouver which evaluated the incremental costs of building a new singe family Part 9 residential home to a performance standard of Energuide 85 (roughly 30% better than VBBL).

[3] While Ground Source Heat Pumps (GSHPs) do give better performance than Air Source Heat Pumps (ASHPs) due to more constant ground temperature, they can be as much as 5 times more expensive than ASHPs. Given that the purpose of the study was to get to EG85 as cost effectively as possible and this was achieved with the ASHP option, modelling GSHPs were excluded.

Table 2: Summary of Part 9 baseline and bundles – Lower Mainland

| **Summary of upgrades: Lower Mainland** | | | |
|---|---|---|---|
| | **Base Case (EG82)** | **Bundle A (EG85)** | **Bundle B (EG85)** |
| **Walls** | 3.86 RSI (R22) | **5.6 RSI (R32)** | 3.86 RSI (R22) |
| **Air tightness** | 3.57 ACH | **1.5 ACH** | 3.57 ACH |
| **Windows** | 2.0 USI (0.35 u-value) | **1.0 USI (0.175 u-value)** | 2.0 USI (0.35 u-value) |
| **Space heating** | 90% efficient boiler | 90% efficient boiler | **95% efficient boiler** |
| **Domestic hot water** | Gas fired tank | Gas fired tank | **Condensing boiler** |
| **Heat pump** | -- | -- | **7 kW air source** |

Table 3: Summary of Part 9 baseline and bundles – Interior BC, natural gas

| **Summary of upgrades: Interior BC (natural gas)** | | | |
|---|---|---|---|
| | **Base Case (EG77)** | **Bundle A (EG82)** | **Bundle B (EG84)** |
| **Walls** | 3.5 RSI (R20) | **7.3 RSI (R41)** | 3.5 RSI (R20) |
| **Air tightness** | 4.55 ACH | **3.57 ACH** | 4.55 ACH |
| **Windows** | 1.4 USI (0.25 u-value) | **1.0 USI (0.175 u-value)** | 1.4 USI (0.25 u-value) |
| **Space heating** | 95% efficient Forced Air Furnace | 95% efficient Forced Air Furnace | 95% efficient Forced Air Furnace |
| **Domestic hot water** | Condensing boiler | Condensing boiler | Condensing boiler |
| **Heat pump** | -- | -- | **12.5 kW air source** |

Table 4: Summary of Part 9 baseline and bundles – Interior BC, electric

| **Summary of upgrades: Interior BC (electric)** | | | |
|---|---|---|---|
| | **Base Case (EG75)** | **Bundle A (EG80)** | **Bundle B (EG83)** |
| **Walls** | 3.5 RSI (R20) | **7.3 RSI (R41)** | 3.5 RSI (R20) |
| **Air tightness** | 4.55 ACH | **3.57 ACH** | 4.55 ACH |
| **Windows** | 1.4 USI (0.25 u-value) | **1.0 USI (0.175 u-value)** | 1.4 USI (0.25 u-value) |
| **Space heating** | 100% efficient baseboard | 100% efficient baseboard | 100% efficient baseboard |
| **Domestic hot water** | Conventional electric storage tank | Conventional electric storage tank | Conventional electric storage tank |
| **Heat pump** | -- | -- | **12.5 kW air source** |

## Summary of Energy Savings

The study calculated energy savings and associated greenhouse gas emissions reductions using energy mixes specific to the City of Vancouver and Terrace, BC.

The City of Vancouver/Lower Mainland bundles have annual energy cost savings that range from 22% to 28%. The impact on greenhouse gas emissions is greater, ranging from 34% to 59%. In the Terrace/Interior BC model, the annual energy savings for a home with natural gas are restricted to between 12.8% and 15.8 %, though greenhouse gas emissions reductions vary greatly from 24.7% to 65.5%. For a home in the Interior powered with electricity[4], energy savings range from 18.9% to 31.3%, and greenhouse gas reductions range from 19.4% to 31.9%. Table 5, Table 6 and Table 7 outline these savings and the resulting changes in emissions.

For detailed breakdown of the energy saving by type of energy (electricity or natural gas), see Appendix III –Hot 2000 technical comparisons.

Table 5: Bundle comparison of energy costs and greenhouse gas emissions – Lower Mainland

| **Summary of energy costs and greenhouse emissions: Lower Mainland** | | | |
|---|---|---|---|
| | **Base Case** | **Bundle A** | **Bundle B** |
| Energy costs | $1,458 | $1,139 | $1,056 |
| **Savings** | **-** | **$319** | **$402** |
| % change | - | 22% | 28% |
| GHG emissions (t) | 3.15 | 2.09 | 1.28 |
| **GHG reductions (t)** | **-** | **1.06** | **1.87** |
| % change | - | 34% | 59% |

Table 6: Bundle comparison of energy costs and greenhouse gas emissions – Interior BC, natural gas

| **Summary of energy costs and greenhouse emissions: Interior BC (natural gas)** | | | |
|---|---|---|---|
| | **Base Case** | **Bundle A** | **Bundle B** |
| Energy costs | $1,574 | $1,326 | $1,373 |
| **Savings** | **-** | **$248** | **$201** |
| % change | - | 15.8% | 12.8% |
| GHG emissions (t) | 3.28 | 2.47 | 1.13 |
| **GHG reductions (t)** | **-** | **0.81** | **2.15** |
| % change | - | 24.7% | 65.5% |

[4] For the various electric scenarios, the DHW was modelled as both a conventional storage tank and as an instantaneous electric but it did not change the Energuide (EG) rating. This is because although the instantaneous electric is about 10% more efficient than a storage tank the amount of energy saved is small in comparison to the heating load and therefore does not change the EG. By comparison, the energy savings from natural gas conventional storage tank to instantaneous natural gas is greater, about 28%, and therefore has more of an impact on the EG rating.

Table 7: Bundle comparison of energy costs and greenhouse gas emissions – Interior BC, electric

| Summary of energy costs and greenhouse emissions: Interior BC (electric) | | | |
|---|---|---|---|
| | **Base Case** | **Bundle A** | **Bundle B** |
| Energy costs | $2,286 | $1,854 | $1,570 |
| **Savings** | **-** | **$432** | **$716** |
| % change | - | 18.9% | 31.3% |
| GHG emissions (t) | 0.72 | 0.58 | 0.49 |
| **GHG reductions (t)** | **-** | **0.14** | **0.23** |
| % change | - | 19.4% | 31.9% |

## Summary of Incremental Costs

This section outlines and compares the different incremental costs associated with each bundle.

### *Bundle A – Envelope upgrades*

The key upgrades in the this option are to (1) increase the air tightness of the building, measured by the air changes per hour (ACH), (2) increase the wall insulation, and (3) increase the thermal performance of the windows. The incremental costs of each of these upgrades are shown in the tables below. This is followed with a description of the methods that builders can use to achieve these performance upgrades.

Table 8: Bundle A incremental cost comparison – Lower Mainland

| *Bundle A: Lower Mainland* | | |
|---|---|---|
| **Baseline** | **Upgrades** | **Costs** |
| Air tightness of 3.57 (ACH) | Upgrade to 1.5 ACH | n/a |
| Wall = 3.86 RSI (R22) | Upgrade to 5.6 RSI (R32) + $1-3.50 psf | $2,978 - $10,423 |
| Overall Window conductance value = 2.0 USI (0.35 u-value) | Upgrade to 1.0 USI (0.175 u-value) | $1,215 |
| | **Total incremental cost** | **$4,193 – $11,638** |

Table 9: Bundle A incremental cost comparison – Interior BC

| *Bundle A: Interior BC (natural gas or electric)* | | |
|---|---|---|
| **Baseline** | **Upgrades** | **Costs** |
| Air tightness of 4.55 (ACH) | Upgrade to 3.57 ACH | n/a |
| Wall = 3.5 RSI (R20) | Upgrade to 7.3 RSI (R41) + $2-3.75 psf | $5,956 - $11,168 |
| Overall window conductance value = 1.4 USI (0.25 u-value) | Upgrade to 1.0 USI (0.175 u-value) | $730 |
| | **Total incremental cost** | **$6,686 - $11,898** |

**Increasing air-tightness**

Achieving increased air-tightness depends on the quality of the air barrier that is created around the building. While both the BC Building Code and the Vancouver Building By-law 2007 require an effective air barrier, this requirement is not prescriptive and there are many different materials and systems that can be used to create an air barrier.

Various sub-trades interact the with the air barrier, without any of them being expressly responsible for its final integrity. This leaves it to the contractor to ensure that the correct systems, techniques and job-site habits are communicated and adhered to. Because of this, it is not possible to assess incremental costs in a meaningful way.

**Wall insulation upgrades**

This upgrade calls for increased insulation, to RSI 5.64 (R32) in the City of Vancouver model, and to RSI 7.3 (R41) in Terrace. There are three methods can achieve this higher insulation level:

1. Increase the resistance value for the insulation in the 2x6 wall cavity to 5.64 RSI (R32) or 7.3 RSI (R41). This can only be accomplished with spray-foam insulation, which delivers approximately R7 per inch.[5] For the City of Vancouver model this would mean increasing the amount of insulation by 2 inches and in the Terrace model we would require an additional 3 inches. The spray foam ranges in installed cost from $2.00 – $3.50 per sf.

2. Continue with the 3.86 RSI (R22) / 3.5 RSI (R20) in the wall cavity and add extruded polystyrene on the outside. XPS can deliver approximately 4.7-5R per inch. With the City of Vancouver model, 2 inches would result in the effective value of 5.64 RSI (R32).[6] For the Terrace model, 4 inches or more would be required. In the case of XPS, there is an additional $1.51 per sf for 2 inches or $3.02 per sf for 4 inches, but this is only the material cost and doesn't include installation.

3. Use structurally insulated panels that have an RSI of 5.64 (R32) or 7.3 RSI (R41). SIPs require a completely different construction approach and it is not appropriate to compare a SIP installation with other construction approaches. However, the incremental cost of going from a structurally insulated panel that is R24 (6 inch) to R32 (8 inch) is approximately $1.00 - $1.50 per sf, and to go from R20 (5 inch) to R40 (10 inch) is approximately $2.50 - $3.75 per sf.

The incremental costs associated with the City of Vancouver model wall upgrade range from $1.00 (for SIPs) to $3.50 (spray foam insulation) per sf of wall area. With the house having a total insulated wall area of 2,978.37 sf, the total incremental cost for the wall upgrade ranges from approximately $2,978 to $10,423.

The incremental costs associated with the Terrace model wall upgrade range from $2.00 - $3.75 psf of wall area. With the house having a total insulated wall area of 2,978.37 sf, the total incremental cost for the wall upgrade ranges from approximately $5,956 - $11,168.

[5] The insulation values associated with each material were compiled by Light House research for the City of Vancouver's Passive Design Toolkit for Homes and are set out on pages 19-21 of that document.
[6] http://wallandceiling.ca/magazine/article/Archetype_Sustainable_House_Green_today_green_tomorrow.html

**Window upgrades**

The windows on the City of Vancouver model building have an overall conductance value of 2.0 USI (0.35 u-value). This is the ENERGYSTAR minimum standard for windows in Zone A. The overall conductance value includes the panes, the frame, and the window style (slider, awning, casement, picture, etc). For example, a double-pane, low-e, argon filled sliding window from Westcoast Windows has a USI value of 1.77, whereas a casement or picture of the same would have a 1.55 USI.

In the City of Vancouver upgrade, the overall conductance of the windows was increased to 1.0 USI (0.175 u-value). At this value, the window would be triple-paned, with 2 coats of low-e, and double argon filled.[7] The lowest possible value while still maintaining two panes and a vinyl frame is approximately 1.6 USI (0.28).[8]

The cost difference between USI 2.0 and 1.0 is approximately $3.33 per sf. With our model house having a total window area of 365.43 sf, the total incremental cost for the window upgrade is $1,215.

The windows on the Terrace model building have an overall conductance value of 1.4 USI (0.25 u-value). This is currently the ENERGYSTAR minimum standard for windows in Zone D, but effective June 1, 2010 the qualification levels for all of the products will become more stringent by eliminating the current level for Zone A and moving the remaining qualification levels up one zone. New levels have for Zone D have been created.[9] The model windows must be upgraded to 1.0 USI (0.175 u-value).

Table 10: Updates to ENERGYSTAR window standards

| Windows | | | | | |
|---|---|---|---|---|---|
| Zone | Heating Degree-Day Range | Compliance Paths | | | |
| | | Energy Rating (ER) | or | U-Factor | |
| | | Minimum ER (dimensionless) Maximum U-Factor 2.00 $W/m^2 \cdot K$ (0.35 $Btu/h \cdot ft.^2 \cdot °F$) | | Maximum U-Factor $W/m^2 \cdot K$ ($Btu/h \cdot ft.^2 \cdot °F$) | Minimum ER (dimensionless) |
| A | ≤ 3500 | 21 | or | 1.80 (0.32) | 13 |
| B | > 3500 to ≤ 5500 | 25 | or | 1.60 (0.28) | 17 |
| C | > 5500 to ≤ 8000 | 29 | or | 1.40 (0.25) | 21 |
| D | > 8000 | 34 | or | 1.20 (0.21) | 25 |

The cost difference between USI 1.4 and 1.0 is less significant, as USI 1.4 implies minimum triple pane glass. The incremental costs would be for increasing the number of panes that have a low-e

[7] JELD–WEN Windows & Doors, conversation with sales associate, March 2009.
[8] West Coast Windows, JELD-WEN – March 2009.
[9] http://oee.nrcan.gc.ca/residential/business/manufacturers/requirements/index.cfm?attr=12#announcement

coating, or the number of argon filled spaces, and would run at approximately $1.50 per sf.[10] With our model house having a total window area of 365.43 sf, the total incremental cost for the window upgrade is approximately $730.

### *Bundle B – Mechanical upgrades, air source heat pump*

The key upgrades in this option are (1) to increase the efficiency of the boiler, (2) upgrading the domestic hot water to a condensing boiler, and (3) integrating an air source heat pump. The incremental costs for each of these upgrades are shown in the tables below.

Table 11: Bundle B incremental cost comparison – Lower Mainland

| ***Bundle B: Lower Mainland*** | | |
|---|---|---|
| **Baseline** | **Upgrades** | **Costs** |
| Condensing boiler = 90% efficient | Upgrade to a 95% efficient condensing boiler | $0 |
| Domestic hot water = direct vent (sealed) | Upgrade to condensing boiler | $330 |
| No heat pump | Upgrade to 7kW air source heat pump. | $8,350 |
| | **Total incremental cost** | **$8,680** |

Table 12: Bundle B incremental cost comparison – Interior BC

| ***Bundle B: Interior BC (natural gas or electric)*** | | |
|---|---|---|
| **Baseline** | **Upgrades** | **Costs** |
| No heat pump | Upgrade to 12.5kW air source heat pump. | $8,480 |
| | **Total incremental cost** | **$8,480** |

According to industry feedback, most boilers on the market today are 92% - 95% efficient and so increasing the efficiency from the base case is just a matter of picking the right model. There is negligible incremental cost associated with this increase in efficiency rating.

In upgrading of the domestic hot water system to a condensing boiler, the incremental cost is approximately $330 more than the gas-fired tank.[11]

The 7kW (2 tonne) or 12.5kW (3.5 tonne) air source heat pumps are a significant cost (approximately $8,300 and $8,500 respectively, supply only), which result in a minimum pay-back of roughly 12 years[12].

[10] JELD–WEN Windows & Doors, conversation with sales associate, February 2010.
[11] Integrity Mechanical, March 2009
[12] Estimate provided by Mitsubishi Electric March 1st 2010 - http://www.mitsubishielectric.ca

### *Incentives*

There are a number of incentives available for all of the upgrades outlined above, including federal grants and BC Hydro special offers. The may change the incremental cost calculations slightly in specific cases. For example, PST and GST[13] may be exempt on select brands of windows, and payment can be deferred for up to six months for others. A complete list is of grants and incentives can be accessed here: http://www.sustainablebuildingcentre.com/resourcecentre/grants_incentives.

## Cost Effectiveness of Upgrades

The value of energy savings and greenhouse gas reductions outlined above have been adjusted based on each upgrade's expected lifespan and used to calculate a simple net cost of installation. Light House did not apply a discount rate to the future energy savings. Although there is a time value of money consideration, energy costs are also projected to increase. It is beyond the scope of this project to determine what the net effect of this process would be, and therefore TVM has been ignored in this model. The cost effectiveness is summarized in the tables below.

Table 13: Cost effectiveness of each bundle - Lower Mainland

| ***Cost-effectiveness in reducing GHGs: Lower Mainland*** | | |
|---|---|---|
| | **Bundle A** | **Bundle B** |
| Expected lifespan of upgrade | 40 years | 20 years |
| Incremental Cost | $4,193 to $11,638 | $8,330 to $12,558 |
| Value of energy savings (energy saving * expected lifespan) | $12,760 | $8,040 |
| Net cost / payback (incremental cost – value of energy savings) | - $8,567 to - $1,122 | $290 to $4,518 |
| GHG tonnes reduced over lifespan (tonnes reduced * expected lifespan | 42.4 | 37.4 |
| **Cost/tonne of GHG reduced** | **$--** | **$8 - $121** |

[13] It is anticipated that any change from PST/GST to HST (as proposed by the BC Government as of date of writing) will also similarly exempt high efficiency equipment and appliances.

Table 14: Cost effectiveness of each bundle - Interior BC, natural gas

| ***Cost-effectiveness in reducing GHGs: Interior BC – natural gas*** | | |
|---|---|---|
| | **Bundle A** | **Bundle B** |
| Expected lifespan of upgrade | 40 years | 20 years |
| Incremental Cost | $6,686 to $11,898 | $8,680 |
| Value of energy savings (energy saving * expected lifespan) | $9,920 | $4,020 |
| Net cost / payback (incremental cost – value of energy savings) | - $3,234 to $1,978 | $4,660 |
| GHG tonnes reduced over lifespan (tonnes reduced * expected lifespan | 32.4 | 43 |
| **Cost/tonne of GHG reduced** | **$-- to $61** | **$108** |

Table 15: Cost effectiveness of each bundle - Interior BC, electric

| ***Cost-effectiveness in reducing GHGs: Interior BC – electric*** | | |
|---|---|---|
| | **Bundle A** | **Bundle B** |
| Expected lifespan of upgrade | 40 years | 20 years |
| Incremental Cost | $6,686 to $11,898 | $8,480 |
| Value of energy savings (energy saving * expected lifespan) | $17,280 | $14,320 |
| Net cost / payback (incremental cost – value of energy savings) | - $10,594 to - $5,382 | - $5,840 |
| GHG tonnes reduced over lifespan (tonnes reduced * expected lifespan | 5.6 | 4.6 |
| **Cost/tonne of GHG reduced** | **$--** | **$--** |

## Summary and Caveats

Based on this study, Bundle A offers the highest cost effectiveness for reduction of greenhouse gas emissions regardless of climate and primary energy source. In each model, the energy savings over 40 years outweighs the incremental costs associated with the strategies of Bundle A, which focus on improvements to the building envelope and air-tightness. A major consideration is that the model is dependent on the assumed characteristics of the base building, and for buildings that have not been built to current BC or Vancouver building codes and bylaws, the incremental cost for each Bundle may vary.

The envelope upgrades of Bundle A are often considered a considerable capital investment versus mechanical upgrades represented by Bundle B, but this study does indicate that due to the longer lifespan of these upgrades, they represent high cost effectiveness in terms of GHG reductions. However, a homeowner's investment horizon may be considerably less than 40 years in many instances[14].

[14] Interview with the City of Vancouver suggest that for multi-family and starter-home categories, the term of ownership is less than 2 years. In most cases, homes are bought and sold within a 5 year window.

# Section II: Part 3 Buildings

Light House identified three categories of buildings on which to focus this part of the study: medium commercial, medium hotel and mid-rise multi unit residential. This is based on the contribution of these buildings to greenhouse gas emissions, and the proportion of these buildings in the given municipalities (both estimated to be high, based on data provided by Pembina as part of the BC Hydro CPR 2007 Refuelling Study.

BC Hydro model building types were used to determine the base case for the Lower Mainland and Interior BC climatic regions, with a number of Energy Conservation Measures (ECMs) modelled for their effectiveness to improve energy performance by 30 percent over ASHRAE 90.1 – 2004.

Recollective Consulting (www.recollective.ca) undertook this study using the EE4 Version 1.7 energy modelling software, released and administered by Natural Resources Canada. The base buildings were assumed to be located in Burnaby, BC and Terrace, BC. Recollective modelled the estimated energy savings associated with a number of ECMs, and then provided recommendations on bundles which would best meet the target 30% improvement in energy consumption over the ASHRA 90.1 – 2004 baseline. Broadly, ECMs that were considered to best meet the targets included enhanced envelope performance, variable speed fans and pumps, hydronic heating and cooling, high efficiency condensing boilers, low flow plumbing fixtures and enhanced ventilation with heat recovery. Choices were not based on an evaluation of cost effectiveness, rather on likelihood of achieving the target energy performance standard.

The complete energy modelling study is attached in Appendix II: Part 3 Energy Study Report. Highlights of the study are outlined below, followed by a discussion of cost estimates for achieving specific bundles of measures.

## Summary of Energy Conservation Measures

The following is a list of ECMs modelled for each building type and climatic region:

1. Improved insulation of Wall and Roof
2. Improved window performance (U value and SHGC)
3. Reduced lighting power density (10% and 25% over ASHRAE 90.1 – 2004)
4. Heat recovery (60% efficiency)
5. Hydronic heating and cooling system
6. Variable speed fans
7. Variable speed pumps
8. Low flow plumbing fixtures
9. High efficiency condensing boilers (94% efficiency)
10. Renewable energy such as solar PV and solar hot water heating

The tables below indicate what specific strategies have been implemented to accomplish the ECMs that have been modelled for each building type. For instance, ECM 1. Improved insulation of Wall and Roof is achieved by increasing the wall R-value from R15 to R18, and the roof R-value from R30 to R40.

Table 16: Summary baseline and ECMs for Office building

| **Office** | o Height: 10-storey<br>o Floor Area: 9000 m2<br>o Window to Wall Ratio: 50% | |
|---|---|---|
| | **Base building** | **Improved building strategies** |
| | **As per ASHRAE 90.1 – 2004** | |
| Building Envelope<br>*Wall*<br>*Roof*<br>*Fenestration* | As per ASHRAE 90.1 – 2004<br>R15<br>R30 | <br>R18<br>R40<br>U=0.40, SHGC = 0.38 |
| HVAC System efficiency | Boiler and Chiller, VAV system, no heat recovery | 60% efficiency – through centralized heat recovery ventilator<br>In-floor radiant heating and cooling<br>Variable speed fans/Demand Control Ventilation<br>Variable speed pumps |
| Lighting System | As per ASHRAE 90.1 – 2004 | 10% Lighting Power Density Reduction over ASHRAE 90.1 – 2004<br>25% Lighting Power Density Reduction over ASHRAE 90.1 – 2004<br>Daylight sensors in perimeter space – Continuous dimming |
| Plug Loads<br>Domestic Hot Water Loads | As per default input in EE4 library<br>As per default calculation by EE4<br>Gas fired boiler to heat domestic hot water, 82% efficiency<br>Regular flow rate plumbing fixtures | <br><br>High efficiency condensing boilers with 94% efficiency<br>Low flow plumbing fixtures<br>*Sink (0.03 L/s)*<br>*Lavatory (0.03 L/s)*<br>*Shower head/Bathtub (0.09 L/s)* |
| Infiltration | As per default input in EE4 library | |

Table 17: Summary baseline and ECMs for Hotel

| **Hotel** | o Height: 10-storey<br>o Floor Area: 8000 m2<br>o Window to Wall Ratio: 40% | |
|---|---|---|
| | **Base building** | **Improved building strategies** |
| | **As per ASHRAE 90.1 – 2004** | |
| Building Envelope<br>*Wall*<br>*Roof*<br>*Fenestration* | As per ASHRAE 90.1 – 2004<br>R15<br>R30 | <br>R18<br>R40<br>U=0.40, SHGC = 0.38 |
| HVAC System efficiency | Boiler and Chiller, Fan coil system, no heat recovery | 60% efficiency – through centralized heat recovery ventilator<br>In-floor radiant heating and cooling<br>Variable speed fans/Demand Control Ventilation<br>Variable speed pumps |
| Lighting System | As per ASHRAE 90.1 - 2004 | 10% Lighting Power Density Reduction over ASHRAE 90.1 – 2004<br>25% Lighting Power Density Reduction over ASHRAE 90.1 – 2004<br>Daylight sensors in perimeter space – Continuous dimming |
| Plug Loads | As per default input in EE4 library | |
| Domestic Hot Water Loads | As per default calculation by EE4<br>Gas fired boiler to heat domestic hot water, 82% efficiency<br>Regular flow rate plumbing fixtures | <br>High efficiency condensing boilers with 94% efficiency<br>Low flow plumbing fixtures<br>*Sink (0.03 L/s)*<br>*Lavatory (0.03 L/s)*<br>*Shower head/Bathtub (0.09 L/s)* |
| Infiltration | As per default input in EE4 library | |

Table 18: Summary baseline and ECMs for Mid rise MURB

| **MURB** | o Height: 10-storey<br>o Floor Area: 5000 m2<br>o Window to Wall Ratio: 45% | |
|---|---|---|
| | **Base building** | **Improved building strategies** |
| | **As per ASHRAE 90.1 – 2004** | |
| Building Envelope | As per ASHRAE 90.1 – 2004 | |
| *Wall* | R15 | R18 |
| *Roof* | R30 | R40 |
| *Fenestration* | | U=0.40, SHGC = 0.5 |
| HVAC System efficiency | Electric heating, no cooling, no heat recovery | 60% efficiency – through centralized heat recovery ventilator<br>In-floor radiant heating/overhead radiant heating<br>In-floor radiant heating/overhead radiant heating w/ Variable speed pumps |
| Lighting System | As per ASHRAE 90.1 – 2004 | 40% CFLs (40%*13+60%*60=41.2, 1-41.2/60=0.31 or 31% Lighting Power Density<br>100% CFLs (1-13/60=0.78 or 78% Reduction) |
| Plug Loads | As per default input in EE4 library | |
| Domestic Hot Water Loads | As per default calculation by EE4<br>Gas fired boiler to heat domestic hot water, 82% efficiency<br>Regular flow rate plumbing fixtures | <br>High efficiency condensing boilers with 94% efficiency<br>Low flow plumbing fixtures<br>*Sink (0.03 L/s)*<br>*Lavatory (0.03 L/s)*<br>*Shower head/Bathtub (0.09 L/s)* |
| Infiltration | As per default input in EE4 library | |

## Summary of Energy Study Results

Based on the energy savings associated with each ECM, Recollective Consulting have outlined bundles of strategies that would be most effective at achieving a 30% improvement in energy use over ASHRAE 90.1 – 2004. The results of the energy improvement associated with each ECM are provided in detail in Appendix II: Part 3 Energy Study Report. This report also discusses the energy saving potential of other ECMs in more detail. The tables below highlight the ECMs that Recollective has suggested be part of the bundles for each building in two different climatic regions

Table 19: Burnaby Office ECM Bundles

| | **Base building** | **Improved building strategies** | **Energy saving** | **Energy saving** |
|---|---|---|---|---|
| | **As per ASHRAE 90.1 – 2004** | | **GJ** | **%** |
| HVAC System efficiency | Boiler and Chiller, VAV system, no heat recovery | In-floor radiant heating and cooling | 936 | 17.8% |
| | | Variable speed fans/Demand Control Ventilation | 372 | 7.1% |
| | | Variable speed pumps | 431 | 8.2% |
| Domestic Hot Water Loads | Regular flow rate plumbing fixtures | Low flow plumbing fixtures<br>*Sink (0.03 L/s)*<br>*Lavatory (0.03 L/s)*<br>*Showerhead/Bathtub (0.09 L/s)* | 265 | 5.0% |
| **COMBINED ENERGY REDUCTION POTENTIAL** | | | 1642 | 31.2% |

Table 20: Burnaby Hotel ECM Bundles

| | Base building | Improved building strategies | Energy saving | Energy saving |
|---|---|---|---|---|
| | **As per ASHRAE 90.1 – 2004** | | **GJ** | **%** |
| Domestic Hot Water Loads | Regular flow rate plumbing fixtures | Low flow plumbing fixtures<br>*Sink (0.03 L/s)*<br>*Lavatory (0.03 L/s)*<br>*Shower head/Bathtub (0.09 L/s)* | 2010 | 28.1% |
| | Gas fired boiler to heat domestic hot water, 82% efficiency | High efficiency condensing boilers with 94% efficiency | 643 | 9.0% |
| **COMBINED ENERGY REDUCTION POTENTIAL** | | | 2465 | 34.5% |

Table 21: Burnaby MURB ECM Bundles

| | Base building | Improved building strategies | Energy saving | Energy saving |
|---|---|---|---|---|
| | **As per ASHRAE 90.1 – 2004** | | **GJ** | **%** |
| Building Envelope | As per ASHRAE 90.1 – 2004<br>Fenestration | U=0.40, SHGC = 0.5 | 232 | 12.2% |
| Domestic Hot Water Loads | Regular flow rate plumbing fixtures | Low flow plumbing fixtures<br>Sink (0.03 L/s)<br>Lavatory (0.03 L/s)<br>Shower head/Bathtub (0.09 L/s) | 372 | 19.6% |
| **COMBINED ENERGY REDUCTION POTENTIAL** | | | 604 | 31.7% |

Table 22: Terrace Office ECM Bundles

| | Base building | Improved building strategies | Energy saving | Energy saving |
|---|---|---|---|---|
| | **As per ASHRAE 90.1 – 2004** | | **GJ** | **%** |
| Building Envelope | As per ASHRAE 90.1 – 2004<br>*Fenestration* | U=0.40, SHGC = 0.38 | 381 | 6.4% |
| HVAC System efficiency | Boiler and Chiller, VAV system, no heat recovery | In-floor radiant heating and cooling | 725 | 12.2% |
| | | Variable speed pumps | 567 | 9.5% |
| Domestic Hot Water Loads | Gas fired boiler to heat domestic hot water, 82% efficiency | High efficiency condensing boilers with 94% efficiency | 367 | 6.2% |
| **COMBINED ENERGY REDUCTION POTENTIAL** | | | 1833 | 30.8% |

Table 23: Terrace Hotel ECM Bundles

| | Base building | Improved building strategies | Energy saving | Energy saving |
|---|---|---|---|---|
| | **As per ASHRAE 90.1 – 2004** | | **GJ** | **%** |
| Domestic Hot Water Loads | Gas fired boiler to heat domestic hot water, 82% efficiency | High efficiency condensing boilers with 94% efficiency | 2010 | 25.5% |
| | Regular flow rate plumbing fixtures | Low flow plumbing fixtures<br>*Sink (0.03 L/s)*<br>*Lavatory (0.03 L/s)*<br>*Shower head/Bathtub (0.09 L/s)* | 705 | 8.9% |
| **COMBINED ENERGY REDUCTION POTENTIAL** | | | 2527 | 32.0% |

Table 24: Terrace MURB ECM Bundles

| | Base building<br>As per ASHRAE 90.1 – 2004 | Improved building strategies | Energy saving<br>GJ | Energy saving<br>% |
|---|---|---|---|---|
| Building Envelope | As per ASHRAE 90.1 – 2004<br>*Fenestration* | U=0.40, SHGC = 0.5 | 271 | 12.4% |
| Lighting System | As per ASHRAE 90.1 - 2004 | 40% CFLs (40%*13+60%*60=41.2, 1-41.2/60=0.31 or 31% Lighting Power Density | 44 | 2.0% |
| Domestic Hot Water Loads | Regular flow rate plumbing fixtures | Low flow plumbing fixtures<br>*Sink (0.03 L/s)*<br>*Lavatory (0.03 L/s)*<br>*Shower head/Bathtub (0.09 L/s)* | 372 | 17.1% |
| **COMBINED ENERGY REDUCTION POTENTIAL** | | | 694 | 31.9% |

## Summary of Incremental Costs

It is important to note that costs are not itemized based on specific ECM but rather reflect general costs for changes that could be expected based on Light House's and Omicron Group's knowledge of the industry. These include soft costs, permitting, and other construction related impacts.

### *Office buildings*

The office market has led the uptake of energy efficiency improvements and over time has refined design and construction methodologies to drive down incremental costs associated with energy efficiency improvements.

Costs increments are estimated based on the degree of change necessary to the building envelope and the mechanical and electrical systems. The assumptions are based on a generic building and assumes a replacement approach to basic building components with no synergies or efficiency or trade-off savings (worst case):

**Architecture = 40% of total project cost;**
Envelope 60% of total architectural cost;
Incremental envelope performance enhancement 10%
**Total incremental cost of architectural work 2.4%**

**Mechanical = 20% of total project cost**
Cost of incremental mechanical performance enhancement 20%
**Total incremental cost of mechanical work = 4%**[15]

**Electrical = 15% of total project cost;**
Cost of incremental electrical performance enhancement 10%
**Total incremental cost of electrical work = 1.5%**

**Total incremental cost of achieving the enhanced building = 7.9%**

[15] Interview with Cobalt Engineering suggested a range of 2 – 4% for necessary improvements related to mechanical services for offices which is line with the Omicron estimate.

Interviews with practitioners confirm that in many instances, these costs have been fully absorbed[16]. This is particularly the case with higher quality Class A projects in high-demand locations (such as downtown Vancouver, Victoria, etc). However, these will have assumed a higher base cost. An incremental cost range of 0 – 7.9%[17] is presented conditional on location and class of office proposed with the higher increments related to lower spec offices located in smaller communities. Costs are presented as a unit of gross floor area (GFA).

Table 25: Office incremental cost assessment

| **Office** | o Height: 10-storey<br>o Floor Area: 9,000sm (96,876sf)<br>o Window to Wall Ratio: 50% | Incremental cost premium:<br>0% to 7.9% |
|---|---|---|
| | **Base building** | **Improved building** |
| Cost per unit GFA | $2,206 - $2,959/sm ($205-275/sf) | $2,380 - $3193/sm ($221 - $297/sf) |
| Incremental cost per unit GFA | | $0 - $234/sm ($0 - $22/sf) |
| Cost for 9,000sm building | $19.8m - $26.6m | $21.4m - $28.7m |
| Total incremental cost | | $0 - $2.1m* |

*Note that incremental cost is directly related to how close a project is to the margin. The closer to the marginal cost, the greater the potential for incremental costs. Therefore, while some projects may not incur an incremental cost, they will be positioned at a higher base building price point.

### *Hotels*

The hotel market is characterized by a wide spread of amenity from the basic to the luxury international suite format. While cost increments to improve energy efficiency for the affordable end of the market will be high (estimated in the range of 7.7%)[18], energy an environmental performance is increasingly absorbed into high-end urban projects[19] and resort projects that focus on the eco-tourism market[20]. Significant energy saving potential is offered through swimming pool heat recovery, presence of parkades, etc, making higher performance easier to attain for more extensively appointed buildings.

Costs increments are estimated based on the degree of change necessary to the building envelope and the mechanical and electrical systems. The assumptions are based on a generic building and assumes a replacement approach to basic building components with no synergies or efficiency or trade-off savings (worst case):

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[16] According to Cobalt Engineering and Discovery Parks Inc, the LEED Platinum rated Discovery Green in Burnaby BC is 31.8% better than ASHRAE 90.1.2004 in terms of cost and 25.8% better energy. The additional costs were effectively zero as the enhanced performance was achieved through the substitution of a conventional HVAC system with a Variable Refrigerant Flow System from Mitsubishi Canada.

[17] Cost estimate provided by the Omicron Group

[18] Cost estimate provided by the Omicron Group.

[19] According to Ledcor Construction, a geo-exchange system was included into the Shangri-la hotel in Vancouver with no impact over the budget.

[20] For example the LEED Platinum Parkside Resort and Spa, Victoria

**Architecture = 40% of total project cost;**
Envelope 55% of total architectural cost;
Incremental envelope performance enhancement 10%
**Total incremental cost of architectural work 2.2%**

**Mechanical = 20% of total project cost;**
Cost of incremental mechanical performance enhancement 20%
**Total incremental cost of mechanical work = 4%**

**Electrical = 15% of total project cost;**
Cost of incremental electrical performance enhancement 10%
**Total incremental cost of electrical work = 1.5%**

**Total incremental cost of achieving the enhanced building = 7.7%**

An incremental cost range of 0 – 7.7%[21] is presented conditional on location and class of hotel and proposed with the higher increments related to lower spec, less well-appointed projects (no pool, etc) located in smaller communities. Costs are presented as a unit of gross floor area (GFA).

Table 26: Hotel incremental cost assessment

| **Hotel** | o Height: 10-storey<br>o Floor Area: 8,000sm (86,240sf)<br>o Window to Wall Ratio: 40% | Incremental cost premium:<br>0% to 7.7% |
|---|---|---|
| | **Base building** | **Improved building** |
| Cost per unit GFA | $2,588 - $3,020/sm ($240-280/sf) | $2,787 - $3,252/sm ($258 - $302/sf) |
| Incremental cost per unit GFA | | $0 - $233/sm ($0 - $22/sf) |
| Cost for 8,000sm building | $20.7m - $24.1m | $22.3m - $26.0m |
| Total incremental cost | | $0 - $1.8m* |

*Note that incremental cost is directly related to how close a project is to the margin. The closer to the marginal cost, the greater the potential for incremental costs. Therefore, while some projects may not incur an incremental cost, they will be positioned at a higher base building price point.

### *MURB*

The speculative multi-family market conforms to a fairly consistent level of base building construction with price-point differentiation occurring largely from fit and finish strategies. In some urban centres (Kelowna, Victoria, Vancouver), the market has matured sufficiently to accommodate an increasing emphasis on energy performance.

Costs increments are estimated based on the degree of change necessary to the building envelope and the mechanical and electrical systems. The assumptions are based on a generic

[21] Cost estimate provided by the Omicron Group

building and assumes a replacement approach to basic building components with no synergies or efficiency or trade-off savings (worst case):

**Architecture = 40% of total project cost;**
Envelope 60% of total architectural cost;
Incremental envelope performance enhancement 10%
**Total incremental cost of architectural work 2.4%**

**Mechanical = 20% of total project cost**
Cost of incremental mechanical performance enhancement 20%
**Total incremental cost of mechanical work = 4%**

**Electrical = 15% of total project cost;**
Cost of incremental electrical performance enhancement 5%
**Total incremental cost of electrical work = 0.75%**

**Total incremental cost of achieving the enhanced building = 7.15%**

Experienced developers are reporting that the costs of energy performance enhancements are dropping. As an example, Vancity's first high performance building was the Verdant in Burnaby installed a geo exchange system for an approximate budget increase of roughly 5%. This experience helped Vancity to reduce the incremental cost for its 8 storey concrete MURB at Dockside Green to 2%. Vancity is currently developing a five-storey, concrete, mixed-use building (35% more efficient than ASHRAE 90.1.2004) that will likely use only a small geo-exchange loop field to service only the commercial retail units. It is anticipated that there will be negligible cost impact for this project[22]. As a result it is fair to say that the range of cost impacts are from 0% to 7.15%.

Table 27: MURB incremental cost assessment

| MURB | o Height: 10-storey<br>o Floor Area: 5000sm (53,900sf)<br>o Window to Wall Ratio: 45% | Incremental cost premium:<br>0% to 7.15% |
|---|---|---|
| | **Base building** | **Improved building** |
| Cost per unit GFA | $2,804 - $3,505/sm ($260 - $325/sf) | $3,004 - $3,755/sm ($279 - $348/sf) |
| Incremental cost per unit GFA | | $0 - $251/sm ($19 - $23/sf) |
| Cost for 5,000sm building | $14.0m - $17.5m | $15.1m - $18.7m |
| Total incremental cost | | $0 - $1.25m* |

*Note that incremental cost is directly related to how close a project is to the margin. The closer to the marginal cost, the greater the potential for incremental costs. Therefore, while some projects may not incur an incremental cost, they will be positioned at a higher base building price point.

[22] Interview with Vancity Enterprises, March 2010

# Appendix I: Part 9 base case building descriptions

## City of Vancouver base case description

Table 28: Base case description – Lower Mainland

| **Lower Mainland baseline building: Energuide 80 home constructed in 2008** | | | |
|---|---|---|---|
| Type of house: | Single Detached | Plan Shape: | Rectangular |
| Number of storeys: | Two | Front orientation: | South |
| House thermal mass level: | | 2x6 Wood frame construction, 50mm / 2inches Gyproc walls and ceiling<br>Wooden floor | |
| Building Envelope Surface Area: | | 614.1 $m^2$ | |
| Ventilation: | | Heat Recovery Ventilator 855 efficiency | |
| Primary Water Heating Fuel: | | Natural Gas | |
| Air Tightness Level: | | 3.57 ACH @ 50 Pa. | |
| Nominal insulation values: | | Wall | 3.86 RSI |
| | | Ceiling | 7 RSI |
| | | Basement | 3.86 RSI |
| | | Under slab | 2.1 RSI |
| | | Floor above crawl space | 4.9 RSI |
| | | Floor headers | 3.9 RSI |
| Overall window conductance value: | | 2.0 USI | |
| Heating system: | | Condensing boiler | 90% efficiency |
| | | Heat Pump | NO |
| Water Heating Equipment: | | Direct vent (sealed) | |
| Annual consumption: | | Natural Gas | 59,798 MJ |
| | | Electricity | 9,017 kWh |
| Annual costs: | | Natural Gas | $897 |
| | | Electricity | $561 |
| Total cost: | $1,458 | GHG Emissions | 3.15 tonnes |

## Terrace BC base case description

Table 29: Base case description – Interior BC, natural gas

| **Interior BC natural gas baseline building: Energuide 77 home constructed in 2009** | | | |
|---|---|---|---|
| Type of house: | Single Detached | Plan Shape: | Rectangular |
| Number of storeys: | Two | Front orientation: | South |
| House thermal mass level: | | 2x6 Wood frame construction, 50mm / 2inches<br>Gyproc walls and ceiling<br>Wooden floor | |
| Building Envelope Surface Area: | | 614.1 $m^2$ | |
| Ventilation: | | NO | |
| Primary Water Heating Fuel: | | Natural Gas | |
| Air Tightness Level: | | 4.55 ACH @ 50 Pa. | |
| Nominal insulation values: | | Wall | 3.5 RSI |
| | | Ceiling | 7.7 RSI |
| | | Basement | 3.86 RSI |
| | | Under slab | 2.1 RSI |
| | | Floor above crawl space | 4.9 RSI |
| | | Floor headers | 3.5 RSI |
| Overall window conductance value: | | 1.4 USI | |
| Heating system: | | Forced Air Furnace | 95% efficiency |
| | | Heat Pump | NO |
| Water Heating Equipment: | | Instantaneous condensing | |
| Annual consumption: | | Natural Gas | 62,415 MJ |
| | | Electricity | 9,111 kWh |
| Annual costs: | | Natural Gas | $936 |
| | | Electricity | $638 |
| Total cost: | $1,574 | GHG Emissions | 3.28 tonnes |

Table 30: Base case description – Interior BC, electric

| **Interior BC electric baseline building: Energuide 77 home constructed in 2009** | | | | |
|---|---|---|---|---|
| Type of house: | Single Detached | Plan Shape: | Rectangular | |
| Number of storeys: | Two | Front orientation: | South | |
| House thermal mass level: | | 2x6 Wood frame construction, 50mm / 2inches Gyproc walls and ceiling<br>Wooden floor | | |
| Building Envelope Surface Area: | | 614.1 $m^2$ | | |
| Ventilation: | | NO | | |
| Primary Water Heating Fuel: | | Electric | | |
| Air Tightness Level: | | 4.55 ACH @ 50 Pa. | | |
| Nominal insulation values: | | Wall | 3.5 RSI | |
| | | Ceiling | 7.7 RSI | |
| | | Basement | 3.86 RSI | |
| | | Under slab | 2.1 RSI | |
| | | Floor above crawl space | 4.9 RSI | |
| | | Floor headers | 3.5 RSI | |
| Overall window conductance value: | | 1.4 USI | | |
| Heating system: | | Electric Baseboard | 100% efficiency | |
| | | Heat Pump | NO | |
| Water Heating Equipment: | | Electric storage tank | | |
| Annual consumption: | | Natural Gas | 0 MJ | |
| | | Electricity | 32,654 kWh | |
| Annual costs: | | Natural Gas | $0 | |
| | | Electricity | $2,286 | |
| Total cost: | $2,286 | GHG Emissions | 0.72 tonnes | |

The HOT 2000 model gives a value for total greenhouse gas emissions that is not based on the BC energy mix. To account for this, the building's annual energy consumption was multiplied by the BC average emissions per unit of energy, as supplied by BC Housing:

- 22 tonnes of GHGs per gigawatt hour of electricity,
- 0.0494 tonnes per gigajoule of natural gas.

Using these numbers, the baseline building emits a total of 3.15 tonnes of greenhouse gases (GHG) per year and operates with $1,458 in energy costs. This includes only regulated plug loads.

# Appendix II: Part 3 Energy Study Report

# Appendix III —Hot 2000 technical comparisons

## City of Vancouver model

| Bundle | HOT 2000 File | EnerGuide Rating | GHG Emissions[6] (tonne) | GHG Emissions[7] (tonne) | Air Tightness ACH @ 50 Pa. | Nominal Insulation Values (RSI) | | | | | | Overall[5] Window Conductance Value (USI) | Ventilation | | | Fuel | Type | Efficiency (%) | Heat Pump | Fuel | Type | Heat Recovery (43%-54% Efficiency) | Insulation Blanket (R10) | Natural Gas (MJ) | Electricity (kWh) | Natural Gas | Electricity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Wall | Ceiling | Bsmnt | Under Slab | Floor Above CS | Floor Headers | | Type | L/s | hr/day | | | | | | | | | | | | |
| Base | van_special_base_EG_80 | 80 | 7.838 | 3.152 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2.0 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 90 | No | NG | Direct Vent | No | N | 59,798 | 9,017 | $897 | $561 |
| Base Plus | van_special_base_EG_80_plus | 80 | 7.566 | 2.874 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2.0 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 90 | No | NG | Instantaneuos with pilot | No | N | 54,169 | 9,025 | $813 | $561 |
| Bundle A | van_special_EG_85_ins | 85 | 6.815 | 2.088 | 1.5 | 5.6 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 1.0 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 90 | No | NG | Direct Vent | No | N | 38,217 | 9,095 | $573 | $566 |
| Bundle A1 | van_special_EG_85_ins2 | 83 | 7.051 | 2.315 | 1.5 | 5.6 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 3.0 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 90 | No | NG | Direct Vent | No | N | 42,811 | 9,108 | $642 | $567 |
| Bundle B1 | van_special_EG_85_mech1 | 85 | 7.777 | 1.282 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (9.5 kW) | 96.4 | 7 kW Air Source COP 3.0 | NG | Combo space & DHW | No | N | 20,379 | 12,490 | $306 | $777 |
| Bundle B | van_special_EG_85_mech2 | 85 | 7.679 | 1.197 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (9.5 kW) | 95 | 7 kW Air Source COP 3.0 | NG | Condensing Boiler | Yes | N | 18,688 | 12,463 | $280 | $775 |
| Bundle C1 | van_special_EG_85_re | 85 | 6.055 | 2.653 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2.0 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 90 | No | NG | Direct Vent | No | N | 59,798 | 9,017 | $897 | $561 |
| Bundle C2 | van_special_EG_85_re2 | 87 | 7.433 | 1.153 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2.0 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (9.5 kW) | 90 | 7 kW Ground Source COP 3.0 | NG | Direct Vent | No | N | 26,946 | 12,113 | $404 | $753 |
| Bundle C | van_special_EG_85_re3 | 87 | 7.445 | 1.147 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2.0 | HRV[4] 85% Efficiency | 40 | 24 | Elec. | Electric Baseboard (9.5 kW) | 100 | 7 kW Ground Source COP 3.0 | NG | Direct Vent | No | N | 26,801 | 12,147 | $402 | $756 |
| Bundle B2 | van_special_EG_85_mech4 | 82 | 7.004 | 2.322 | 3.57 | 3.86 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 2 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 96.4 | No | NG | Combo space & DHW | No | N | 51,980 | 9,034 | $780 | $562 |
| Bundle D1 | van_special_EG_85_ins3 | 84 | 7.009 | 2.274 | 1.5 | 5.6 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 1.6 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 95 | No | NG | Direct Vent | No | N | 41,967 | 9,108 | $630 | $567 |
| Bundle D | van_special_EG_85_ins3 | 85 | 6.55 | 1.829 | 1.5 | 5.6 | 7 | 3.86 | 2.1 | 4.9 | 3.9 | 1.6 | HRV[4] 85% Efficiency | 40 | 24 | NG | Condensing Boiler (41 kW) | 95 | No | NG | Direct Vent | No | N | 41,967 | 9,108 | $630 | $567 |

## Terrace, BC model

Location: Terrace BC   Degree Days: 4400
Number of storeys: 2
House Thermal Mass: 2x6 wood frame construction, gyproc walls and ceilings
Building Envelope
Building Total Floor Area: 264.8 sm (2850 sf)
Basement: 1.3m (4 ft) non-heated crawl space

| Bundle | HOT 2000 File | EnerGuide Rating | GHG Emissions[6] (tonne) | GHG Emissions[7] (tonne) | Air Tightness ACH @ 50 Pa. | Nominal Insulation Values (RSI) | | | | | Overall[5] Window Conductance Value (USI) | Ventilation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Wall | Ceiling | Floor Above CS | CS Walls | Floor Headers | | Type | L/s | hr/day |
| Base-BCBC-ng | ter2_bcbc-ng | 77 | 9.387 | 3.284 | 4.55 | 3.5 | 7.7 | 4.9 | 2.1 | 3.5 | 1.4 | n/a | 0 | 0 |
| Base-BCBC-el | ter2_bcbc-el | 75 | 17.704 | 0.718 | 4.55 | 3.5 | 7.7 | 4.9 | 2.1 | 3.5 | 1.4 | n/a | 0 | 0 |
| Bundle A-ng | ter2_A_ng | 82 | 8.205 | 2.468 | 3.57 | 7.3 | 11.2 | 4.9 | 2.1 | 7.3 | 1.0 | n/a | 0 | 0 |
| Bundle A-el | ter2_A_el | 80 | 14.358 | 0.583 | 3.57 | 7.3 | 11.2 | 4.9 | 2.1 | 7.3 | 1.0 | n/a | 0 | 0 |
| Bundle B-ng | ter2_B_ng | 84 | 9.935 | 1.128 | 4.55 | 3.5 | 7.7 | 4.9 | 2.1 | 3.5 | 1.4 | n/a | 0 | 0 |
| Bundle B-el | ter2_B_el | 83 | 12.162 | 0.494 | 4.55 | 3.5 | 7.7 | 4.9 | 2.1 | 3.5 | 1.4 | n/a | 0 | 0 |

| Bundle | Heating System | | | | Domestic Hot Water | | | | Annual Consumption | | Annual C | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fuel | Type | Efficiency (AFUE %) | Heat Pump | Fuel | Type | Heat Recovery (43%-54% Efficiency) | Insulation Blanket (R10) | Natural Gas (MJ) | Electricity (kWh) | Natural Gas | Electrici |
| Base-BCBC-ng | NG | Forced Air Furnace (12.5 kW) | 95 | No | NG | Instantaneous Condensing (EF 0.83) | No | N | 62,415 | 9,111 | $936 | $6 |
| Base-BCBC-el | EL | Electric Baseboard (12.5 kW) | 100 | No | EL | Electric Conventional Tank (EF 0.82) | No | N | 0 | 32,654 | $0 | $2,2 |
| Bundle A-ng | NG | Forced Air Furnace (10 kW) | 95 | No | NG | Instantaneous Condensing (EF 0.83) | No | N | 45,897 | 9,103 | $688 | $6 |
| Bundle A-el | EL | Electric Baseboard (10 kW) | 100 | No | EL | Electric Conventional Tank (EF 0.82) | No | N | 0 | 26,483 | $0 | $1,[illegible] |
| Bundle B-ng | NG | Forced Air Furnace (12.5 kW) | 95 | 12.5 kW Air Source 7.1 HSPF | NG | Instantaneous Condensing (EF 0.83) | No | N | 15,584 | 16,277 | $234 | $1,1 |
| Bundle B-el | EL | Electric Baseboard (12.5 kW) | 100 | 12.5 kW Air Source 7.1 HSPF | EL | Electric Conventional Tank (EF 0.82) | No | N | 0 | 22,433 | $0 | $1,[illegible] |

[3] Excess electrical production is fed back into the grid and therefore all electricity generated will reduce annual costs.  epending upon the hot water usage in the house, i.e. domestic and/or heating, will determine how much of the potential energy gener

[5] U values vary depending upon window size. U value is imperial.

[6] GHG calculations done by HOT 2000 which uses coal fired electrical generation to calculate GHG emissions for electrcity

[7] GHG calculations done by using BC Housing numbers for GHG emissions (22T/GWh - Electricity, 0.0494 T/GJ - Natural Gas)

# Appendix IV —Mechanical Cost Estimate

**Integrity** MECHANICAL

February 3, 2009

Light House Sustainable Building Centre
1575 Johnston Street, Granville Island
Vancouver, BC
V6H 2R9

**RE: City of Vancouver Incremental Cost Study**

Eileen,

Please note the additional costs for each of the specified upgraded bundles outlined in your Stage I Report (*December 18, 2008*).

**Bundle A:** No Mechanical Upgrades

*ESTIMATE: $0.00 + Taxes*

**Bundle B:** Upgrade to 95% Efficient Gas-Fired Boiler
Add 3 Ton Air-Source Heat Pump w/ Integrated Reverse Cycle Chiller

*ESTIMATE: $15,228.00 + Taxes*

**Bundle C:** Upgrade to 95% Efficient Gas-Fired Boiler
Add 3 Ton Air-Source Heat Pump w/ Integrated Reverse Cycle Chiller
Upgrade to Indirect-Fired Domestic Hot Water Tank

*ESTIMATE: $15,558.00 +Taxes*

**Bundle D:** Add Solar Hot Water Heating System

*ESTIMATE: $9,760.00 + Taxes*

Please don't hesitate to call with any questions you may have.

Thank you very much,

Richard Giordano

/1

**Integrity Mechanical**
Phone: 604-988-3700 705 West 15th Street North Vancouver, V7M 1T2 Fax: 604-988-3730

# Appendix V – Ground Source Heat Pump Estimate

GEOTILITY
GEOTHERMAL SYSTEMS

June 11, 2009

Mr. Matthew Zipchen
c/o Light House Sustainable Building Centre
1575 Johnson St. Granville Island
Vancouver, B.C. V6H 3R9

Dear Mr. Zipchen,

RE: Estimated Geothermal Costs

As per your email of June 5th, the following is a rough estimate of related costs to install a geothermal (geoexchange) system in a 2850 sq/ft single family home in Vancouver. It should be noted that the exact location needs to be identified to determine the geological conditions for drilling production and thermal conductivity properties.

This home would require a three ton water to air ground source heat pump which will provide space heating and cooling. There is also the option of providing a supplemental source of domestic hot water through a desuper heater.

The heat exchanger (ground loops) would be a vertical closed loop system. The approximate cost including drilling, loop fabrication, insertion, grouting and reverse return headers is $9,000.00. The interior piping and heat pump installation (start-up and commissioning) is $7,000.00.

The interior distribution (ductwork) would be relative to a conventional application i.e. gas furnace.

Thank you for your interest in geothermal technology. If you require any further information or clarification, please do not hesitate to contact me.

Cheers,

Barry Milner – Marketing Director

# Appendix VI – Air Source Heat Pump Estimate

MITSUBISHI ELECTRIC
*Changes for the Better*

**MITSUBISHI ELECTRIC SALES CANADA INC.**
**HVAC EQUIPMENT AND SUPPLIES**
**107-3686 Bonneville Place**
**Burnaby, BC V3N 4T6**
**Tel: (604) 415-6487 Fax: (604) 415-6480**

## Quote

| | |
|---|---|
| Date: | March 1, 2010 |
| Quote #: | BCME0226-7 |
| Customer ID: | #N/A |
| Expiration Date: | March 31, 2010 |

To: Light House Sustainable Building Center

2060 Pine Street
Vancouver BC V6J 4P8
Phone : 604-677-3619
Fax : 604-682-5961
E-mail : [illegible]@sustainablebuildingcentre.com

| Salesperson | Job | | Shipping Terms | Delivery Date | Payment Terms | Due Date |
|---|---|---|---|---|---|---|
| Mike | | | Freight Not Included | | | |

| Qty | Model # | Description | Unit Price | | Line Total |
|---|---|---|---|---|---|
| 1 | ZUBA-PACKAGE-1 | ZUBA CENTRAL - OPTIONAL HEAT | | | $ 7,284.00 |
| 1 | 65500905 | 7.5 KW HEATER WITH TERMINAL BLOCK | | | $ 175.00 |

| | |
|---|---|
| Subtotal | $ 7,459.00 |
| GST | $ 372.95 |
| PST Applicable | $ 522.13 |
| Total | $ 8,354.08 |

To accept this Quotation please sign,print and return:____________________________

Quotation prepared by: *Mike Ely*

**This Quotation is for 30 days**

Tel:604-415-6487 Fax:604-415-6480
Quotation Validity: 30 days, subject to MESCA term and conditions. Please ask us for a copy of Terms and Conditions if required
It is the responsibility of the recipient to verify and confirm that the equipment selection and system design is correct. Final design liability lies with others.
Stock of the equipment should be confirmed at time of ordering.
Prices shown are for this project only. We reserve the right to amend our prices accordingly.
A rehandling fee will be charged for any items returned to MESCA after delivery. This fee will be at MESCA's discretion and all Transport costs shall be the responsibility of the customer.
Mesca will only accept items back if they are in unopened and packaging is in "as new" condition.

Version 9

MITSUBISHI ELECTRIC
*Changes for the Better*

# Quote

**MITSUBISHI ELECTRIC SALES CANADA INC.**
**HVAC EQUIPMENT AND SUPPLIES**
**107-3686 Bonneville Place**
**Burnaby, BC V3N 4T6**
**Tel: (604) 415-6487 Fax: (604) 415-6480**

| | |
|---|---|
| Date: | February 26, 2010 |
| Quote #: | BCME0226-7 |
| Customer ID: | #N/A |
| Expiration Date: | March 28, 2010 |

To: Light House Sustainable Building Center

2060 Pine Street
Vancouver BC V6J 4P8
Phone : 604-677-3619
Fax : 604-682-5961
E-mail : [illegible]@sustainablebuildingcentre.com

| Salesperson | Job | | Shipping Terms | Delivery Date | Payment Terms | Due Date |
|---|---|---|---|---|---|---|
| Mike | | | Freight Not Included | | | |

| Qty | Model # | Description | Unit Price | | Line Total |
|---|---|---|---|---|---|
| 1 | ZUBA-PACKAGE-1 | ZUBA CENTRAL - OPTIONAL HEAT | | | $ 7,284.00 |
| 1 | 65500908 | 12.5 KW HEATER WITH C/BREAKER | | | $ 287.00 |

| | |
|---|---|
| Subtotal | $ 7,571.00 |
| GST | $ 378.55 |
| PST Applicable | $ 529.97 |
| Total | $ 8,479.52 |

To accept this Quotation please sign,print and return:____________________

Quotation prepared by: *Mike Ely*

**This Quotation is for 30 days**

Tel:604-415-6487 Fax:604-415-6480
Quotation Validity: 30 days, subject to MESCA term and conditions. Please ask us for a copy of Terms and Conditions if required
It is the responsibility of the recipient to verify and confirm that the equipment selection and system design is correct. Final design liability lies with others.
Stock of the equipment should be confirmed at time of ordering.
Prices shown are for this project only. We reserve the right to amend our prices accordingly.
A rehandling fee will be charged for any items returned to MESCA after delivery. This fee will be at MESCA's discretion and all Transport costs shall be the responsibility of the customer.
Mesca will only accept items back if they are in unopened and packaging is in "as new" condition.

Version 9

RECOLLECTIVE
Buildings • Community • Ecology

# Energy Study Report

# 15 Municipalities


Prepared by:

**Jack Cui**
**Senior Building Energy Analyst**

Reviewed by:

**Brenda Martens**
**Principal**

**Recollective Consulting**
Suite #109 - 5 West Pender St.
Vancouver BC - Canada
V6B 1R3

Phone: 604.669.4940 ext 208
Fax: 604.669.4945
Email: jack@recollective.ca



Issued March 08, 2010

## TABLE OF CONTENTS

## 1.0 SUMMARY

This report represents the energy study results for 15 municipalities mostly located in BC. The 15 municipalities are interested in energy-saving strategies in achieving 30% energy reduction over ASHRAE 90.1 – 2004.

Three building types and two building locations were selected. The building types were office building, hotel, and multi-unit residential building (MURB). The two building locations were Burnaby and Terrace.

Energy conservation measures (ECM) were proposed and groups or bundles of ECMs were analysed per building type at each building location. The energy conservation measures for office building and hotel are listed in Table 1.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.38 |
| ECM6 | 10% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM7 | 25% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM8 | Daylight sensors in perimeter space – Continuous dimming |
| ECM9 | 60% efficiency heat recovery – through centralized heat recovery ventilator |
| ECM10 | In-floor radiant heating and cooling |
| ECM11 | Variable speed fans/Demand Control Ventilation |
| ECM12 | Variable speed pumps |
| ECM13 | Low flow plumbing fixtures |
| ECM14 | High efficiency condensing boilers with 94% efficiency (space heating and domestic hot water heating) |

Table 1. Energy Conservation Measures for Office Building and Hotel Building

The energy conservation measures for MURB are listed in Table 2.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.5 |
| ECM6 | 40% CFLs (31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM7 | 100% CFLs (78% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM8 | 60% efficiency HRV – through centralized heat recovery ventilator |
| ECM9 | In-floor radiant heating or overhead radiant heating panel |
| ECM10 | In-floor radiant heating or overhead radiant heating panel with Variable speed pumps |
| ECM11 | Low flow plumbing fixtures |
| ECM12 | High efficiency condensing boilers with 94% efficiency (Domestic hot water heating only) |

Table 2. Energy Conservation Measures for MURB

Based on the energy study results, the following bundles of ECMs were found effective in achieving 30%

energy reduction over ASHRAE 90.1 – 2004:

| | Burnaby | Terrace |
|---|---|---|
| Office | In-floor radiant heating and cooling, demand control ventilation, variable speed pumps, and low-flow plumbing fixtures | Window U = 0.4, SHGC = 0.38, in-floor radiant heating and cooling, variable speed pumps, and high efficiency boilers with 94% efficiency (minimum) for space heating and hot water heating. |
| Hotel | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating |
| MURB | Window U = 0.4, SHGC = 0.5, and low-flow plumbing fixtures | Window U = 0.4, SHGC = 0.5, 40% CFLs (or 31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004), and low-flow plumbing fixtures |

Table 3. Proposed Energy-Saving Strategies

The energy study was based on a "box-type" building with no detailed architectural/mechanical/electrical design, and the results of this study may vary for specific individual buildings. This energy study report should be used as a reference for guidance in energy-saving designs against ASHRAE 90.1 – 2004. We recommend further cost analysis and payback calculations for the selected energy-saving strategies. We also recommend pursuing passive design strategies that give real world energy savings, but are not necessarily accounted for in the energy modelling, such as building orientation, reducing the window to wall ratio, and external shading, etc.

## 2.0 BACKGROUND

The 15 municipalities mostly located in BC are interested in determining what energy-saving strategies would be able to reduce energy consumption by 30% over ASHRAE 90.1 – 2004. Three building types and two building locations were selected. The building types were office building, hotel, and multi-unit residential building (MURB). The two building locations were Burnaby and Terrace. The following building floor areas were assumed:

1. Ten-storey Office Building: 9,000 $m^2$
2. Ten-storey Hotel: 8,000 $m^2$
3. Ten-storey MURB: 5,000 $m^2$

Baseline Building

The baseline buildings were established with ASHRAE 90.1 - 2004. The baseline building parameters for each building type are listed in Appendix A.

Energy Conservation Measures

Based on the baseline building model, a series of Energy Conservation Measures (ECMs) were evaluated separately to determine the effectiveness of each ECM independently.

Finally, a series of ECMs were grouped into a bundle to determine the overall energy performance of the combined ECMs, taking into account the interactions among the individual ECMs.

The energy conservation measures for office building and hotel are listed in Table 1.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.38 |
| ECM6 | 10% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM7 | 25% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM8 | Daylight sensors in perimeter space – Continuous dimming |
| ECM9 | 60% efficiency heat recovery – through centralized heat recovery ventilator |
| ECM10 | In-floor radiant heating and cooling |
| ECM11 | Variable speed fans/Demand Control Ventilation |
| ECM12 | Variable speed pumps |
| ECM13 | Low flow plumbing fixtures |
| ECM14 | High efficiency condensing boilers with 94% efficiency (space heating and domestic hot water heating) |

Table 1. Energy Conservation Measures for Office Building and Hotel Building

Low-flow plumbing fixtures are considered:
1. 0.09 L/s or 1.5 GPM flow rate of Showerhead
2. 0.03 L/s or 0.5 GPM flow rate of Faucet

The energy conservation measures for MURB are listed in Table 2.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.5 |
| ECM6 | 40% CFLs (31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM7 | 100% CFLs (78% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM8 | 60% efficiency HRV – through centralized heat recovery ventilator |
| ECM9 | In-floor radiant heating or overhead radiant heating panel |
| ECM10 | In-floor radiant heating or overhead radiant heating panel with Variable speed pumps |
| ECM11 | Low flow plumbing fixtures |
| ECM12 | High efficiency condensing boilers with 94% efficiency (Domestic hot water heating only) |

Table 2. Energy Conservation Measures for MURB

Energy Modelling Software

The energy study was performed with Natural Resources Canada's EE4 Version 1.7.

## 3.0 ENERGY STUDY RESULTS

The energy modelling results are listed below per building type at each building location.

### 3.1 BURNABY

| Office | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 2,013 | 1,869 | 1,840 | 1,990 | 1,984 | 1,625 | 2,062 | 2,138 | 2,164 | 2,013 | 1,214 | 1,723 | 2,093 | 2,013 | 1,747 | 1,173 |
| Space Cooling (GJ) | 234 | 234 | 234 | 234 | 234 | 245 | 232 | 230 | 229 | 234 | 290 | 220 | 142 | 234 | 234 | 219 |
| Fans & Pumps (GJ) | 697 | 697 | 696 | 697 | 697 | 712 | 695 | 692 | 691 | 697 | 504 | 629 | 278 | 697 | 697 | 175 |
| Water Heating (GJ) | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 122 | 329 | 122 |
| Interior Lighting (GJ) | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 925 | 772 | 719 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 |
| Receptacle and Process Loads (GJ) | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 |
| Total Regulated Energy (GJ) | 4,357 | 4,212 | 4,183 | 4,334 | 4,328 | 3,995 | 4,300 | 4,217 | 4,189 | 4,357 | 3,421 | 3,985 | 3,926 | 4,092 | 4,034 | 2,715 |
| Total Energy Consumption (GJ) | 5,263 | 5,118 | 5,088 | 5,240 | 5,233 | 4,900 | 5,206 | 5,123 | 5,095 | 5,263 | 4,327 | 4,891 | 4,831 | 4,998 | 4,939 | 3,621 |
| Energy Saving (GJ) | N/A | 145 | 174 | 23 | 29 | 362 | 57 | 140 | 168 | 0 | 936 | 372 | 431 | 265 | 323 | 1,642 |
| **Energy Saving (%)** | N/A | 2.7% | 3.3% | 0.4% | 0.6% | 6.9% | 1.1% | 2.7% | 3.2% | 0.0% | 17.8% | 7.1% | 8.2% | 5.0% | 6.1% | **31.2%** |
| Proposed Bundle | | | | | | | | | | | Yes | Yes | Yes | Yes | | |

Table 3. Energy Study Results – Burnaby Office

For the office building in Burnaby, the in-floor radiant heating/cooling system with demand control ventilation, variable speed pumps, and low-flow plumbing fixtures would be able to reduce 31.2% of energy consumption relative to ASHRAE 90.1 – 2004. In addition, since the baseline building has 50% efficiency heat recovery, the ECM9 (60% heat recovery efficiency) will not be able to demonstrate any energy saving. It is also recommended to consider other significant energy-saving strategies such as ECM5 (Window U = 0.40, SHGC = 0.38) and ECM14 (High efficiency condensing boilers with 94% efficiency for space heating and domestic hot water heating).

| Hotel | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 1,620 | 1,458 | 1,425 | 1,599 | 1,593 | 1,343 | 1,653 | 1,702 | 1,719 | 1,179 | 1,879 | 1,508 | 1,728 | 1,620 | 1,406 | 1,406 |
| Space Cooling (GJ) | 388 | 389 | 389 | 389 | 390 | 398 | 380 | 369 | 381 | 402 | 342 | 355 | 353 | 388 | 388 | 388 |
| Fans & Pumps (GJ) | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,217 | 526 | 1,021 | 779 | 1,111 | 1,111 | 1,111 |
| Water Heating (GJ) | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 876 | 2,456 | 634 |
| Interior Lighting (GJ) | 926 | 926 | 926 | 926 | 926 | 926 | 832 | 694 | 764 | 926 | 926 | 926 | 926 | 926 | 926 | 926 |
| Receptacle and Process Loads (GJ) | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 |
| Total Regulated Energy (GJ) | 6,930 | 6,769 | 6,736 | 6,910 | 6,905 | 6,662 | 6,862 | 6,762 | 6,861 | 6,610 | 6,558 | 6,696 | 6,672 | 4,920 | 6,287 | 4,465 |
| Total Energy Consumption (GJ) | 7,142 | 6,981 | 6,949 | 7,123 | 7,117 | 6,875 | 7,074 | 6,974 | 7,073 | 6,822 | 6,771 | 6,909 | 6,884 | 5,132 | 6,499 | 4,677 |
| Energy Saving (GJ) | N/A | 161 | 194 | 20 | 25 | 267 | 68 | 168 | 69 | 320 | 372 | 233 | 258 | 2,010 | 643 | 2,465 |
| **Energy Saving (%)** | N/A | 2.3% | 2.7% | 0.3% | 0.4% | 3.7% | 1.0% | 2.4% | 1.0% | 4.5% | 5.2% | 3.3% | 3.6% | 28.1% | 9.0% | **34.5%** |
| Proposed Bundle | | | | | | | | | | | | | | Yes | Yes | |

Table 4. Energy Study Results – Burnaby Hotel

For the hotel in Burnaby, the hot water heating energy is a significant percentage and therefore the first step to achieve 30% energy reduction over ASHRAE 90.1 – 2004 is to reduce hot water heating energy. Any other energy-saving strategies without changing HVAC system such as ECM5 (Window U = 0.40, SHGC = 0.38), ECM12 (Variable Speed Pumps), and ECM 14 (High efficiency condensing boilers with 94% efficiency for space heating and domestic hot water heating), will be the design strategies to achieve 30% energy reduction.

| MURB | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 882 | 842 | 822 | 865 | 859 | 651 | 925 | 993 | 850 | 1,071 | 1,154 | 882 | 882 | 651 |
| Space Cooling (GJ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fans & Pumps (GJ) | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 407 | 171 | 60 | 38 | 38 | 38 |
| Water Heating (GJ) | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 164 | 457 | 164 |
| Interior Lighting (GJ) | 276 | 276 | 276 | 276 | 276 | 276 | 191 | 63 | 276 | 276 | 276 | 276 | 276 | 276 |
| Receptacle and Process Loads (GJ) | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 |
| Total Regulated Energy (GJ) | 1,733 | 1,692 | 1,672 | 1,715 | 1,710 | 1,501 | 1,691 | 1,630 | 2,069 | 2,055 | 2,027 | 1,360 | 1,653 | 1,129 |
| Total Energy Consumption (GJ) | 1,905 | 1,864 | 1,845 | 1,887 | 1,882 | 1,673 | 1,863 | 1,803 | 2,242 | 2,228 | 2,199 | 1,533 | 1,825 | 1,301 |
| Energy Saving (GJ) | N/A | 41 | 60 | 18 | 23 | 232 | 42 | 102 | -337 | -323 | -294 | 372 | 80 | 604 |
| **Energy Saving (%)** | N/A | 2.1% | 3.2% | 0.9% | 1.2% | 12.2% | 2.2% | 5.4% | -17.7% | -16.9% | -15.4% | 19.6% | 4.2% | **31.7%** |
| Proposed Bundle | | | | | | Yes | | | | | | Yes | | |

Table 5. Energy Study Results – Burnaby MURB

For the MURB in Burnaby, the space heating and hot water heating are two major energy consumers. ECM5 with SHGC of 0.5 will be able to use solar gain to reduce space heating requirements. Low-flow plumbing fixtures will be able to significantly reduce hot water heating energy. However, comparing to electric heating system, the in-floor radiant heating system is not demonstrating energy reduction in a MURB.

For the MURB, ECM8 (60% efficiency heat recovery) reduces space heating energy through make-up air unit but it will increase fan energy as well. Overall, heat recovery ventilator in the MURB does not reduce energy consumption over the baseline building. In addition, ECM9 and ECM10 (In-floor radiant heating with and without Variable Speed Pumps) consumes more energy than the baseline building mostly because in-floor radiant heating system requires hydronic pumps but the baseline building with electric baseboard heating does not, and secondly the efficiency of electric heating is 100% while the efficiency of in-floor radiant heating with gas-fired boilers is 80%.

## 3.2 TERRACE

| Office | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 2,347 | 2,172 | 2,136 | 2,317 | 2,308 | 1,908 | 2,391 | 2,458 | 2,482 | 2,347 | 1,670 | 2,093 | 2,509 | 2,347 | 2,037 | 1,279 |
| Space Cooling (GJ) | 321 | 319 | 319 | 320 | 320 | 339 | 318 | 313 | 316 | 321 | 415 | 302 | 213 | 321 | 321 | 367 |
| Fans & Pumps (GJ) | 971 | 968 | 967 | 970 | 969 | 1,011 | 964 | 956 | 963 | 971 | 828 | 952 | 349 | 971 | 971 | 217 |
| Water Heating (GJ) | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 122 | 329 | 329 |
| Interior Lighting (GJ) | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 927 | 772 | 855 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 |
| Receptacle and Process Loads (GJ) | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 |
| Total Regulated Energy (GJ) | 5,051 | 4,871 | 4,835 | 5,019 | 5,010 | 4,670 | 4,986 | 4,885 | 5,002 | 5,051 | 4,326 | 4,759 | 4,484 | 4,787 | 4,684 | 3,219 |
| Total Energy Consumption (GJ) | 5,957 | 5,777 | 5,741 | 5,925 | 5,916 | 5,576 | 5,892 | 5,791 | 5,908 | 5,957 | 5,232 | 5,665 | 5,390 | 5,692 | 5,590 | 4,124 |
| Energy Saving (GJ) | N/A | 180 | 216 | 32 | 41 | 381 | 65 | 166 | 49 | 0 | 725 | 292 | 567 | 265 | 367 | 1,833 |
| **Energy Saving (%)** | N/A | 3.0% | 3.6% | 0.5% | 0.7% | 6.4% | 1.1% | 2.8% | 0.8% | 0.0% | 12.2% | 4.9% | 9.5% | 4.4% | 6.2% | **30.8%** |
| Proposed Bundle | | | | | | Yes | | | | | Yes | | Yes | | Yes | |

Table 6. Energy Study Results – Terrace Office

For the office building in Terrace, the in-floor radiant heating/cooling system with variable speed pumps, improved window performance, and high efficiency boilers would be able to reduce 30.8% of energy consumption relative to ASHRAE 90.1 – 2004. In addition, since the baseline building has 50% efficiency heat recovery, the ECM9 (60% efficiency heat recovery) will not be able to demonstrate any energy saving. It is also recommended to consider other significant energy-saving strategies such as ECM11 (Demand control ventilation) and ECM13 (Low-flow plumbing fixtures) as well. The recommended energy-saving strategies for the office building in Terrace are different from the ones in Burnaby due to the change of climatic conditions.

| Hotel | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 2,088 | 1,883 | 1,841 | 2,059 | 2,051 | 1,736 | 2,121 | 2,170 | 2,187 | 1,557 | 2,366 | 1,951 | 2,307 | 2,088 | 1,812 | 1,812 |
| Space Cooling (GJ) | 455 | 453 | 453 | 456 | 457 | 463 | 448 | 436 | 447 | 465 | 407 | 419 | 424 | 455 | 455 | 455 |
| Fans & Pumps (GJ) | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,435 | 718 | 1,244 | 834 | 1,329 | 1,329 | 1,329 |
| Water Heating (GJ) | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 876 | 2,456 | 634 |
| Interior Lighting (GJ) | 926 | 926 | 926 | 926 | 926 | 926 | 834 | 694 | 764 | 926 | 926 | 926 | 926 | 926 | 926 | 926 |
| Receptacle and Process Loads (GJ) | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 |
| Total Regulated Energy (GJ) | 7,684 | 7,477 | 7,435 | 7,656 | 7,648 | 7,340 | 7,617 | 7,515 | 7,613 | 7,269 | 7,302 | 7,426 | 7,377 | 5,674 | 6,979 | 5,157 |
| Total Energy Consumption (GJ) | 7,896 | 7,689 | 7,647 | 7,869 | 7,861 | 7,552 | 7,829 | 7,728 | 7,825 | 7,481 | 7,515 | 7,638 | 7,589 | 5,886 | 7,191 | 5,369 |
| Energy Saving (GJ) | N/A | 207 | 249 | 28 | 35 | 344 | 67 | 168 | 71 | 415 | 381 | 258 | 307 | 2,010 | 705 | 2,527 |
| **Energy Saving (%)** | N/A | 2.6% | 3.2% | 0.3% | 0.4% | 4.4% | 0.8% | 2.1% | 0.9% | 5.3% | 4.8% | 3.3% | 3.9% | 25.5% | 8.9% | **32.0%** |
| Proposed Bundle | | | | | | | | | | | | | | Yes | Yes | |

Table 7. Energy Study Results – Terrace Hotel

For the hotel in Terrace, the hot water heating energy is a significant percentage and therefore the first step to achieve 30% energy reduction over ASHRAE 90.1 – 2004 is to reduce hot water heating energy. Any other energy-saving strategies without changing HVAC system such as ECM5 (Window U = 0.40, SHGC = 0.38), ECM12 (Variable speed pumps), and ECM 14 (High efficiency condensing boilers with 94% efficiency for space heating and domestic hot water heating), will be the design strategies to achieve 30% energy reduction. The energy results are the same as the hotel building in Burnaby.

| MURB | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 1,157 | 1,109 | 1,085 | 1,134 | 1,127 | 886 | 1,197 | 1,261 | 1,014 | 1,351 | 1,479 | 1,157 | 1,157 | 919 |
| Space Cooling (GJ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fans & Pumps (GJ) | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 426 | 287 | 111 | 38 | 38 | 38 |
| Water Heating (GJ) | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 164 | 457 | 164 |
| Interior Lighting (GJ) | 276 | 276 | 276 | 276 | 276 | 276 | 191 | 63 | 276 | 276 | 276 | 276 | 276 | 191 |
| Receptacle and Process Loads (GJ) | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 |
| Total Regulated Energy (GJ) | 2,007 | 1,959 | 1,936 | 1,984 | 1,978 | 1,736 | 1,963 | 1,898 | 2,253 | 2,450 | 2,403 | 1,635 | 1,927 | 1,313 |
| Total Energy Consumption (GJ) | 2,179 | 2,131 | 2,108 | 2,157 | 2,150 | 1,909 | 2,135 | 2,071 | 2,425 | 2,623 | 2,575 | 1,807 | 2,099 | 1,485 |
| Energy Saving (GJ) | N/A | 48 | 71 | 23 | 29 | 271 | 44 | 109 | -246 | -443 | -396 | 372 | 80 | 694 |
| **Energy Saving (%)** | N/A | 2.2% | 3.3% | 1.0% | 1.3% | 12.4% | 2.0% | 5.0% | -11.3% | -20.3% | -18.2% | 17.1% | 3.7% | **31.9%** |
| Proposed Bundle | | | | | | Yes | Yes | | | | | Yes | | |

Table 9. Energy Study Results – Terrace MURB

Due to the change of climatic conditions, space heating energy in Terrace is required more than in Burnaby. Therefore, for the MURB in Terrace, in addition to ECM5 (Window U = 0.40, SHGC = 0.38) and ECM 11 (Low-flow plumbing fixtures), one more ECM was required to achieve 30% energy reduction over ASHRAE 90.1 – 2005, and ECM6 (10% lighting power density reduction over ASHRAE 90.1 – 2004) was recommended. Overall, the recommended ECM5, ECM6, and ECM11, would be able to achieve 31.9% energy reduction.

For the MURB, heat recovery ventilator (ECM8) reduces space heating energy through make-up air unit but it will increase fan energy as well. Overall, heat recovery ventilator in the MURB does not reduce energy consumption over the baseline building. In addition, in-floor radiant heating (ECM9 and ECM10) consumes more energy than the baseline building mostly because in-floor radiant heating system requires hydronic pumps but the baseline building with electric baseboard heating does not, and secondly the efficiency of electric heating is 100% while the efficiency of in-floor radiant heating with gas-fired boilers is 80%.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the above analysis, the following energy-saving strategies are recommended in order to achieve 30% energy reduction over ASHRAE 90.1 – 2004:

| | Burnaby | Terrace |
|---|---|---|
| Office | In-floor radiant heating and cooling, demand control ventilation, variable speed pumps, and low-flow plumbing fixtures (ECM10, ECM11, ECM12, and ECM13) | Window U = 0.4, SHGC = 0.38, in-floor radiant heating and cooling, variable speed pumps, and high efficiency boilers with 94% efficiency (minimum) for space heating and hot water heating (ECM5, ECM10, ECM12, and ECM14) |
| Hotel | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating (ECM13 and ECM14) | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating (ECM13 and ECM14) |
| MURB | Window U = 0.4, SHGC = 0.5, and low-flow plumbing fixtures (ECM5 and ECM11) | Window U = 0.4, SHGC = 0.5, 40% CFLs (or 31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004), and low-flow plumbing fixtures (ECM5, ECM6, and ECM11) |

Table 10. Proposed Energy-Saving Strategies

The energy study was based on a "box-type" building with no detailed architectural/mechanical/electrical design, and the results of this study may vary for specific individual buildings. This energy study report should be used as a reference for guidance in energy-saving designs against ASHRAE 90.1 – 2004. We recommend further cost analysis and payback calculations for the selected energy-saving strategies. We also recommend pursuing passive design strategies that give real world energy savings, but are not necessarily accounted for in the energy modelling, such as building orientation, reducing the window to wall ratio, and external shading, etc.

# Appendix A: Baseline Building Parameters

## Office Building

| | Project Baseline |
|---|---|
| **Exterior Surfaces** | |
| Wall Overall R-Value (IP Unit) | R8.1 (Mass Building: U=0.123) |
| Roof Overall R-Value (IP Unit) | R15.9 (Insulation Entirely Above Deck: U=0.063) |
| **Glazing** | |
| Glazing Percent | 50% |
| Window U-Value (IP Unit) | 0.46 |
| Solar Heat Gain Coefficient | 0.26 |
| **Space Conditions** | |
| Lighting | 1.0 $W/ft^2$ or 10.76 $W/m^2$ |
| Equipment Density | 0.7 $W/ft^2$ or 7.5 $W/m^2$ |
| Lighting Controls | N/A |
| **HVAC Systems Type** | |
| Air handling unit | Hot Water Heating and Cooling with Economizer |
| Space Heating | VAV plus Hot Water Reheat |
| Principle heating Fuel Type | Natural Gas |
| Cooling Source | Chilled Water |
| **Fan System** | |
| Make-up Air Unit | N/A |
| Fan Power | 1.1 hp/1000 CFM |
| Outside Air | 18 CFM/Person or 8.5 L/s/Person |
| Occupant Density | 25 $m^2$/person |
| Heat Reclaim | 50% Efficiency |
| **HVAC Controls** | |
| Economizer | Differential Enthalpy |
| **Central Plant** | |
| Central Heating System | Natural Gas Boiler |
| Central Heating Efficiency (AFUE) | 80.00% |
| Central Cooling System | Chiller - Centrifugal |
| Central Cooling Efficiency | COPstd=5.0;IPLVstd=5.25 |
| Air Cooled - Fan Power | 176,000 BTUH/Horsepower |
| Pumps | Head: 150 feet |
| **Domestic Hot Water** | |
| Heating Efficiency (AFUE) | 80.00% |
| Plumbing Fixtures - Flow Rates | Shower Heads: 0.16 L/s or 2.5 GPM; Peak Load Percentage: 25%<br>Faucets: 0.14 L/s or 2.2 GPM; Peak Load Percentage: 75% |
| **Operating Conditions** | |
| Indoor Design Temperatures | Winter: 21.1°C; Summer: 23.3°C |
| Operating Schedules | As per EE4 Default |
| | |
| Building Floor Area ($m^2$) | 9,000 |

## Hotel

| | Project Baseline |
|---|---|
| **Exterior Surfaces** | |
| Wall Overall R-Value (IP Unit) | R8.1 (Mass Building: U=0.123) |
| Roof Overall R-Value (IP Unit) | R15.9 (Insulation Entirely Above Deck: U=0.063) |
| **Glazing** | |
| Glazing Percent | 40% |
| Window U-Value (IP Unit) | 0.57 |
| Solar Heat Gain Coefficient | 0.39 |
| **Space Conditions** | |
| Lighting | 1.0 W/ft$^2$ or 10.76 W/m$^2$ |
| Equipment Density | 0.23 W/ft$^2$ or 2.5 W/m$^2$ |
| Lighting Controls | N/A |
| **HVAC Systems Type** | |
| Air handling unit | N/A |
| Space Heating | Fan coil |
| Principle heating Fuel Type | Natural Gas |
| Cooling Source | Chilled Water |
| **Fan System** | |
| Make-up Air Unit | Supply Air Temperature = 18$^o$C with Heating and Cooling Coils |
| Fan Power | 1.2 hp/1000 CFM |
| Outside Air | 11.65 CFM/Person or 5.5 L/s/Person |
| Occupant Density | 25 m$^2$/person |
| Heat Reclaim | N/A |
| **HVAC Controls** | |
| Economizer | Differential Enthalpy |
| **Central Plant** | |
| Central Heating System | Natural Gas Boiler |
| Central Heating Efficiency (AFUE) | 80.00% |
| Central Cooling System | Chiller - Centrifugal |
| Central Cooling Efficiency | COPstd=5.0;IPLVstd=5.25 |
| Air Cooled - Fan Power | 176,000 BTUH/Horsepower |
| Pumps | Head: 150 feet |
| **Domestic Hot Water** | |
| Heating Efficiency (AFUE) | 80.00% |
| Plumbing Fixtures - Flow Rates | Shower Heads: 0.16 L/s or 2.5 GPM; Peak Load Percentage: 25%<br>Faucets: 0.14 L/s or 2.2 GPM; Peak Load Percentage: 75% |
| **Operating Conditions** | |
| Indoor Design Temperatures | Winter: 21.1$^o$C; Summer: 23.3$^o$C |
| Operating Schedules | As per EE4 Default |
| | |
| Building Floor Area (m$^2$) | 8,000 |

**Assumptions:**

1. It is assumed that the fan power of fan coils is calculated with 0.7 Watt/L/s or 0.33 Watt/CFM.

## MURB

| | Project Baseline |
|---|---|
| **Exterior Surfaces** | |
| Wall Overall R-Value (IP Unit) | R11.1 (Mass Building: U=0.09) |
| Roof Overall R-Value (IP Unit) | R15.9 (Insulation Entirely Above Deck: U=0.063) |
| **Glazing** | |
| Glazing Percent | 45% |
| Window U-Value (IP Unit) | 0.46 |
| Solar Heat Gain Coefficient | 0.26 |
| **Space Conditions** | |
| Lighting | 0.7 $W/ft^2$ or 7.5 $W/m^2$ |
| Equipment Density | 0.23 $W/ft^2$ or 2.5 $W/m^2$ |
| Lighting Controls | N/A |
| **HVAC Systems Type** | |
| Air handling unit | N/A |
| Space Heating | Electric Baseboard |
| Principle heating Fuel Type | Electric |
| Cooling Source | N/A |
| **Fan System** | |
| Make-up Air Unit | Supply Air Temperature = 18°C with gas heating only |
| Fan Power | 1.2 hp/1000 CFM |
| Outside Air | 16 CFM/person or 7.5 L/s/person |
| Occupant Density | 60 $m^2$/person |
| Heat Reclaim | N/A |
| **HVAC Controls** | |
| Economizer | N/A |
| **Central Plant** | |
| Central Heating System | N/A |
| Central Heating Efficiency (AFUE) | N/A |
| Central Cooling System | N/A |
| Central Cooling Efficiency | N/A |
| Air Cooled - Fan Power | N/A |
| Pumps | N/A |
| **Domestic Hot Water** | |
| Heating Efficiency (AFUE) | 80.00% |
| Plumbing Fixtures - Flow Rates | Shower Heads: 0.16 L/s or 2.5 GPM; Peak Load Percentage: 25%<br>Faucets: 0.14 L/s or 2.2 GPM; Peak Load Percentage: 75% |
| **Operating Conditions** | |
| Indoor Design Temperatures | Winter: 21.1°C; Summer: 23.3°C |
| Operating Schedules | As per EE4 Default |
| | |
| Building Floor Area ($m^2$) | 5,000 |

# Energy Study Report

# 15 Municipalities

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## 1.0 SUMMARY

This report represents the energy study results for 15 municipalities mostly located in BC. The 15 municipalities are interested in energy-saving strategies in achieving 30% energy reduction over ASHRAE 90.1 – 2004.

Three building types and two building locations were selected. The building types were office building, hotel, and multi-unit residential building (MURB). The two building locations were Burnaby and Terrace.

Energy conservation measures (ECM) were proposed and groups or bundles of ECMs were analysed per building type at each building location. The energy conservation measures for office building and hotel are listed in Table 1.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.38 |
| ECM6 | 10% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM7 | 25% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM8 | Daylight sensors in perimeter space – Continuous dimming |
| ECM9 | 60% efficiency heat recovery – through centralized heat recovery ventilator |
| ECM10 | In-floor radiant heating and cooling |
| ECM11 | Variable speed fans/Demand Control Ventilation |
| ECM12 | Variable speed pumps |
| ECM13 | Low flow plumbing fixtures |
| ECM14 | High efficiency condensing boilers with 94% efficiency (space heating and domestic hot water heating) |

Table 1. Energy Conservation Measures for Office Building and Hotel Building

The energy conservation measures for MURB are listed in Table 2.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.5 |
| ECM6 | 40% CFLs (31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM7 | 100% CFLs (78% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM8 | 60% efficiency HRV – through centralized heat recovery ventilator |
| ECM9 | In-floor radiant heating or overhead radiant heating panel |
| ECM10 | In-floor radiant heating or overhead radiant heating panel with Variable speed pumps |
| ECM11 | Low flow plumbing fixtures |
| ECM12 | High efficiency condensing boilers with 94% efficiency (Domestic hot water heating only) |

Table 2. Energy Conservation Measures for MURB

Based on the energy study results, the following bundles of ECMs were found effective in achieving 30%

energy reduction over ASHRAE 90.1 – 2004:

| | Burnaby | Terrace |
|---|---|---|
| Office | In-floor radiant heating and cooling, demand control ventilation, variable speed pumps, and low-flow plumbing fixtures | Window U = 0.4, SHGC = 0.38, in-floor radiant heating and cooling, variable speed pumps, and high efficiency boilers with 94% efficiency (minimum) for space heating and hot water heating. |
| Hotel | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating |
| MURB | Window U = 0.4, SHGC = 0.5, and low-flow plumbing fixtures | Window U = 0.4, SHGC = 0.5, 40% CFLs (or 31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004), and low-flow plumbing fixtures |

Table 3. Proposed Energy-Saving Strategies

The energy study was based on a "box-type" building with no detailed architectural/mechanical/electrical design, and the results of this study may vary for specific individual buildings. This energy study report should be used as a reference for guidance in energy-saving designs against ASHRAE 90.1 – 2004. We recommend further cost analysis and payback calculations for the selected energy-saving strategies. We also recommend pursuing passive design strategies that give real world energy savings, but are not necessarily accounted for in the energy modelling, such as building orientation, reducing the window to wall ratio, and external shading, etc.

## 2.0 BACKGROUND

The 15 municipalities mostly located in BC are interested in determining what energy-saving strategies would be able to reduce energy consumption by 30% over ASHRAE 90.1 – 2004. Three building types and two building locations were selected. The building types were office building, hotel, and multi-unit residential building (MURB). The two building locations were Burnaby and Terrace. The following building floor areas were assumed:

1. Ten-storey Office Building: 9,000 $m^2$
2. Ten-storey Hotel: 8,000 $m^2$
3. Ten-storey MURB: 5,000 $m^2$

Baseline Building

The baseline buildings were established with ASHRAE 90.1 - 2004. The baseline building parameters for each building type are listed in Appendix A.

Energy Conservation Measures

Based on the baseline building model, a series of Energy Conservation Measures (ECMs) were evaluated separately to determine the effectiveness of each ECM independently.

Finally, a series of ECMs were grouped into a bundle to determine the overall energy performance of the combined ECMs, taking into account the interactions among the individual ECMs.

The energy conservation measures for office building and hotel are listed in Table 1.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.38 |
| ECM6 | 10% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM7 | 25% Lighting Power Density Reduction over ASHRAE 90.1 – 2004 |
| ECM8 | Daylight sensors in perimeter space – Continuous dimming |
| ECM9 | 60% efficiency heat recovery – through centralized heat recovery ventilator |
| ECM10 | In-floor radiant heating and cooling |
| ECM11 | Variable speed fans/Demand Control Ventilation |
| ECM12 | Variable speed pumps |
| ECM13 | Low flow plumbing fixtures |
| ECM14 | High efficiency condensing boilers with 94% efficiency (space heating and domestic hot water heating) |

Table 1. Energy Conservation Measures for Office Building and Hotel Building

Low-flow plumbing fixtures are considered:
1. 0.09 L/s or 1.5 GPM flow rate of Showerhead
2. 0.03 L/s or 0.5 GPM flow rate of Faucet

The energy conservation measures for MURB are listed in Table 2.

| ECM# | ECM Description |
|---|---|
| ECM1 | R15 Wall |
| ECM2 | R18 Wall |
| ECM3 | R30 Roof |
| ECM4 | R40 Roof |
| ECM5 | Window U = 0.40, SHGC = 0.5 |
| ECM6 | 40% CFLs (31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM7 | 100% CFLs (78% Lighting Power Density Reduction over ASHRAE 90.1 – 2004) |
| ECM8 | 60% efficiency HRV – through centralized heat recovery ventilator |
| ECM9 | In-floor radiant heating or overhead radiant heating panel |
| ECM10 | In-floor radiant heating or overhead radiant heating panel with Variable speed pumps |
| ECM11 | Low flow plumbing fixtures |
| ECM12 | High efficiency condensing boilers with 94% efficiency (Domestic hot water heating only) |

Table 2. Energy Conservation Measures for MURB

Energy Modelling Software

The energy study was performed with Natural Resources Canada's EE4 Version 1.7.

## 3.0 ENERGY STUDY RESULTS

The energy modelling results are listed below per building type at each building location.

### 3.1 BURNABY

| Office | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 2,013 | 1,869 | 1,840 | 1,990 | 1,984 | 1,625 | 2,062 | 2,138 | 2,164 | 2,013 | 1,214 | 1,723 | 2,093 | 2,013 | 1,747 | 1,173 |
| Space Cooling (GJ) | 234 | 234 | 234 | 234 | 234 | 245 | 232 | 230 | 229 | 234 | 290 | 220 | 142 | 234 | 234 | 219 |
| Fans & Pumps (GJ) | 697 | 697 | 696 | 697 | 697 | 712 | 695 | 692 | 691 | 697 | 504 | 629 | 278 | 697 | 697 | 175 |
| Water Heating (GJ) | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 122 | 329 | 122 |
| Interior Lighting (GJ) | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 925 | 772 | 719 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 |
| Receptacle and Process Loads (GJ) | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 |
| Total Regulated Energy (GJ) | 4,357 | 4,212 | 4,183 | 4,334 | 4,328 | 3,995 | 4,300 | 4,217 | 4,189 | 4,357 | 3,421 | 3,985 | 3,926 | 4,092 | 4,034 | 2,715 |
| Total Energy Consumption (GJ) | 5,263 | 5,118 | 5,088 | 5,240 | 5,233 | 4,900 | 5,206 | 5,123 | 5,095 | 5,263 | 4,327 | 4,891 | 4,831 | 4,998 | 4,939 | 3,621 |
| Energy Saving (GJ) | N/A | 145 | 174 | 23 | 29 | 362 | 57 | 140 | 168 | 0 | 936 | 372 | 431 | 265 | 323 | 1,642 |
| **Energy Saving (%)** | N/A | 2.7% | 3.3% | 0.4% | 0.6% | 6.9% | 1.1% | 2.7% | 3.2% | 0.0% | 17.8% | 7.1% | 8.2% | 5.0% | 6.1% | **31.2%** |
| Proposed Bundle | | | | | | | | | | | Yes | Yes | Yes | Yes | | |

Table 3. Energy Study Results – Burnaby Office

For the office building in Burnaby, the in-floor radiant heating/cooling system with demand control ventilation, variable speed pumps, and low-flow plumbing fixtures would be able to reduce 31.2% of energy consumption relative to ASHRAE 90.1 – 2004. In addition, since the baseline building has 50% efficiency heat recovery, the ECM9 (60% heat recovery efficiency) will not be able to demonstrate any energy saving. It is also recommended to consider other significant energy-saving strategies such as ECM5 (Window U = 0.40, SHGC = 0.38) and ECM14 (High efficiency condensing boilers with 94% efficiency for space heating and domestic hot water heating).

| Hotel | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 1,620 | 1,458 | 1,425 | 1,599 | 1,593 | 1,343 | 1,653 | 1,702 | 1,719 | 1,179 | 1,879 | 1,508 | 1,728 | 1,620 | 1,406 | 1,406 |
| Space Cooling (GJ) | 388 | 389 | 389 | 389 | 390 | 398 | 380 | 369 | 381 | 402 | 342 | 355 | 353 | 388 | 388 | 388 |
| Fans & Pumps (GJ) | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,111 | 1,217 | 526 | 1,021 | 779 | 1,111 | 1,111 | 1,111 |
| Water Heating (GJ) | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 876 | 2,456 | 634 |
| Interior Lighting (GJ) | 926 | 926 | 926 | 926 | 926 | 926 | 832 | 694 | 764 | 926 | 926 | 926 | 926 | 926 | 926 | 926 |
| Receptacle and Process Loads (GJ) | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 |
| Total Regulated Energy (GJ) | 6,930 | 6,769 | 6,736 | 6,910 | 6,905 | 6,662 | 6,862 | 6,762 | 6,861 | 6,610 | 6,558 | 6,696 | 6,672 | 4,920 | 6,287 | 4,465 |
| Total Energy Consumption (GJ) | 7,142 | 6,981 | 6,949 | 7,123 | 7,117 | 6,875 | 7,074 | 6,974 | 7,073 | 6,822 | 6,771 | 6,909 | 6,884 | 5,132 | 6,499 | 4,677 |
| Energy Saving (GJ) | N/A | 161 | 194 | 20 | 25 | 267 | 68 | 168 | 69 | 320 | 372 | 233 | 258 | 2,010 | 643 | 2,465 |
| **Energy Saving (%)** | N/A | 2.3% | 2.7% | 0.3% | 0.4% | 3.7% | 1.0% | 2.4% | 1.0% | 4.5% | 5.2% | 3.3% | 3.6% | 28.1% | 9.0% | **34.5%** |
| Proposed Bundle | | | | | | | | | | | | | | Yes | Yes | |

Table 4. Energy Study Results – Burnaby Hotel

For the hotel in Burnaby, the hot water heating energy is a significant percentage and therefore the first step to achieve 30% energy reduction over ASHRAE 90.1 – 2004 is to reduce hot water heating energy. Any other energy-saving strategies without changing HVAC system such as ECM5 (Window U = 0.40, SHGC = 0.38), ECM12 (Variable Speed Pumps), and ECM 14 (High efficiency condensing boilers with 94% efficiency for space heating and domestic hot water heating), will be the design strategies to achieve 30% energy reduction.

| MURB | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 882 | 842 | 822 | 865 | 859 | 651 | 925 | 993 | 850 | 1,071 | 1,154 | 882 | 882 | 651 |
| Space Cooling (GJ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fans & Pumps (GJ) | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 407 | 171 | 60 | 38 | 38 | 38 |
| Water Heating (GJ) | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 164 | 457 | 164 |
| Interior Lighting (GJ) | 276 | 276 | 276 | 276 | 276 | 276 | 191 | 63 | 276 | 276 | 276 | 276 | 276 | 276 |
| Receptacle and Process Loads (GJ) | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 |
| Total Regulated Energy (GJ) | 1,733 | 1,692 | 1,672 | 1,715 | 1,710 | 1,501 | 1,691 | 1,630 | 2,069 | 2,055 | 2,027 | 1,360 | 1,653 | 1,129 |
| Total Energy Consumption (GJ) | 1,905 | 1,864 | 1,845 | 1,887 | 1,882 | 1,673 | 1,863 | 1,803 | 2,242 | 2,228 | 2,199 | 1,533 | 1,825 | 1,301 |
| Energy Saving (GJ) | N/A | 41 | 60 | 18 | 23 | 232 | 42 | 102 | -337 | -323 | -294 | 372 | 80 | 604 |
| **Energy Saving (%)** | N/A | 2.1% | 3.2% | 0.9% | 1.2% | 12.2% | 2.2% | 5.4% | -17.7% | -16.9% | -15.4% | 19.6% | 4.2% | **31.7%** |
| Proposed Bundle | | | | | | Yes | | | | | | Yes | | |

Table 5. Energy Study Results – Burnaby MURB

For the MURB in Burnaby, the space heating and hot water heating are two major energy consumers. ECM5 with SHGC of 0.5 will be able to use solar gain to reduce space heating requirements. Low-flow plumbing fixtures will be able to significantly reduce hot water heating energy. However, comparing to electric heating system, the in-floor radiant heating system is not demonstrating energy reduction in a MURB.

For the MURB, ECM8 (60% efficiency heat recovery) reduces space heating energy through make-up air unit but it will increase fan energy as well. Overall, heat recovery ventilator in the MURB does not reduce energy consumption over the baseline building. In addition, ECM9 and ECM10 (In-floor radiant heating with and without Variable Speed Pumps) consumes more energy than the baseline building mostly because in-floor radiant heating system requires hydronic pumps but the baseline building with electric baseboard heating does not, and secondly the efficiency of electric heating is 100% while the efficiency of in-floor radiant heating with gas-fired boilers is 80%.

## 3.2 TERRACE

| Office | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 2,347 | 2,172 | 2,136 | 2,317 | 2,308 | 1,908 | 2,391 | 2,458 | 2,482 | 2,347 | 1,670 | 2,093 | 2,509 | 2,347 | 2,037 | 1,279 |
| Space Cooling (GJ) | 321 | 319 | 319 | 320 | 320 | 339 | 318 | 313 | 316 | 321 | 415 | 302 | 213 | 321 | 321 | 367 |
| Fans & Pumps (GJ) | 971 | 968 | 967 | 970 | 969 | 1,011 | 964 | 956 | 963 | 971 | 828 | 952 | 349 | 971 | 971 | 217 |
| Water Heating (GJ) | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 386 | 122 | 329 | 329 |
| Interior Lighting (GJ) | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 927 | 772 | 855 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 | 1,027 |
| Receptacle and Process Loads (GJ) | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 | 906 |
| Total Regulated Energy (GJ) | 5,051 | 4,871 | 4,835 | 5,019 | 5,010 | 4,670 | 4,986 | 4,885 | 5,002 | 5,051 | 4,326 | 4,759 | 4,484 | 4,787 | 4,684 | 3,219 |
| Total Energy Consumption (GJ) | 5,957 | 5,777 | 5,741 | 5,925 | 5,916 | 5,576 | 5,892 | 5,791 | 5,908 | 5,957 | 5,232 | 5,665 | 5,390 | 5,692 | 5,590 | 4,124 |
| Energy Saving (GJ) | N/A | 180 | 216 | 32 | 41 | 381 | 65 | 166 | 49 | 0 | 725 | 292 | 567 | 265 | 367 | 1,833 |
| **Energy Saving (%)** | N/A | 3.0% | 3.6% | 0.5% | 0.7% | 6.4% | 1.1% | 2.8% | 0.8% | 0.0% | 12.2% | 4.9% | 9.5% | 4.4% | 6.2% | **30.8%** |
| Proposed Bundle | | | | | | Yes | | | | | Yes | | Yes | | Yes | |

Table 6. Energy Study Results – Terrace Office

For the office building in Terrace, the in-floor radiant heating/cooling system with variable speed pumps, improved window performance, and high efficiency boilers would be able to reduce 30.8% of energy consumption relative to ASHRAE 90.1 – 2004. In addition, since the baseline building has 50% efficiency heat recovery, the ECM9 (60% efficiency heat recovery) will not be able to demonstrate any energy saving. It is also recommended to consider other significant energy-saving strategies such as ECM11 (Demand control ventilation) and ECM13 (Low-flow plumbing fixtures) as well. The recommended energy-saving strategies for the office building in Terrace are different from the ones in Burnaby due to the change of climatic conditions.

| Hotel | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | ECM13 | ECM14 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 2,088 | 1,883 | 1,841 | 2,059 | 2,051 | 1,736 | 2,121 | 2,170 | 2,187 | 1,557 | 2,366 | 1,951 | 2,307 | 2,088 | 1,812 | 1,812 |
| Space Cooling (GJ) | 455 | 453 | 453 | 456 | 457 | 463 | 448 | 436 | 447 | 465 | 407 | 419 | 424 | 455 | 455 | 455 |
| Fans & Pumps (GJ) | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,329 | 1,435 | 718 | 1,244 | 834 | 1,329 | 1,329 | 1,329 |
| Water Heating (GJ) | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 2,886 | 876 | 2,456 | 634 |
| Interior Lighting (GJ) | 926 | 926 | 926 | 926 | 926 | 926 | 834 | 694 | 764 | 926 | 926 | 926 | 926 | 926 | 926 | 926 |
| Receptacle and Process Loads (GJ) | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 | 212 |
| Total Regulated Energy (GJ) | 7,684 | 7,477 | 7,435 | 7,656 | 7,648 | 7,340 | 7,617 | 7,515 | 7,613 | 7,269 | 7,302 | 7,426 | 7,377 | 5,674 | 6,979 | 5,157 |
| Total Energy Consumption (GJ) | 7,896 | 7,689 | 7,647 | 7,869 | 7,861 | 7,552 | 7,829 | 7,728 | 7,825 | 7,481 | 7,515 | 7,638 | 7,589 | 5,886 | 7,191 | 5,369 |
| Energy Saving (GJ) | N/A | 207 | 249 | 28 | 35 | 344 | 67 | 168 | 71 | 415 | 381 | 258 | 307 | 2,010 | 705 | 2,527 |
| **Energy Saving (%)** | N/A | 2.6% | 3.2% | 0.3% | 0.4% | 4.4% | 0.8% | 2.1% | 0.9% | 5.3% | 4.8% | 3.3% | 3.9% | 25.5% | 8.9% | **32.0%** |
| Proposed Bundle | | | | | | | | | | | | | | Yes | Yes | |

Table 7. Energy Study Results – Terrace Hotel

For the hotel in Terrace, the hot water heating energy is a significant percentage and therefore the first step to achieve 30% energy reduction over ASHRAE 90.1 – 2004 is to reduce hot water heating energy. Any other energy-saving strategies without changing HVAC system such as ECM5 (Window U = 0.40, SHGC = 0.38), ECM12 (Variable speed pumps), and ECM 14 (High efficiency condensing boilers with 94% efficiency for space heating and domestic hot water heating), will be the design strategies to achieve 30% energy reduction. The energy results are the same as the hotel building in Burnaby.

| MURB | Baseline Building | ECM1 | ECM2 | ECM3 | ECM4 | ECM5 | ECM6 | ECM7 | ECM8 | ECM9 | ECM10 | ECM11 | ECM12 | Proposed Bundle |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Space Heating (GJ) | 1,157 | 1,109 | 1,085 | 1,134 | 1,127 | 886 | 1,197 | 1,261 | 1,014 | 1,351 | 1,479 | 1,157 | 1,157 | 919 |
| Space Cooling (GJ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fans & Pumps (GJ) | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 38 | 426 | 287 | 111 | 38 | 38 | 38 |
| Water Heating (GJ) | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 537 | 164 | 457 | 164 |
| Interior Lighting (GJ) | 276 | 276 | 276 | 276 | 276 | 276 | 191 | 63 | 276 | 276 | 276 | 276 | 276 | 191 |
| Receptacle and Process Loads (GJ) | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 | 172 |
| Total Regulated Energy (GJ) | 2,007 | 1,959 | 1,936 | 1,984 | 1,978 | 1,736 | 1,963 | 1,898 | 2,253 | 2,450 | 2,403 | 1,635 | 1,927 | 1,313 |
| Total Energy Consumption (GJ) | 2,179 | 2,131 | 2,108 | 2,157 | 2,150 | 1,909 | 2,135 | 2,071 | 2,425 | 2,623 | 2,575 | 1,807 | 2,099 | 1,485 |
| Energy Saving (GJ) | N/A | 48 | 71 | 23 | 29 | 271 | 44 | 109 | -246 | -443 | -396 | 372 | 80 | 694 |
| **Energy Saving (%)** | N/A | 2.2% | 3.3% | 1.0% | 1.3% | 12.4% | 2.0% | 5.0% | -11.3% | -20.3% | -18.2% | 17.1% | 3.7% | **31.9%** |
| Proposed Bundle | | | | | | Yes | Yes | | | | | Yes | | |

Table 9. Energy Study Results – Terrace MURB

Due to the change of climatic conditions, space heating energy in Terrace is required more than in Burnaby. Therefore, for the MURB in Terrace, in addition to ECM5 (Window U = 0.40, SHGC = 0.38) and ECM 11 (Low-flow plumbing fixtures), one more ECM was required to achieve 30% energy reduction over ASHRAE 90.1 – 2005, and ECM6 (10% lighting power density reduction over ASHRAE 90.1 – 2004) was recommended. Overall, the recommended ECM5, ECM6, and ECM11, would be able to achieve 31.9% energy reduction.

For the MURB, heat recovery ventilator (ECM8) reduces space heating energy through make-up air unit but it will increase fan energy as well. Overall, heat recovery ventilator in the MURB does not reduce energy consumption over the baseline building. In addition, in-floor radiant heating (ECM9 and ECM10) consumes more energy than the baseline building mostly because in-floor radiant heating system requires hydronic pumps but the baseline building with electric baseboard heating does not, and secondly the efficiency of electric heating is 100% while the efficiency of in-floor radiant heating with gas-fired boilers is 80%.

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the above analysis, the following energy-saving strategies are recommended in order to achieve 30% energy reduction over ASHRAE 90.1 – 2004:

| | Burnaby | Terrace |
|---|---|---|
| Office | In-floor radiant heating and cooling, demand control ventilation, variable speed pumps, and low-flow plumbing fixtures (ECM10, ECM11, ECM12, and ECM13) | Window U = 0.4, SHGC = 0.38, in-floor radiant heating and cooling, variable speed pumps, and high efficiency boilers with 94% efficiency (minimum) for space heating and hot water heating (ECM5, ECM10, ECM12, and ECM14) |
| Hotel | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating (ECM13 and ECM14) | Low-flow plumbing fixtures and high efficiency condensing boilers with 94% efficiency (minimum) for space heating and domestic hot water heating (ECM13 and ECM14) |
| MURB | Window U = 0.4, SHGC = 0.5, and low-flow plumbing fixtures (ECM5 and ECM11) | Window U = 0.4, SHGC = 0.5, 40% CFLs (or 31% Lighting Power Density Reduction over ASHRAE 90.1 – 2004), and low-flow plumbing fixtures (ECM5, ECM6, and ECM11) |

Table 10. Proposed Energy-Saving Strategies

The energy study was based on a "box-type" building with no detailed architectural/mechanical/electrical design, and the results of this study may vary for specific individual buildings. This energy study report should be used as a reference for guidance in energy-saving designs against ASHRAE 90.1 – 2004. We recommend further cost analysis and payback calculations for the selected energy-saving strategies. We also recommend pursuing passive design strategies that give real world energy savings, but are not necessarily accounted for in the energy modelling, such as building orientation, reducing the window to wall ratio, and external shading, etc.

## Appendix A: Baseline Building Parameters

## Office Building

| | Project Baseline |
|---|---|
| **Exterior Surfaces** | |
| Wall Overall R-Value (IP Unit) | R8.1 (Mass Building: U=0.123) |
| Roof Overall R-Value (IP Unit) | R15.9 (Insulation Entirely Above Deck: U=0.063) |
| **Glazing** | |
| Glazing Percent | 50% |
| Window U-Value (IP Unit) | 0.46 |
| Solar Heat Gain Coefficient | 0.26 |
| **Space Conditions** | |
| Lighting | 1.0 $W/ft^2$ or 10.76 $W/m^2$ |
| Equipment Density | 0.7 $W/ft^2$ or 7.5 $W/m^2$ |
| Lighting Controls | N/A |
| **HVAC Systems Type** | |
| Air handling unit | Hot Water Heating and Cooling with Economizer |
| Space Heating | VAV plus Hot Water Reheat |
| Principle heating Fuel Type | Natural Gas |
| Cooling Source | Chilled Water |
| **Fan System** | |
| Make-up Air Unit | N/A |
| Fan Power | 1.1 hp/1000 CFM |
| Outside Air | 18 CFM/Person or 8.5 L/s/Person |
| Occupant Density | 25 $m^2$/person |
| Heat Reclaim | 50% Efficiency |
| **HVAC Controls** | |
| Economizer | Differential Enthalpy |
| **Central Plant** | |
| Central Heating System | Natural Gas Boiler |
| Central Heating Efficiency (AFUE) | 80.00% |
| Central Cooling System | Chiller - Centrifugal |
| Central Cooling Efficiency | COPstd=5.0;IPLVstd=5.25 |
| Air Cooled - Fan Power | 176,000 BTUH/Horsepower |
| Pumps | Head: 150 feet |
| **Domestic Hot Water** | |
| Heating Efficiency (AFUE) | 80.00% |
| Plumbing Fixtures - Flow Rates | Shower Heads: 0.16 L/s or 2.5 GPM; Peak Load Percentage: 25%<br>Faucets: 0.14 L/s or 2.2 GPM; Peak Load Percentage: 75% |
| **Operating Conditions** | |
| Indoor Design Temperatures | Winter: 21.1°C; Summer: 23.3°C |
| Operating Schedules | As per EE4 Default |
| | |
| Building Floor Area ($m^2$) | 9,000 |

## Hotel

| | Project Baseline |
|---|---|
| **Exterior Surfaces** | |
| Wall Overall R-Value (IP Unit) | R8.1 (Mass Building: U=0.123) |
| Roof Overall R-Value (IP Unit) | R15.9 (Insulation Entirely Above Deck: U=0.063) |
| **Glazing** | |
| Glazing Percent | 40% |
| Window U-Value (IP Unit) | 0.57 |
| Solar Heat Gain Coefficient | 0.39 |
| **Space Conditions** | |
| Lighting | 1.0 W/ft$^2$ or 10.76 W/m$^2$ |
| Equipment Density | 0.23 W/ft$^2$ or 2.5 W/m$^2$ |
| Lighting Controls | N/A |
| **HVAC Systems Type** | |
| Air handling unit | N/A |
| Space Heating | Fan coil |
| Principle heating Fuel Type | Natural Gas |
| Cooling Source | Chilled Water |
| **Fan System** | |
| Make-up Air Unit | Supply Air Temperature = 18$^o$C with Heating and Cooling Coils |
| Fan Power | 1.2 hp/1000 CFM |
| Outside Air | 11.65 CFM/Person or 5.5 L/s/Person |
| Occupant Density | 25 m$^2$/person |
| Heat Reclaim | N/A |
| **HVAC Controls** | |
| Economizer | Differential Enthalpy |
| **Central Plant** | |
| Central Heating System | Natural Gas Boiler |
| Central Heating Efficiency (AFUE) | 80.00% |
| Central Cooling System | Chiller - Centrifugal |
| Central Cooling Efficiency | COPstd=5.0;IPLVstd=5.25 |
| Air Cooled - Fan Power | 176,000 BTUH/Horsepower |
| Pumps | Head: 150 feet |
| **Domestic Hot Water** | |
| Heating Efficiency (AFUE) | 80.00% |
| Plumbing Fixtures - Flow Rates | Shower Heads: 0.16 L/s or 2.5 GPM; Peak Load Percentage: 25%<br>Faucets: 0.14 L/s or 2.2 GPM; Peak Load Percentage: 75% |
| **Operating Conditions** | |
| Indoor Design Temperatures | Winter: 21.1$^o$C; Summer: 23.3$^o$C |
| Operating Schedules | As per EE4 Default |
| | |
| Building Floor Area (m$^2$) | 8,000 |

**Assumptions:**

1. It is assumed that the fan power of fan coils is calculated with 0.7 Watt/L/s or 0.33 Watt/CFM.

## MURB

| | Project Baseline |
|---|---|
| **Exterior Surfaces** | |
| Wall Overall R-Value (IP Unit) | R11.1 (Mass Building: U=0.09) |
| Roof Overall R-Value (IP Unit) | R15.9 (Insulation Entirely Above Deck: U=0.063) |
| **Glazing** | |
| Glazing Percent | 45% |
| Window U-Value (IP Unit) | 0.46 |
| Solar Heat Gain Coefficient | 0.26 |
| **Space Conditions** | |
| Lighting | 0.7 W/ft$^2$ or 7.5 W/m$^2$ |
| Equipment Density | 0.23 W/ft$^2$ or 2.5 W/m$^2$ |
| Lighting Controls | N/A |
| **HVAC Systems Type** | |
| Air handling unit | N/A |
| Space Heating | Electric Baseboard |
| Principle heating Fuel Type | Electric |
| Cooling Source | N/A |
| **Fan System** | |
| Make-up Air Unit | Supply Air Temperature = 18$^o$C with gas heating only |
| Fan Power | 1.2 hp/1000 CFM |
| Outside Air | 16 CFM/person or 7.5 L/s/person |
| Occupant Density | 60 m$^2$/person |
| Heat Reclaim | N/A |
| **HVAC Controls** | |
| Economizer | N/A |
| **Central Plant** | |
| Central Heating System | N/A |
| Central Heating Efficiency (AFUE) | N/A |
| Central Cooling System | N/A |
| Central Cooling Efficiency | N/A |
| Air Cooled - Fan Power | N/A |
| Pumps | N/A |
| **Domestic Hot Water** | |
| Heating Efficiency (AFUE) | 80.00% |
| Plumbing Fixtures - Flow Rates | Shower Heads: 0.16 L/s or 2.5 GPM; Peak Load Percentage: 25%<br>Faucets: 0.14 L/s or 2.2 GPM; Peak Load Percentage: 75% |
| **Operating Conditions** | |
| Indoor Design Temperatures | Winter: 21.1$^o$C; Summer: 23.3$^o$C |
| Operating Schedules | As per EE4 Default |
| | |
| Building Floor Area (m$^2$) | 5,000 |