LIFE-CYCLE ECONOMIC ASSESSMENT OF ASHRAE 90.1 APPLIED TO BRITISH COLUMBIA

Curt Hepting, P.Eng.
EnerSys Analytics Inc.
chepting@enersys.ca

Rod Yeoh, P.Eng.
Omicron Consulting Group
ryeoh@omicronconsulting.com

SUMMARY

A working group, formed for the Review of Energy Performance Measures for Buildings (REPBC) in British Columbia, commissioned EnerSys Analytics Inc. and Omicron Consulting Group to evaluate the cost-effectiveness of the ANSI/ASHRAE/IESNA Standard 90.1-2001 (ASHRAE 90.1 or Standard) for applicability in British Columbia. ASHRAE 90.1 is a widely recognized standard that provides minimum requirements concerning energy performance in new commercial buildings and in new residential buildings over three storeys.

EnerSys and Omicron teamed together to review and evaluate ASHRAE 90.1 for areas of concern in which a significant share of the new commercial market does not comply with the Standard. Where applicable, we then conducted a life-cycle cost (LCC) analysis on alternative practices that will satisfy the Standard. From the review and analysis, we were able to assess which areas of the Standard may be met with some resistance in the market and the relative LCC implications of compliance. The REPBC can then make an informed decision about the possible adoption of ASHRAE 90.1 including what, if any, claims of exemption should be provided for the new commercial market in British Columbia.

For the most part, the ASHRAE 90.1 Standard provides for a minimum level of energy-efficiency that is cost-effective and/or already standard practice in British Columbia. Several issues with the Standard are not commonly followed but are cost-effective. There are a few issues that appear to not be cost-effective and hence, may be candidates for exemption in adoption of ASHRAE 90.1 for British Columbia.

This paper discusses our approach to the LCC assessment of the ASHRAE 90.1 Standard and provides further results from the analysis.

BACKGROUND

This study was commissioned by the New Commercial Buildings Workgroup assembled for the Review of Energy Performance Measures for Buildings in British Columbia (REPBC). The goal of the REPBC is to develop recommendations for the Government of British Columbia to improve energy efficiency in new and existing buildings in B.C. The new commercial building workgroup is focused on energy efficiency in new commercial buildings, and reports to a Ministers' Advisory Group, which in turn reports directly to the Ministry of Energy and Mines and the Ministry of Community Aboriginal and Women's Services.

The REPBC process will develop these recommendations based on the following provincial government policy objectives:

- Improving energy efficiency in buildings
- Harmonization with national initiatives surrounding building and energy codes and standards
- Energy and building affordability and quality
- Provincial energy security and reliability
- Private sector investment opportunities
- Environmental responsibility, including climate change mitigation
- Innovation and best practices

Further to the policy objectives listed above, the following criteria will also be applied to all recommendations:

- Technical feasibility
- Affordability
- Economic Efficiency
- Compliance
- Energy security and reliability
- Occupant health
- Environmental Impacts

The New Commercial Buildings Workgroup decided that both the ANSI/ASHRAE/IESNA Standard 90.1-2001 (ASHRAE 90.1 or Standard) and Canada's Model National Energy Code for Buildings (MNECB) would form the basis of recommendations made to the Ministry. In order to justify this decision, it was decided that further analysis was required to determine the cost-effectiveness of ASHRAE 90.1 in the Province. As part of its mandate, the REPBC Workgroup commissioned EnerSys Analytics Inc. (EnerSys) and Omicron Consulting Group (Omicron) to evaluate the life-cycle cost (LCC) implications of applying ASHRAE 90.1-2001 to the British Columbia new commercial construction market.

ASHRAE Standard 90.1-2001

ASHRAE 90.1 is a widely recognized standard that provides minimum requirements concerning energy performance in new commercial buildings and residential buildings over three storeys. It has been adopted in many jurisdictions across Canada and North America, including the City of Vancouver and Ontario, and will be legislated by July 2004 as the minimum energy code requirement in the United States. Further, it is the basis for credits provided by the increasingly popular environmental rating system, LEED™, as supported by the U.S. Green Building Council and British Columbia's own governing body for LEED (LEED-BC).

ASHRAE 90.1 provides for two main paths for compliance: (1) prescriptive and (2) energy cost budget (ECB). The prescriptive path requires that new designs comply on an itemized basis with prescribed requirements of the Standard. The ECB method provides for more flexibility by allowing energy performance simulations to demonstrate that the overall annual energy cost for a given design is less than that for a similar model with all building characteristics fixed at the minimum prescribed level. Based on feedback from Vancouver's Energy Utilization By-Law official, the prescriptive path of compliance is by far most widely followed—mainly because it is simplest and takes the least amount of time.

Within the prescriptive path, compliance may be satisfied following a trade-off method for the building envelope and interior lighting. The trade-off method essentially provides for deficiencies in some prescriptive elements (e.g., window U-value below the prescribed value) to be offset with increased levels in other elements (e.g., R-value of walls and roof above the prescribed value). From City of Vancouver By-Law experiences, most practitioners utilize the trade-off method of compliance—particularly for the building envelope. Hence, because of the preference for applying the prescriptive path's trade-off method, we focused our assessment on compliance issues as they primarily relate to this method of ASHRAE 90.1 compliance.

The ASHRAE 90.1-2001 standard is comprised of twelve sections. Five of these sections deal with administration, definitions, scope, references, etc. The remaining seven sections deal directly with specific requirements, and are titled:

- Building Envelope;
- Heating,
- Ventilating and Air Conditioning;
- Service Water Heating;
- Power;
- Lighting;
- Other Equipment; and
- Energy Cost Budget (ECB) Method.

The first sections deal with the prescriptive compliance path while the last section deals with the ECB compliance path. These seven sections are further divided into subsections that deal with specific requirements.

The ASHRAE 90.1 Standard is scheduled for publication every 3 years. The 2001 version is also the first version to be published using the ANSI and ASHRAE continuous maintenance procedures. Thus, the project committee is continually considering changes and proposing addenda for public review. When addenda are approved, notices will be published on the ASHRAE website.

APPROACH

The first step in our LCC assessment involved reviewing ASHRAE 90.1 to identify issues within the Standard that may be met with resistance by a significant portion of the new commercial market. Our review and subsequent energy analyses focused on the following three weather regions:

- Lower Mainland and Vancouver Island (ASHRAE 90.1 Table B-18 prescriptive building envelope requirements), represented in the energy performance analysis using Vancouver typical year weather data;
- Southern Interior, (ASHRAE 90.1 Table B-17 prescriptive building envelope requirements), represented in the energy performance analysis using Summerland typical year weather data;
- Northern Interior (ASHRAE 90.1 Table B-22 prescriptive building envelope requirements), represented in the energy performance analysis using Prince George typical year weather data.

Based on our collective experience with new commercial designs in British Columbia, we reviewed the Standard's mandatory and prescriptive requirements to screen out items that are already standard practice. We defined standard practice as construction standards that we perceived at least 80% of the current construction in B.C. adheres to. In our opinion, the vast majority of the Standard's many stipulations are already standard practice in B.C., although it is possible that nearly any of the requirements may be violated in relatively rare cases. The standard has approximately 135 mandatory and prescriptive requirements. Within these 135 requirements, there are over 370 specific requirements for equipment efficiency and lighting power allowances.

The Standard review provided for a relatively short list of 20 stipulations that were identified as not standard practice in British Columbia. Note that not all stipulations that are not standard practice are applicable for LCC energy performance analysis. Some issues cannot be addressed adequately with LCC since they represent institutional market barriers. We also felt LCC was not appropriate for cases in which the Standard minimum has been widely accepted in some jurisdictions and the alternative approach would be considered poor construction practice (e.g., single-pane storefront windows). Finally, some Standard requirements have already been proven so cost-effective that LCC is unnecessary since the design community is generally aware of the economic benefits.

For the items warranting further LCC analysis, we applied hourly energy performance simulation using DOE2.1e archetype building models. The archetypes selected depended on the particular stipulation being evaluated. We tested the cost-effectiveness by selecting the most appropriate archetype(s) for which the particular ASHRAE 90.1 stipulation may be an issue and is not considered common practice. In each case, we generated monthly energy requirements by fuel type using the DOE2.1e energy models for (1) a typical baseline representing common practice and (2) an alternative case with the particularly Standard requirement implemented. Appendix A provides further details of the key assumptions and building characteristics used for each modelling exercise.

From the modelled energy use, we determined the annual energy costs and relative cost savings by applying the current applicable rate tariffs for each regional electricity and natural gas provider (Appendix A lists the rates for each fuel provider). Finally, the LCC assessment for each Standard stipulation was determined by applying the economic conditions prescribed by the REPBC Working Group, as detailed in Appendix A.

RESULTS

We performed LCC analysis on ten ASHRAE 90.1 stipulations for the three selected British Columbia regions, for over 40 energy analysis scenarios and eight referenced case studies. The selection for LCC analysis applied to stipulations that are not necessarily common practice (e.g., over ~20% or the market does not already adhere to the Standard provision). The analysis included a baseline assessment with “medium” economic parameters, along with “high” and “low” sensitivity scenarios. As further detailed in Appendix A, the following economic conditions applied to each scenario:

- Medium scenario: 8% discount rate with average “medium” electricity and natural gas price forecasts provided by the REPBC working group, providing for –1.0% in fossil fuel and +2.0% in electricity price escalation.
- Low scenario: 4% discount rate with average “high” electricity and natural gas price forecasts provided by the REPBC working group, providing for +2.3% in fossil fuel and +3.5% in electricity price escalation.
- High scenario: 12% discount rate with average “low” electricity and natural gas price forecasts provided by the REPBC working group, providing for –1.9% in fossil fuel and +1.7% in electricity price escalation.

Tables 1–3 below, along with the expanded impact tables in Appendix C, list the ASHRAE 90.1 provisions that we evaluated for each region, respectively. Within each table, we categorized the LCC results based on the overall cost-effectiveness indicators for each of the ASHRAE 90.1 stipulations as such:

(1) Failed: all LCC tests indicate negative life-cycle cost savings (i.e., increased the overall net present value costs) over 25 years for the low, medium and high scenarios.

(2) Marginal: one of the scenarios showed a positive life-cycle cost savings, but at least one of the remaining scenarios demonstrated a negative LCC savings over 25 years.

(3) Passed: all LCC savings were positive, indicating that net present value costs would decrease over 25 years for all scenarios.

The issues highlighted in the summary tables are further described and detailed in Appendix A. Appendix A not only describes the potentially conflicting ASHRAE 90.1 stipulation, but also describes the analysis process and key assumptions.

Table 1. ASHRAE 90.1-2001 Stipulations for Coastal Region

	ASHRAE 90.1 Stipulation	LCC Savings ($/m²)	Standard Issue/Comments
PASS	Exhaust Heat Recovery (6.3.6.1)	$35.17 med. $20.51 to 90.31	Required on air handlers with over 70% outside air, over 5000 cfm and with no exhaust source above 75% of the supply; not common practice.
PASS	Glazing, Residential (5.3.2)	$4.87 med. $0.69 to 10.89	For buildings with high glazing percentages (i.e., >40%), Standard calls for overall U-value that is common but not always installed.
PASS	Wall R-value requirements, residential steel frame construction (5.3.1.2)	$1.85 med. $0.63 to 3.61	Overall wall R-value and insulation requirements exceed level provided for most designs.
PASS	Condenser Heat Recovery for Service Water (6.3.6.2)	N/A - see Appendix A	Applies to facilities with large cooling and domestic hot water loads; most likely located in major urban centres.
MARGINAL	Mass wall R-value requirements (5.3.1.2)	$8.12 med. -$12.10 to 75.02	Overall wall R-value and insulation requirements exceed levels provided for most designs with solid masonry walls.
MARGINAL	Glazing, Commercial (5.3.2)	-$3.94 med. -$5.98 to 3.51	For buildings with high glazing percentages (i.e., >40%), Standard calls for overall U-value that is common but not always installed.
FAIL	Mandatory Automatic lighting shut-off (9.2.1.1)	-$0.19 med. -$0.44 to -1.08	Retail outlets over 5,000 square feet are required to have automatic controls to shut off all interior lighting.
FAIL	Water-source heat pumps must have two-position valve interlock (6.3.2.2)	-$0.57 med. -$0.87 to -0.57	Two-position valves on units are readily available at a nominal cost, but are not standard equipment yet.

Table 2. ASHRAE 90.1-2001 Stipulations for Southern Interior Region

	ASHRAE 90.1 Stipulation	LCC Savings ($/m²)	Standard Issue/Comments
PASS	Exhaust Heat Recovery (6.3.6.1)	$38.34 med. $23.13 to 95.31	Required on air handlers with over 70% outside air, over 5000 cfm and with no exhaust source above 75% of the supply; not common practice.
PASS	Mass wall R-value requirements (5.3.1.2)	$27.91 med. $2.45 to 106.03	Overall wall R-value and insulation requirements exceed levels provided for most designs with solid masonry walls.
PASS	Glazing, Commercial (5.3.2)	$4.91 med. $1.66 to 13.12	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.
PASS	Glazing, Residential (5.3.2)	$4.74 med. $1.31 to 9.68	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.
PASS	Wall R-value requirements, commercial steel frame construction (5.3.1.2)	$3.32 med. $1.66 to 8.85	Overall wall R-value and insulation requirements exceed level provided for many designs.
PASS	Mandatory Automatic lighting shut-off (9.2.1.1)	$1.59 med. $0.82 to 1.53	Retail outlets over 5,000 square feet are required to have automatic controls to shut off all interior lighting.
PASS	Wall R-value requirements, residential steel frame construction (5.3.1.2)	$1.22 med. $0.19 to 2.71	Overall wall R-value and insulation requirements exceed level provided for most designs.
PASS	Condenser Heat Recovery for Service Water (6.3.6.2)	N/A - see Appendix A	Applies to facilities with large cooling and domestic hot water loads; most likely located in major urban centres.
FAIL	Water-source heat pumps must have two-position valve interlock (6.3.2.2)	-$0.20 med. -$0.61 to -0.01	Two-position valves on units are readily available at a nominal cost, but are not standard equipment yet.

Table 4 provides overall impacts estimated for the new commercial and multiunit residential market (four storeys and above). We calculated the overall market-wide impacts by applying the normalized indicators from the analysis for each of the stipulations (in Tables 1 – 3) to new construction market shares. In addition, we included estimates for portions of the market that still follow the poor construction practice of installing single pane windows (particularly, for retail). The market shares were derived from BC Hydro's Conservation Potential Review study by building type and aligned with each of the modelled stipulations as best as possible.

Table 3. ASHRAE 90.1-2001 Stipulations for Northern Interior Region

	ASHRAE 90.1 Stipulation	LCC Savings ($\$/m^2$)	Standard Issue/Comments
PASS	Exhaust Heat Recovery (6.3.6.1)	$60.05 med. $38.26 to 140.51	Required on air handlers with over 70% outside air, over 5000 cfm and with no exhaust source above 75% of the supply; not common practice.
PASS	Mass wall R-value requirements (5.3.1.2)	$51.02 med. $17.74 to 161.02	Overall wall R-value and insulation requirements exceed levels provided for most designs with solid masonry walls.
PASS	Glazing, Residential (5.3.2)	$7.52 med. $3.09 to 14.36	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.
PASS	Wall R-value requirements, commercial steel frame construction (5.3.1.2)	$4.49 med. $2.39 to 11.82	Overall wall R-value and insulation requirements exceed level provided for many designs..
PASS	Glazing, Commercial (5.3.2)	$3.98 med. $1.19 to 12.03	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.
PASS	Wall R-value requirements, residential steel frame construction (5.3.1.2)	$3.83 med. $1.87 to 7.60	Overall wall R-value and insulation requirements exceed level provided for most designs.
FAIL	Mandatory Automatic lighting shut-off (9.2.1.1)	-$0.61 med. -$0.73 to -1.89	Retail outlets over 5,000 square feet are required to have automatic controls to shut off all interior lighting.
FAIL	Wall R-value requirements, residential wood frame construction (5.3.1.2)	-$6.94 med. -$8.10 to -2.83	Standard calls for higher insulation levels than typical practice.

Because of the level of accuracy associated with the forecasted market shares, representation of how construction practices differ from ASHRAE stipulations, and other factors, the overall impacts in Table 4 only provide rough indicators. But the underlying indicators are that ASHRAE 90.1-2001 would provide a positive societal benefit to British Columbia. If the Standard were adopted without any exemptions, roughly $3.6 million in annual energy costs would be avoided at an incremental capital cost of about $26 million, providing for a LCC net present value (NPV) savings of nearly $14 million. In addition, 340 TJ of energy would be avoided annually, resulting in annual emission reductions of over 19 million kg of CO_2 (equivalent to roughly 5,000 passenger automobiles).

The above estimates are for after the first year of adhering to the Standard, based on projections for 2005. As Table 4 shows, NPV cost and energy savings respectively grow to roughly $69 million and 1,700 TJ per year within 5 years, and $206 million and 5,200 TJ per year within 15 years. Since the impacts are relatively sustained, this means that the accumulation of savings would amount to roughly $1.6 billion and 41,000 TJ over 15 years. This translates into an avoidance of about 2.3 million metric tons of CO_2.

Table 4. Overall Impact of ASHRAE 90.1-2001 on New Construction Market

	Coastal	Southern Interior	Northern Interior	Total (2005)	Annual*	
					5-Year	15-Year
25-Yr NPV Savings ($ millions)						
Medium Scenario	$11.1	$1.7	$1.0	$13.7	$68.7	$206.2
Low Scenario	$43.3	$5.2	$2.8	$51.3	$256.4	$769.2
High Scenario	$0.8	$0.6	$0.4	$1.8	$8.9	$26.8
Annual Energy Use Savings						
Electricity (GWh)	9.8	0.9	0.3	11.0	55.2	165.6
Fossil Fuel (TJ)	261	28	15	304	1,521	4,564
Total (TJ)	296	32	16	344	1,720	5,160
Annual Energy Cost Savings ($ millions)						
Electricity	$0.59	$0.07	$0.02	$0.68	$3.40	$10.21
Fossil Fuel	$2.51	$0.27	$0.15	$2.93	$14.63	$43.88
Total	$3.10	$0.34	$0.17	$3.61	$18.03	$54.10
Incremental Net Costs ($ millions)						
Capital	$22.9	$2.0	$0.8	$25.7	$128.6	$385.7
Annual Maintenance	$0.043	$0.004	$0.002	$0.049	$0.246	$0.738
Annual Emission Savings (thousand metric tonnes)						
Total CO_2	16.7	1.8	0.9	19.3	96.5	289.5

** Annual savings/costs in year indicated after invoking Standard*

Appendix A further discusses other issues that might be met with some initial resistance in the market, but did not warrant further LCC analysis. This was often because the relevant issue would impact a small portion of new designs. For other cases, LCC was not deemed appropriate as the stipulation concerned issues that related to good practice but for which energy analysis is problematic (e.g., shut-off damper controls). One such issue that likely will be met with particular resistance is the mandatory requirement for vestibules or revolving doors for entrances to spaces over 3000 ft² in buildings over four storeys (5.5.3.4). While this is good practice, it is commonly not done in British Columbia—and energy analysis of such an issue is quite problematic due to the vague assumptions required for infiltration and/or return air impacts.

One ASHRAE 90.1 stipulation that is becoming standard practice, but is not yet fully followed by all designers, is the mandatory use of ventilation controls for high occupancy areas (6.2.3.8). CO_2 controls that perform this function have proven to be one of the most cost-effective options that may be applied to highly variable, high occupancy spaces (e.g., meeting rooms, gyms). Consequently, LCC analysis was not necessary for such a cost-effective measure that is rapidly gaining market acceptance. Note that this was not included in the previous overall impacts assessment, making it more conservative.

A final mandatory ASHRAE 90.1 provision for which LCC analysis was not appropriate concerns the accreditation of windows and doors (5.2.2 & 5.5.2 – 5.5.3). This provision indicates that windows and doors are to be labeled by a "nationally recognized accreditation organization." This rarely happens in Canada, in which case, ASHRAE 90.1 stipulates that compliance must be satisfied using the unrealistically poor prescriptive requirements listed in Appendix A of the Standard. The net result is that all new commercial designs would technically not satisfy the Standard, regardless of the compliance method.

CONCLUSION

The ASHRAE 90.1 Standard provides for a minimum level of energy-efficiency for which all but a few stipulations are cost-effective and/or already standard practice in British Columbia. As described in this paper, there are several issues within the Standard that are commonly not followed yet are cost-effective. Further, there are four key stipulations that prove uneconomical. Finally, a couple ASHRAE 90.1 mandatory requirements pose design or market barriers (i.e., vestibules and fenestration accreditation).

For those stipulations that pose design or market barriers, exemptions may be most appropriate – at least in the near term. For fenestration accreditation, standardized window labeling is recommended but will likely take some time to establish for Canada. The stipulations that failed the LCC tests are candidates for exclusion as well. Although, the provision for two position valves on water-source heat pump units may be satisfied over time with equipment manufacturers *only* providing units that comply with ASHRAE requirements, as is usually the case.

ASHRAE supports the adoption of the Standard with consideration for certain "candidates for exemption" that may be applied for a given jurisdiction. Hence, given the relatively few provisions that appear uneconomical or present market barriers, adoption of ASHRAE 90.1-2001 for British Columbia appears technically viable, with a few possible exemptions. Further, its acceptance is strengthened by the fact that ASHRAE is a recognized standard for minimum energy-efficiency by design professionals in British Columbia and across North America. In fact, most/all U.S. states reference the Standard as part of its energy code and must adopt it by July 2004. Also, the Standard is accepted in Ontario and the City of Vancouver has recognized ASHRAE 90.1 as part of its Energy Utilization By-Law since 1991. Consequently, it appears there would be little resistance or reason to not adopt ASHRAE 90.1-2001 in British Columbia as its minimum energy-efficiency code.

REFERENCES

American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE). 2001. ASHRAE Standard: Energy Standard for Buildings Except Low-Rise Residential Buildings (ANSI/ASHRAE/IESNA Standard 90.1-2001). ISSN 1041-2336. ASHRAE: Atlanta, Georgia.

Berry, T. et al.; December 2003; "The Costs and Benefits of Hydronic Heating in New Multifamily Residential Construction in the Lower Mainland of British Columbia;" Compass Resource Management Ltd., EnerSys Analytics Inc. and Thornley BKG Consultants Inc.

Commercial Building Incentive Program (CBIP) Web Site, including CBIP Technical Guidelines: http://oee.nrcan.gc.ca/newbuildings/technical_guide.cfm

Hepting, C. and D. Ehret, March 2002; "Verification of LEED-BC v1.0 Energy Credit 1 Point Awards forBuilding Energy Conservation in British Columbia;" EnerSys Analytics Inc.

Hepting, C. and D. Ehret; in preparation, "Verification of LEED-Canada v1.0 Energy Credit 1 Point Awards for Building Energy Conservation in Canada;" EnerSys Analytics Inc.

APPENDIX A:

REPBC LCC REVIEW AND ANALYSIS NOTES

APPENDIX A: ASHRAE 90.1-2001 LCC Assessment Notes

This appendix describes the issues and areas of concern that may affect a significant portion of new commercial construction projects should British Columbia adopt the *ANSI/ASHRAE/IESNA Standard 90.1-2001: Energy Standard for Buildings Except Low-Rise Residential* (Standard). The issues reflect aspects of the Standard that EnerSys Analytics Inc. (EnerSys) and Omicron Consulting Group (Omicron) anticipate would be met with resistance from the new commercial construction market. Note that many aspects of the Standard could meet some resistance in relatively rare cases, but we focus on aspects of the Standard that apply to situations that would likely be more common. These aspects of the Standard are then deemed as candidates for further life-cycle economic analysis (LCC).

This appendix presents issues that may be met with resistance, but do not necessarily all warrant LCC. For instance, some issues cannot be addressed adequately with LCC since they represent institutional market barriers (e.g., window labelling). In addition, relatively rare situations did not warrant LCC, although we felt these situations warranted some discussion. We also felt LCC was not appropriate for cases in which the Standard minimum has been widely accepted in some jurisdictions (e.g., double-pane windows in Vancouver) and the alternative approach would be considered poor construction practice (e.g., single pane storefront windows). Finally, some Standard requirements have already been proven so cost-effective that LCC is unnecessary since the design community is aware of the economic benefits (e.g., demand controlled ventilation in gyms).

ASHRAE 90.1-2001 COMPLIANCE ISSUES

The following issues are organized by major section in the ASHRAE Standard. The primary focus is on Standard compliance following the prescriptive path, including use of the envelope and lighting trade-off options. Next, we consider the application of the “Energy Cost Budget” (ECB) method, requiring energy performance modelling, but only in cases where it is likely to be utilized.

All issues are listed with the specific ASHRAE section reference included. We also provide insights as to the life-cycle implications, in which case, key assumptions and analysis details are provided. Standard requirements that warranted LCC are designated in blue.

Section 5. Building Envelope

***Mandatory* window and door accreditation requirements (5.2.2 / 5.5.2-5.5.3):** According to the mandatory requirements of the Standard, windows and doors must essentially be labelled by a “nationally recognized accreditation organization, such as the National Fenestration Rating Council, and shall be labeled and certified by the manufacturer." This applies to the U-value, solar heat gain coefficient (SHGC) and air leakage. To our knowledge, this is rarely done in Canada, particularly for the entire window including framing.

Sample of the new NFRC Label

If strictly enforced, this provision would meet with great resistance since non-labeled windows and doors would have to use referenced values from Appendix A in the Standard, which lists values that do not comply with the prescriptive shell requirements. For example, A8.2 allows for U-value = 0.90 for any aluminum framed double pane system, regardless of the thermal break in the frame and any low-e coatings, gas fills, etc. On the other hand, the common practice of using center-of-glass U-values to reflect the overall performance of a window assembly should be avoided since the framing and spacers make a significant different in the performance. In lieu of *properly* using a fenestration-rating program, such as Window 4.1 from Lawrence Berkeley Laboratory, we suggest referencing the ASHRAE's tables for representative U-factors, solar heat gain and visible transmittance values for fenestration products in the "2001 ASHRAE Fundamentals Handbook." Alternately, Natural Resources Canada has recently released FRAME™plus Online (http://p10a.enermodal.com/WebFPlus/). This WEB application is designed to rapidly provide thermal performance ratings for fenestration assemblies including spandrel panels.

As this represents an institutional market barrier, LCC analysis is not appropriate or applicable.

***Mandatory* vestibule requirement (5.5.3.4):** Like the MNECB, the ASHRAE Standard requires vestibules for entrances to spaces over 3000 ft² in buildings over four storeys, and that do not instead have revolving doors. This typically most affects high-rise offices, hotels and possibly multi-unit residential buildings (MURBs), depending on the size of the foyer entrance area. This provision mainly impacts the Lower Mainland/Vancouver Island area, as colder climates tend to have vestibules. Note that this provision is often not enforced in many jurisdictions or by the CBIP.

Modelling for LCC purposes was not conducted since it is very problematic. The implications are such that entrances without vestibules would allow for more conditioned air to flow out the entrance instead of being relieved via the air *handler since most buildings are pressurized. Only in rare cases would additional ventilation be required to balance the system (e.g., exhaust plus air leakage exceeds occupant fresh air requirements). Hence, properly balanced HVAC designs would still have the same amount of outside air, resulting in negligible energy difference for simulation purposes. (Note that localized comfort issues are likely to be of greater concern.)*

***Wall R-value requirements, commercial steel frame construction (5.3.1.2)*:** For non-residential spaces, the required insulation R-values and/or overall assembly U-value may be an issue for curtain wall or metal framed construction for offices that are over 50% glazing. Such office configurations will need to apply (1) the shell trade-off method[1] or (2) the energy cost budget (ECB) method of compliance. For typical offices with 40–50% glazing, the prescriptive requirement may also be an issue.

Lower Mainland/Vancouver Island (Table B-18): With a glazing percentage of 40–50%, the prescriptive steel framed wall requirement may be met if good, low-e windows are used. This is something that tends to be readily accepted by the market for high percent glazing situations already. As the glazing percentage is pushed beyond 50%, the building envelope tables cannot be used and trade-offs in performance of the wall performance and other elements of the building design must be applied. At around 70% glazing, the shell requirement can still be satisfied using the same low-e glazing, but adding an inch of continuous rigid insulation (R-5)[2]. This is something that we have already seen done for many designs.

Alternatively, the ECB method may be applied and trade-offs with lighting and HVAC tend to provide for compliance. For buildings with ~70% glazing, the ECB method is an approach that is already followed since these projects tend to have higher budgets and often strive to qualify for programs that require this (i.e., CBIP and LEED). *Hence, the need to apply LCC for the steel frame requirements of the Standard in the temperate regions is not necessary since the most of the market practices already comply.*

Southern Interior (Table B-17): The prescriptive steel framed wall requirement specifies that an additional R-3.8 of continuous insulation must be added to the wall, which is not commonly done. Assuming a relatively typical mid-rise office in the Southern Interior with 45% glazing, the extra insulation is required to comply with the Standard using the prescriptive approach or the envelope trade-off method of compliance. We analyzed the LCC implication of adding an extra inch

[1] The building shell trade-off method is the most commonly applied approach to demonstrating compliance according to By-Law representatives at the City of Vancouver.
[2] Overall U-factor of 0.081 (R_o-12.4) based on applying ASHRAE-referenced material thermal resistances for: (1) exterior air film at R-0.17, (2) R-13 insulation in 3.5" metal frames at 16" o.c. (applies equally to curtain wall according to ASHRAE definitions), (3) interior gypsum board at R-0.56 and (4) interior air film at R-0.68.

of continuous polystyrene insulation to the steel framed walls using the NRCan CBIP office archetype with 45% glazing. The key building characteristics that are significant for this situation for the LCC analysis include:

- 9500 ft² net wall area at an assembly R_o[3]-5.5 for typical curtain wall[4]
- 43,200 ft² conditioned floor area over 3 floors
- 1.2 W/ft² diversified peak hourly interior lighting load
- 0.7 W/ft² diversified peak hourly plug load
- 269 ft²/person diversified peak hourly occupant density
- 75 hour/week fan operation with heating setpoint at 71.6°F (22°C)
- 64.4°F (18°C) heating setback
- Natural gas heating using an 80% efficient on/off boiler with HW reset
- All other prescriptive requirements of the Standard are minimally satisfied
- Summerland weather data for a typical meteorological year

The incremental cost for the added insulation is estimated at $1.10/ft² of wall area ($10,450), with no incremental annual maintenance costs. This is based on the incremental cost to install interior rigid insulation, with provision for wider sills. At this cost, the LCC NPV savings is positive at over $3.30/m², with the sensitivity range from nearly $1.70/m² to $8.90/m², using the LCC analysis parameters and rates provided by the Steering Committee.

<u>Northern Interior (Table B-22):</u> The prescriptive steel framed wall requirement specifies that an additional R-7.5 of continuous insulation must be added to the wall, which is not commonly done. Assuming a relatively typical mid-rise office in the Southern Interior with 45% glazing, extra insulation beyond the typical batts between framing members is required to comply with the Standard using the prescriptive approach or the envelope trade-off method of compliance. However, evaluation with the envelope trade-off method indicates that only an inch of R-5 polystyrene is required to provide for compliance. Hence, we analyzed the LCC implication of adding an extra inch of continuous polystyrene insulation to the steel framed walls using the same archetype configuration as for the Southern Interior (except using Prince George prescriptive requirements and weather).

The incremental cost for the added insulation is estimated at $1.10/ft² of wall area[5] ($10,450), with no incremental annual maintenance costs. This is based on the incremental cost to install interior rigid insulation, with provision for wider

---

[3] R_o refers to the overall thermal resistance (R-value) for an assembly, including interior and exterior air films.

[4] Note that applying prescribed ASHRAE procedures from the Standard's Appendix A provides for a minimum assembly R_o-7.4 for a typical 3.5" steel stud assembly, including gypsum wall board and air films. However, tests on many curtain wall systems indicate poorer performance (as referenced by CBIP guidelines, for instance).

[5] Derived from pricing provided by A. Kesteloo of Thornley BKG Consultants Inc. in support of similar economic analyses for the City of Vancouver By-Law update to ASHRAE 90.1-2001 (Dec-2003). All following costing for adding continuous rigid insulation to metal-framed walls is derived from the same source.

sills. At this cost, the LCC NPV savings is positive at nearly $4.50/m², with the sensitivity range from nearly $2.40/m² to $11.80/m², using the LCC analysis parameters and rates provided by the Steering Committee.

***Wall R-value requirements, residential steel frame construction (5.3.1.2)*:** When combined with high percentages of glazing, this is probably the biggest "problem area" for high-rise multiunit residential buildings (MURBs) since the Standard requires continuous insulation in addition to R-13 insulation between the framing. In our experience, this is particularly a problem in the Lower Mainland because most new high-rise MURBs fall well below the energy code.

Lower Mainland/Vancouver Island (Table B-18): With a glazing percentage of 60%, the prescriptive steel framed wall requirement may be met if the additional insulation is added and good, low-e windows are used as required by the Standard. Providing for low-e windows is something that at least the Vancouver market already appears to readily accept for high percent glazing situations. However, adding insulation to the walls is not common practice.

Indications using a typical high-rise MURB configuration with the envelope trade-off method shows that approximately 1.5” of rigid polystyrene insulation (R-7.5) must be added to just comply with the Standard, given 60% glazing. Note that above this typical level, compliance becomes much more problematic, as it requires installation of a significantly better glazing system and/or applying mechanical efficiencies to compensate for the envelope performance deficiency via the ECB method (e.g., installing mechanical heat recovery to offset the window losses).

The most cost-effective means of complying with the cost (and saving energy) is to reduce the percentage of glazing. Assuming the market will not accept this in this weather region, we focused on the cost-effectiveness of adding 1.5 inches of continuous rigid insulation (R-7.5). We evaluated the LCC implications using the high-rise MURB archetype from the hydronic heating study for Terasen Gas, Natural Resources Canada and The City of Vancouver[6] (with 60% glazing). The key building characteristics that are significant for this situation for the LCC analysis include:

- 20,700 ft² net wall area at an assembly R_o-5.5 for typical curtain wall[7]
- 138,000 ft² conditioned floor area over 12 floors
- 0.84 W/ft² diversified peak hourly interior lighting load

[6] “The Costs and Benefits of Hydronic Heating in New Multifamily Residential Construction in the Lower Mainland of British Columbia” report by Trent Barry, Compass Resource Management (Compass Resource Management, EnerSys Analytics, Inc., Thornley BKG Consultants, Ltd.), December 2003.

[7] Note that applying prescribed ASHRAE procedures from the Standard’s Appendix A provides for a minimum assembly R_o-7.4 for a typical 3.5” steel stud assembly, including gypsum wall board and air films. However, tests on many curtain wall systems indicate poorer performance (as referenced by CBIP guidelines, for instance).

- 0.49 W/ft² diversified peak hourly plug load
- 70°F heating setpoint
- 67°F average heating setback, applied approximately 42 hours/week
- Electric resistance heating in suites; gas-fired make-up air units at 80% full-load efficiency
- All other prescriptive requirements of the Standard are met or exceeded
- Vancouver weather data for a typical meteorological year

The incremental cost for the added insulation is estimated at $1.48/ft² of wall area ($30,640), with no incremental annual maintenance costs. This is based on the incremental cost to install interior rigid insulation, with provision for wider sills. At this cost, the LCC NPV savings is positive at nearly $1.90/m², with the sensitivity range from $0.63/m² to $3.60/m², using the LCC analysis parameters and rates provided by the Steering Committee.

<u>Southern Interior (Table B-17):</u> Glazing percentages as high as in Vancouver are less prevalent in the Southern Interior. Therefore, using the same LCC approach as followed for the Coastal region would provide conservative indicators. Hence, the LCC analysis was identical to the approach described for the Coastal region, except using the appropriate Summerland weather data. Also, the shading coefficient was left the same as for Vancouver, although this is higher than specified by the Standard (see discussion on solar heat gain coefficient, page 14).

The incremental cost for the added insulation is estimated at $1.48/ft² of wall area ($30,640), with no incremental annual maintenance costs. This is based on the incremental cost to install interior rigid insulation, with provision for wider sills. At this cost, the LCC NPV savings is positive at over $1.20/m², with the sensitivity range from $0.19/m² to $2.71/m², using the LCC analysis parameters and rates provided by the Steering Committee.

<u>Northern Interior (Table B-22):</u> Glazing percentages as high as in Vancouver are even less prevalent in the Northern Interior than other regions in British Columbia. However, we followed the same LCC approach as followed for the other regions to provide conservative indicators. Hence, the LCC analysis was identical to the approach described for the Coastal region, except using the appropriate Prince George weather data.

The incremental cost for the added insulation is estimated at $1.48/ft² of wall area ($30,640), with no incremental annual maintenance costs. This is based on the incremental cost to install interior rigid insulation, with provision for wider sills. At this cost, the LCC NPV savings is positive at over $3.80/m², with the sensitivity range from about $1.90/m² to $7.60/m², using the LCC analysis parameters and rates provided by the Steering Committee.

***Wall R-value requirements, residential wood frame construction (5.3.1.2)*:** Continuous R-7.5 insulation is required in addition to R-13 between framing in the North for wood-framed walls. Alternatively, the Standard calls for an R_o-19.6 assembly requirement. Depending on the sheathing and siding, it is possible for 2"x6" walls with R-20 insulation in between 24" o.c. framing to just meet the overall assembly R-value requirement. However, 2"x4" construction would require the additional continuous insulation to comply with the Standard.

Assuming a relatively typical low-rise MURB in the Northern Interior with 30% glazing, we analyzed the LCC implication of adding an extra 1.5" of continuous polystyrene (R-7.5) insulation to the wood framed walls. We used the low-rise MURB archetype from the hydronic heating study previously referenced[8]. The key building characteristics that are significant for this situation for the LCC analysis include:

- 12,100 ft² net wall area at an assembly R_o-11 for typical 2"x4" wood stud walls
- 46,000 ft² conditioned floor area over 4 floors
- 0.84 W/ft² diversified peak hourly interior lighting load
- 0.49 W/ft² diversified peak hourly plug load
- 70°F heating setpoint
- 67°F average heating setback, applied approximately 42 hours/week
- Hydronic heating in suites served by gas-fired boiler at 80% full load efficiency; gas-fired make-up air units at 80% full load efficiency
- All other prescriptive requirements of the Standard are met or exceeded, except solar heat gain coefficient (see discussion on page 14)
- Prince George weather data for a typical meteorological year

The incremental cost for the added insulation is estimated at $3.85 per square foot of wall area ($46,585), with no incremental annual maintenance costs. This is based on adding 1.5" inches of insulation on 2.5" furring strips (wood spacers) and an additional layer of sheathing over a typical 2 x 4 stud wall (incremental R_o-8.5, including the additional air space). The additional sheathing is required to provide a backing for mounting the insulation. At this cost, the LCC NPV savings are all *negative* at less than -$6.90/m², with the sensitivity range from about -$8.10/m² to -$2.80/m², using the LCC analysis parameters and rates provided by the Steering Committee. Note that using 2"x6" wall construction, as indicated above, would likely provide nearly the required R-value at lower cost (or even no cost since a lot of construction already uses 2"x6" wood stud walls).

[8] "The Costs and Benefits of Hydronic Heating in New Multifamily Residential Construction in the Lower Mainland of British Columbia" report by Trent Barry, Compass Resource Management (Compass Resource Management, EnerSys Analytics, Inc., Thornley BKG Consultants, Ltd.), December 2003.

***Mass wall R-value requirements (5.3.1.2)*:** Mass walls require continuous insulation with at least R-7.6 or R-11.4 (Northern Interior) or an overall assembly R-value of 8.1 or 11.1 (Northern Interior) for conditioned spaces. This is likely to impact facilities such as churches, gyms, community centres with low budgets, etc. (Reportedly, this was a contentious issue when the MNECB was being developed to have mass walls exempt.)

As this requirement may apply to many different building types and scenarios, we focused on an archetype where this could be of particular concern: big box retail. Our LCC analysis utilized Natural Resources Canada's CBIP big box retail template to evaluate the LCC implication of adding the required amount of insulation to tilt-up concrete walls.

Lower Mainland/Vancouver Island (Table B-18): We analyzed the LCC implication of adding an extra 1.5" of continuous polystyrene (R-7.5) insulation to the concrete walls. The key building characteristics that are significant for this situation for the LCC analysis include:

- 41,300 ft² net wall area at an assembly R_o-2.2 for typical 8" heavy weight hollow concrete block walls (an alternative would be 6" tilt-up concrete with 2" metal framed wall and gypsum board, which adds about R_o-0.5)
- 45,000 ft² conditioned floor area
- 2.79 W/ft² diversified peak hourly interior lighting load
- 0.23 W/ft² diversified peak hourly plug load
- 322 ft²/person diversified peak hourly occupant density (daily avg.)
- 95 hour/week fan operation with heating setpoint at 71.6°F (22°C)
- 64.4°F (18°C) heating setback
- Natural gas heating using package gas-fired units at 80% full load efficiency
- All other prescriptive requirements of the Standard are minimally satisfied
- Vancouver weather data for a typical meteorological year

The incremental cost for the added insulation is estimated at $8.00 per square foot of wall area, with no incremental annual maintenance costs. This is based on adding 1.5" of insulation over the air/vapour barrier and 1.5" furring channels with pre-finished corrugated metal cladding finish (incremental R_o-8.4, including the additional air space). In a typical big box retail building, the retailer would want a durable surface on the inside surface, so the block or concrete wall would be exposed on the inside. However, the furring and insulation could be added on the inside and a finish of plywood or some other durable board could be installed. This means the cladding on the outside may be deleted, for an incremental R_o-7.7, without the additional air space. This reduces the incremental cost to about $6.50 per square foot ($268,500)[9]. At this cost, the LCC NPV savings is positive at approximately $8.10/m², with the sensitivity range from *increasing* the LCC by

[9] Costs provided by Omicron for mass wall R-value options.

over $12/m² to demonstrating savings of up to $75/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Southern Interior (Table B-17): The LCC analysis was identical to the approach described for the Coastal region, except using the appropriate Summerland weather data. The incremental cost for the added insulation and cladding is estimated at $6.50 per square foot of wall area ($268,500), with no incremental annual maintenance costs. At this cost, the LCC NPV savings is positive at nearly $28/m², with the sensitivity range from approximately $2.50/m² to over $106/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Northern Interior (Table B-22): The LCC analysis was identical to the approach described for the Coastal region, except using the appropriate Prince George weather data and adding 2" of insulation instead of only 1.5" (incremental R_o-10.0, including the additional air space). The incremental cost for the added insulation and cladding is estimated at $6.88 per square foot of wall area ($284,100), with no incremental annual maintenance costs. At this cost, the LCC NPV savings is positive at over $51/m², with the sensitivity range from nearly $18/m² to over $161/m², using the LCC analysis parameters and rates provided by the Steering Committee.

***Glazing, Commercial (5.3.2)**:* In commercial buildings, this likely is not an issue beyond what has been discussed previously for metal-framed construction with high percentages of glass. Typical curtain walls with standard double-pane glazing would fall short of the overall U-value with Uo-0.62 versus the Standard's Uo-0.57 for situations with under 40% glazing. The application of curtain wall for buildings with under 40% glazing typically only applies to spot use of the relatively poor performing curtain wall glazing system throughout a building. Hence, applying the envelope trade-off method will likely result in compliance (e.g., the poor curtain wall performance is traded off for other aspect of the shell).

At 40–50% glazing, the Standard prescribes low-e glazing at U_o-0.46. We generally find that this level is minimally required to comply with the Standard using the envelope trade-off method as well. While we find that buildings with relatively high percentages of glazing already incorporate low-e glass, we evaluated the LCC implications of adding low-e glazing (i.e., improving from U_o-0.62 to U_o-0.46) using the typical office CBIP archetypes. In the analysis, we also provided for credit on improvement in the mean radiant temperature by decreasing the effective heating setpoint by up to 1°F (i.e., occupants feel just as comfortable at lower temperatures because of the improvement in the effective temperature due to reduced radiant losses).

Lower Mainland/Vancouver Island (Table B-18): We analyzed the LCC implications of adding high-performance low-e (i.e., centre-of-glass U-value of 0.30) to a typical high-rise office with following key baseline characteristics:

- 62,200 ft² (60%) glazing area, starting with U_o-0.62 for double glazed window units set in typical curtain wall (at R_o-5.5)
- 259,000 ft² conditioned floor area over 18 floors
- 1.2 W/ft² diversified peak hourly interior lighting load
- 0.7 W/ft² diversified peak hourly plug load
- 269 ft²/person diversified peak hourly occupant density
- 75 hour/week fan operation with heating setpoint at 71.6°F (22°C)
- 64.4°F (18°C) heating setback
- Natural gas heating using an 80% efficient on/off boiler, with hot water reset
- All other prescriptive requirements of the Standard are met or exceeded
- Vancouver weather data for a typical meteorological year

The incremental cost for incorporating glazing with a low E coating to meet the required performance characteristics is estimated at $4.00 per square foot of glazing area ($248,800), with no incremental annual maintenance costs. It should be noted that the cost of adding a low-e coating can vary from $2.00 to $8.00 per square foot, depending on a number of factors. We have chosen to use an average cost of $4.00/ft²[10]. At this cost, the LCC NPV savings is *negative* at under $3.90/m², with the sensitivity range from -$6.00/m² to over +$3.50/m², using the LCC analysis parameters and rates provided by the Steering Committee. Note that at the low-end cost of $2.00/ft², the economics improve such that the LCC NPV savings are positive at over $1.20/m², although the high scenario is still negative but at only $0.82/m² instead of -$6.00/m².

<u>Southern Interior (Table B-17):</u> We analyzed the LCC implications of adding high-performance low-e (i.e., centre-of-glass U-value of 0.30, SHGC-0.35) to a typical low-rise office with following key baseline characteristics:

- 7,800 ft² (45%) glazing area, starting with U_o-0.57 for double glazed punched windows with tinting (SHGC-0.50) and thermally broken aluminium frames
- 43,200 ft² conditioned floor area over 3 floors
- 1.2 W/ft² diversified peak hourly interior lighting load
- 0.7 W/ft² diversified peak hourly plug load
- 269 ft²/person diversified peak hourly occupant density
- 75 hour/week fan operation with heating setpoint at 71.6°F (22°C)
- 64.4°F (18°C) heating setback
- Natural gas heating using an 80% efficient on/off boiler with hot water reset
- All other prescriptive requirements of the Standard are met or exceeded
- Summerland weather data for a typical meteorological year

[10] Costs provided by Omicron for all glazing options.

The incremental cost for the better windows is estimated at $4.00 per square foot of glazing area ($31,200), with no incremental annual maintenance costs. This is based on incorporating glazing with a low-e coating, to meet the required performance characteristics. It should be noted that the cost of adding a low-e coating can vary from $2.00 to $8.00 per square foot, depending on a number of factors. We have chosen to use an average cost of $4.00/ft². At this cost, the LCC NPV savings is positive at over $4.90/m², with the sensitivity range from about $1.30/m² to $9.70/m², using the LCC analysis parameters and rates provided by the Steering Committee.

<u>Northern Interior (Table B-22):</u> We analyzed the LCC implications of adding high-performance low-e (i.e., centre-of-glass U-value of 0.30) to a typical low-rise office situation in Prince George. The key assumptions are identical to those of the Southern Interior assessment, except the use of Prince George weather.

The incremental cost for the better windows is estimated at $4.00 per square foot of glazing area ($31,200), with no incremental annual maintenance costs. This is based on incorporating glazing with a low-e coating, to meet the required performance characteristics. It should be noted that the cost of adding a low-e coating can vary from $2.00 to $8.00 per square foot, depending on a number of factors. We have chosen to use an average cost of $4.00/ft². At this cost, the LCC NPV savings is positive at nearly $4.00/m², with the sensitivity range from about $1.90/m² to $7.60/m², using the LCC analysis parameters and rates provided by the Steering Committee.

***Glazing, Residential (5.3.2)**:* The U-value requirements, and issues for the most part, for residential type spaces are identical to those for commercial spaces. Hence, we performed a similar series of LCC evaluations using the MURB archetypes.

<u>Lower Mainland/Vancouver Island (Table B-18):</u> We analyzed the LCC implications of adding high-performance low-e (i.e., centre-of-glass U-value of 0.30, SHGC of 0.47) to a typical high-rise MURB with following key baseline characteristics:

- 31,100 ft² (60%) glazing area, starting with U_o-0.62 for double glazed visibly clear (SHGC-0.86) window units set in typical curtain wall (at R_o-5.5)
- 138,000 ft² conditioned floor area over 12 floors
- 0.84 W/ft² diversified peak hourly interior lighting load
- 0.49 W/ft² diversified peak hourly plug load
- 70°F heating setpoint
- 67°F average heating setback, applied approximately 42 hours/week
- Electric resistance heating in suites; gas-fired make-up air units at 80% full-load efficiency
- All other prescriptive requirements of the Standard are met or exceeded

- Vancouver weather data for a typical meteorological year

Note that the difference in the SHGC was not included in the thermal analysis. This is because energy use actually increases as the SHGC “improves” (i.e., is decreased) because beneficial solar is blocked out and no cooling impacts are observed since MURBs are not cooled here. However, the marked improvement in occupant comfort is not taken into consideration, but is valued from a societal perspective. Hence, the negative energy impact is ignored in this analysis as a proxy for the unquantified societal benefit. Also, blinds would be drawn more often with windows having a higher SHGC, thereby offsetting some of the difference.

The incremental cost for the better windows is estimated at $4.00 per square foot of glazing area ($124,400), with no incremental annual maintenance costs. This is based on incorporating glazing with a low-e coating, to meet the required performance characteristics. It should be noted that the cost of adding a low-e coating can vary from $2.00 to $8.00 per square foot, depending on a number of factors. We have chosen to use an average cost of $4.00/ft². At this cost, the LCC NPV savings is positive at nearly $4.90/m², with the sensitivity range from about $0.69/m² to $10.90/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Southern Interior (Table B-17): Glazing percentages as high as Vancouver’s are less prevalent in the Southern Interior. Also, high-rise MURBs appear proportionately less prevalent as well, although some are being constructed. We performed the LCC analysis using a similar MURB archetype, but with 45% punched windows. Hence, the LCC analysis was identical to the approach described for the Coastal region, except:

- Windows at 23,300 ft² (45%), starting with U_o-0.57 for double-glazed punched windows with thermally broken aluminium frames
- Summerland weather.

The incremental cost for the better windows is estimated at $4.00 per square foot of glazing area ($93,200), with no incremental annual maintenance costs. This is based on incorporating glazing with a low-e coating, to meet the required performance characteristics. It should be noted that the cost of adding a low-e coating can vary from $2.00 to $8.00 per square foot, depending on a number of factors. We have chosen to use an average cost of $4.00/ft². At this cost, the LCC NPV savings is positive at over $4.70/m², with the sensitivity range from about $1.30/m² to $9.70/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Northern Interior (Table B-22): High-rise MURBs in the Northern Interior are relatively rare and likely do not warrant LCC evaluation. However, we conducted an LCC analysis for low-e glazing installed in a typical high-rise MURB in the

Northern Interior using the same approach as for the Southern Interior, except using the appropriate Prince George weather data.

The incremental cost for the better windows is estimated at $4.00 per square foot of glazing area ($93,200), with no incremental annual maintenance costs. This is based on incorporating glazing with a low-e coating, to meet the required performance characteristics. It should be noted that the cost of adding a low-e coating can vary from $2.00 to $8.00 per square foot, depending on a number of factors. We have chosen to use an average cost of $4.00/ft². At this cost, the LCC NPV savings is positive at over $7.50/m², with the sensitivity range from about $3.10/m² to over $14/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Glazing Solar Heat Gain Coefficient (5.3.2.3): The Glazing Solar Heat Gain Coefficient (SHGC) requirements on windows generally indicate requiring tinting or low-e glazing, particularly for the Southern Interior climate. For glazing percentages between 40% and 50%, even low-e glazing in the Southern Interior will require some tinting as well. While prescriptive compliance with the SHGC may not commonly occur, application of the envelope trade-off method (which references the 30-40% prescriptive level) appears to make this a minor issue. This is mainly because cooling has a relatively minor contribution to calculating the Energy Performance Factor (EPF) within the trade-off method in the B.C. climates. In fact, in high-rise office tests for the different regions, decreasing the SHGC actually made the EPF worse. As is often observed in energy performance models, this is assumedly because it blocked out more beneficial solar for heating than it did for cooling.

Thus, using the envelope trade-off method of compliance, the prescriptive window SHGC requirements are not an issue. The main implication is that most designs will have to use the envelope trade-off method of compliance instead of using the direct prescriptive approach. However, as indicated previously, the vast majority of Energy By-Law submissions to the City of Vancouver utilize the envelope trade-off method to demonstrate compliance.

Note that the prescriptive SHGC may be increased (i.e., relaxed) by applying the projection multipliers from Table 5.3.2.3. In other words, it is possible that windows with adequate overhangs will provide for the appropriate adjustment to the SHGC to directly comply with the Standard's prescriptive requirements.

Exposed Floors R-value (5.3.1.4): Wood joist floors in all weather regions require a cavity insulation level of R-30, which may not be common practice. In the North, roughly the same requirement is required for steel joist construction, although we're not sure how common this type of construction is in the northern communities (hence, it may not be an issue).

LCC analysis was not conducted since this situation is not prevalent enough in commercial construction to cause concern. Further, the insulation levels may very well be compliant, assuming insulation between at least 8” wood joists, depending on the remaining materials; 10” joists with insulation easily comply.

Section 6. Heating, Ventilation, Air Conditioning

***Mandatory* Mechanical Equipment Efficiency (6.2.1):** Since North American standards typically reference ASHRAE, complying with the efficiency requirements should not be a problem. In particular, we question if the following efficiency requirements are adhered to:

- Table 6.2.1.B Heat Pump unit: Water Source, cooling mode, larger than 17,000 Btuh and less than 135,000 Btuh – EER 12 is mandated.
- Table 6.2.1.B Heat Pump unit: Ground Water Source, cooling mode, less than 135,000 Btuh – EER 16.2 is mandated.

Most heat pump manufacturers have product lines that easily meet these efficiency requirements. There are some models that fall short, but there is enough availability that we do not foresee resistance from the industry. Further, the lower efficiency units are being phased out of product lines to make way for units that meet the 90.1 requirements. Hence, the present costs are not significantly higher and will not be available in the near future.

Optimum Start Controls (6.2.3.2.3): Individual heating and cooling air distribution systems that have a total design supply air capacity exceeding 10,000 cfm and are served by one or more supply fans shall have optimum start controls. This implies requiring a DDC system, which a lot of smaller projects do not have. On the other hand, a lot of smaller projects do not have air handlers that exceed 10,000 cfm. Hence, this would tend to apply to medium to large projects, where DDC controls are common (even many small project have DDC controls). However, we wanted to point out how this may be a barrier to large additions to existing buildings that do not already have DDC systems.

LCC analysis was not performed since there would be relatively few circumstances when this would be met with resistance—most likely occurring when there are additions to existing buildings. Further, the energy modelling can be problematic in that the potential application could potentially apply to a wide range of baseline conditions (e.g., fan schedules, occupancy patterns, building types, etc.).

Shut-off damper controls (6.2.3.2.4): Typically, exhaust systems do not have motorized dampers installed. Most exhaust systems are installed with backdraft dampers to prevent infiltration of outdoor air, but motorized dampers are not typically installed. The incremental installed cost of motorized dampers for exhaust systems would be approximately $0.15 to $0.20 per cfm of exhaust. This incremental cost is relatively small, and we do not anticipate much resistance from industry.

We did not conduct LCC analysis since evaluating the energy savings is very problematic. It would be very difficult to quantify the reduction in outdoor air infiltration by switching from backdraft dampers to motorized dampers.

***Mandatory* Ventilation Controls for High Occupancy Areas (6.2.3.8):** Systems with design outside air capacities greater than 3000 cfm serving areas with average occupant densities exceeding 100 people per 1000 ft² (10 ft²/people) are required to have controls that will automatically reduce the outside air during partially occupied periods. This applies to spaces such as hotel convention rooms, theatres and gyms. However, it is common for CO_2 demand ventilation controls to be installed in existing situations because it is quite cost-effective. Hence, providing for such control in new construction would be very cost-effective and should be met with little resistance.

LCC analysis was not performed since our experience has shown rapid paybacks (e.g., months) for such spaces with variable high occupancy patterns. Paybacks are so good that many existing schools are retrofitting gyms and theatres.

Exhaust Heat Recovery (6.3.6.1): Systems with over 70% outside air, over 5000 cfm and no exhaust source above 75% of the supply (this excludes most MURBs) require 50% effective heat recovery (on enthalpy, not just the sensible component). Hence, school gyms, theatres and lab systems would now require exhaust heat recovery. Note that there are exclusions for certain types of special applications (e.g., kitchens) or alternative requirements (e.g., labs may have the ability to reduce flow by 50% instead).

For most projects, exhaust heat recovery proves cost-effective in British Columbia. This is based on LCC analysis performed on many of actual design projects. The economic indicators were not what the Steering Committee provided, but paybacks were so rapid that the LCC analysis would easily be satisfied. Also, most of the projects were located in the relatively mild Coastal climate region. Hence, exhaust heat recovery would prove even more cost-effective in the colder Southern Interior and North Interior regions. The following lists a wide range of project analyses for which exhaust heat recovery on typical 100% make-up air units proved cost-effective:

- *High-rise Office/MURB, Vancouver (LCC Analysis, Dec. 2001):* (1) 50% effective HRVs on apartments at a 6.4-year payback, (2) 65% effective HRV units (e.g., using heat pipe technology) on office make-up air at a 2.1-year payback, (3) 75% effective heat recovery (e.g., using heat wheel technology) on office make-up air at a 4.2-year payback.

- *College Building, Quesnel (LCC Analysis, Nov. 2003):* 50% effective heat recovery applied to an additional 5000 cfm of outside air at a 2.5-year payback.
- *Secondary School, Port Moody (LCC Analysis, March 2002):* 55% effective heat recovery applied to 18,000 cfm at a 7.3-year payback.
- *High-Rise MURB, North Vancouver (LCC Analysis, August 2003):* 65% effective heat pipe exhaust heat recovery at 5.1-year payback.
- *Airport Terminal, Vancouver (LCC Analysis, March 2001):* 65% effective heat pipe exhaust heat recovery at 4.0-year payback.

An interesting item to note is that if a MURB included heat recovery in an effort to comply with the Standard following the ECB method, the Reference would suddenly require 50% effective exhaust heat recovery. This would negate most/all of the very significant benefits of adding heat recovery to a MURB—something that is rarely done now. We suggest this provision of the Standard be ignored for MURBs primarily since it is rare to provide for exhaust heat recovery in MURBs. In cases that do specify heat recovery, there is typically a high level of savings at a very good payback. Finally, it is inconsistent to not require heat recovery for a typical MURB without centralized exhaust and then require it if the exhaust is centralized to accommodate exhaust heat recovery. That is, a typical MURB with wall-vented exhaust for every suite does not require heat recovery by the Standard, but switches to requiring it if at least 75% of the exhaust is centralized to accommodate effective heat recovery.

To provide for an estimate on the costs and savings as a policy-level assessment, EnerSys applied the average costs derived from the above case studies to the regional extended care regional archetypes from the LEED-BC study[11]. While the exhaust heat recovery stipulation may apply to any commercial or multiunit residential building with the prerequisite air handling equipment, it would most likely apply to extended care – particularly critical care homes where fresh air is not mixed with return air (i.e., 100% outside air). The following key building characteristics apply to the archetype extended care model:

- 50,000 ft^2 conditioned floor area
- 0.4 cfm/sf of 100% fresh air delivered to suites, which accounts for 64% of the total conditioned floor area, for a total of 12,800 cfm O/A.
- 24-hour/day delivery of fresh air
- 1.4 W/ft^2 diversified peak hourly interior lighting load
- 0.2 W/ft^2 diversified peak hourly plug load

---

[11] Hepting, C. and D. Ehret (March 2002), "Verification of LEED-BC v1.0 Energy Credit 1 Point Awards for Building Energy Conservation in British Columbia." EnerSys Analytics Inc.: Coquitlam, B.C.

- 74°F heating setpoint (extended care homes are typically kept at relatively warm temperatures)
- Two equally sized gas-fired boilers at 80% full-load efficiency with hot water reset
- All other prescriptive requirements of the Standard are met or exceeded

The costs for adding heat recovery varied dramatically depending on the project particulars, from as little as $0.56/cfm for adding to an existing system to as high as $15.10/cfm for a relatively small MURB installation. The cost for MURBs would typically be at the higher end as compared to most other building types because of the ducting reconfiguration and requirements for fire dampers at each floor. The incremental cost for an extended care application would likely be significantly lower.

Lower Mainland/Vancouver Island: The incremental cost for the 65% effective heat pipe heat recovery is estimated at $5/cfm ($64,000), based on the average of the heat recovery installation costs from the workshops (and rounding up). Also, approximately 0.8" of additional static pressure is applied to the units serving the applicable areas. We added $1,280/year in incremental maintenance costs based on 2% of the HRV unit cost, conservatively based on feedback provided during some of our energy performance workshops. At this cost, the LCC NPV savings is positive at over $35/m², with the sensitivity range from about $21/m² to $90/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Southern Interior: The same provisions that applied to the Lower Mainland are applied here, except for the use of Summerland weather data and fuel rates (and cooling provided to all of the building, but barely affects the analysis). At this cost, the LCC NPV savings is positive at over $38/m², with the sensitivity range from about $23/m² to $95/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Northern Interior: The same cost provisions applied to the Lower Mainland are applied here, except for the use of Prince George weather data and fuel rates. At this cost, the LCC NPV savings is positive at over $60/m², with the sensitivity range from about $38/m² to $140/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Minimum Supply Flow During Heating (6.3.2.1): Variable air volume (VAV) systems require minimum supply airflow settings of 0.4 cfm/ft². This is lower than the level at which most actual air distribution equipment typically operates. Also, this requirement tends to contradict ASHRAE's supply air and ventilation requirements of providing for both adequate space mixed air and comfort requirements. Finally, since the minimum flow can affect performance on reheat and fan energy, we have seen CBIP projects provide for design levels at this relatively low level, but end up higher after the building is occupied and the air system balanced. While we realize that this is not the intent of the Standard, this approach to design versus post-occupancy operation is technically not in violation of the Standard.

Because of the above issues, this aspect of the Standard did not warrant further LCC analysis since compliance can be technically satisfied.

Water-source heat pumps must have two-position valve interlock (6.3.4.4): This applies to circulation pumps over 10 horsepower and is readily available in heat pump units but is not standard in British Columbia. However, the City of Vancouver By-Law Ad Hoc participants indicated that this is not a concern since the market will evolve to require it and the incremental cost is relatively small. It makes most sense to require a 2-position valve with variable speed drives (VSD) on the pumps as well, but savings are still realized for better operation on the pump curve without VSDs.

LCC analysis was performed using a typical mid-rise office archetype served by a distributed heat pump HVAC system. Other building types, like hotels and MURBs, may have distributed heat pump systems as well, but we find these situations to be less frequent and/or apply more high-end projects. Distributed heat pumps appear to be most common for offices.

Lower Mainland/Vancouver Island: We used the same typical mid-rise office archetype as defined on page 4, except with 6 storeys instead of 3 and a distributed heat pump HVAC system with the following key characteristics:

- Water-source heat pump with 4.2 COP and 12 EER ratings
- Heat pump loop at 50 ft head and 60% combined impeller and motor pump efficiency
- Boiler and cooling tower at Standard requirements
- Vancouver weather data for a typical meteorological year

The incremental cost for the two-position valves is estimated at $0.30/ft² ($12,960), assuming a unit incremental cost of $300 per heat pump and one heat pump per 1000 ft² [12]. We allocated $0.0060/ft² ($300) for incremental annual maintenance costs, based on an average of 2% of the valves requiring service and/or replacement annually. At this cost, the LCC NPV savings is *negative* at less than –$0.57/m², with the sensitivity range as low as –$0.87/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Southern Interior: Distributed heat pump systems are not as prevalent here as on the Coast. However, we carried out LCC analysis using the same archetype as defined above for the Lower Mainland, except applying Summerland weather data.

[12] Costs provided by Omicron for adding two-position valve to heat pump units.

The incremental cost for the two-position valves is estimated at $0.30/ft² ($12,960), assuming a unit incremental cost of $300 per heat pump and one heat pump per 1000 ft². We allocated $0.0060/ft² ($300) for incremental annual maintenance costs, based on an average of 2% of the valves requiring service and/or replacement annually. At this cost, the LCC NPV savings is *negative* at nearly –$0.20/m², with the sensitivity range from –$0.61/m² to –$0.014/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Northern Interior: Distributed heat pump systems are relatively rare here and therefore did not warrant LCC analysis.

Condenser Heat Recovery for Service Water (6.3.6.2): This applies to facilities that have a large heat rejection capacity (over 500 tons) and a large DHW heating load (over 1 mmBtuh). Hence, this would apply to large hotels, hospitals and other large projects (e.g., Convention Centre complex).

In our experience, condenser heat recovery proved cost-effective in British Columbia for smaller projects that had a significant cooling and heating (DHW or space) load. This is based on LCC analysis performed on several actual design projects. The economic indicators were not what the Steering Committee provided, but paybacks were so rapid that the LCC analysis was easily satisfied. While the projects were located in the relatively mild Coastal climate region, the higher non-winter cooling requirements of the Southern Interior and Northern Interior regions would provide a greater opportunity to utilize the waste heat for large DHW loads. Hence, condenser heat recovery for the conditions addressed by the Standard would prove at least as cost-effective throughout British Columbia as the Coastal region.

The following lists several of the projects analyzed for condenser heat recovery cost-effectiveness:

- *High-rise Office/MURB, Vancouver (LCC analysis, Dec. 2001):* 75 ton condenser heat reclaim directed to the DHW and space heating had a 1.8-year payback.
- *Research Laboratory, Vancouver (LCC analysis, Nov. 2001):* 300 ton heat reclaim chiller at a 4.7-year payback.
- *High-Rise Office, Vancouver (LCC analysis, Sep. 2002):* Chiller heat recovery from 150 ton units in adjacent building had a 1.6-year payback
- *Engineering Laboratory, Vancouver (LCC analysis, April 2003):* 50 ton condenser heat recovery at a 5.2-year payback.

For the overall policy-level impact assessment, this stipulation was not included since the application applies only to the largest and most specialized of buildings. In one respect, this would make the overall assessment conservative. On the other hand, such high profile projects are very likely to implement such energy saving measures.

Section 7. Service Water Heating

***Mandatory* Pool Covers (7.2.5.2):** Heated pools shall be equipped with a vapor retardant pool cover on or at the water surface, which is not typically done. However, in relation to the overall commercial market energy use, the contribution from pool cover savings would be relatively small. Further most of the heat from the pool surface contributes to the adjacent indoor space heating. Hence, most of the savings stem from humidity reduction.

At this stage, LCC analysis was not completed due to the relatively low contribution to the new commercial market. Further, the analysis is relatively complicated, requiring a fair bit of time to properly model. As a Phase II follow-up task, we can evaluate the impact of pool covers if desired.

Section 9. Lighting

***Mandatory* Automatic lighting shut-off (9.2.1.1):** Retail outlets over 5,000 square feet are required to have automatic controls to shut off all interior lighting. Most existing retail outlets do not have such automatic controls presently.

We evaluated the energy implications of this requirement by reducing the lighting schedule for the big box retail CBIP archetype by the equivalent of 4 full-load hours per week during unoccupied hours (i.e., 0.05 of an hour at night). This was conducted for all three weather regions by changing only the weather data and using the same key characteristics:

- 45,000 ft^2 conditioned floor area
- 2.79 W/ft^2 diversified peak hourly interior lighting load, with 75 full-load hours
- 0.23 W/ft^2 diversified peak hourly plug load
- 322 ft^2/person diversified peak hourly occupant density (daily avg.)
- 95 hour/week fan operation with heating setpoint at 71.6°F (22°C)
- 64.4°F (18°C) heating setback
- Natural gas heating using package gas-fired units at 80% full load efficiency
- All other prescriptive requirements of the Standard are satisfied. (SHGC is set at the prescriptive level even though it likely would be higher than listed in the respective Building Envelope tables, as most retail have clear double-pane windows without tinting or low-e. Typical canopies over

limited glazing area or on street-level would likely provide for prescriptive compliance, as referenced in Sections 5.3.2.3.(b) and (c).)

Lower Mainland/Vancouver Island: The incremental cost for the lighting controls is estimated at \$4,500[13], with an incremental annual maintenance cost of \$90. This is based on a 10,000 ft² space using "time of day" control of interior lighting. At this cost, the LCC NPV savings is *negative* at about than –\$0.19/m², with the sensitivity range as low as –\$1.08/m², using the LCC analysis parameters and rates provided by the Steering Committee[14].

Southern Interior: The incremental cost for the lighting controls is estimated at \$4,500, with an incremental annual maintenance cost of \$90. This is based on a 10,000 ft² space using "time of day" control of interior lighting. At this cost, the LCC NPV savings is positive at nearly \$1.60/m², with the sensitivity range from \$0.82/m² to over \$1.50/m², using the LCC analysis parameters and rates provided by the Steering Committee.

Northern Interior: The incremental cost for the lighting controls is estimated at \$4,500, with an incremental annual maintenance cost of \$90. This is based on a 10,000 ft² space using "time of day" control of interior lighting. At this cost, the LCC NPV savings is *negative* at about than –\$0.61/m², with the sensitivity range as low as –\$1.90/m², using the LCC analysis parameters and rates provided by the Steering Committee.

COMMENTS ON ARCHETYPE PERSPECTIVES

The REPBC Working Group has been focusing on an LCC analysis approach that focused on building archetypes. As we have indicated before, our analysis approach focuses on how Standard stipulations may apply in the new commercial market, regardless of the building type. This is because the Standard does not distinguish by building type, except for residential shell requirements and minimum lighting power allowances.

However, in reviewing and evaluating the Standard, the aspect of how the various provisions apply to different archetypes naturally becomes part of the assessment process. As far as archetypes are concerned, the only one that really stands out is the high-rise MURB, particularly in the Lower Mainland. EnerSys' recent assessment on MURBs for the City of Vancouver, Terasen, and NRCan indicated that the high-rise MURBs currently being built downtown are likely to be least 15% *below* code (following the performance path), due to many of the issues highlighted previously.

[13] Costs for lighting controls provided by Omicron.
[14] Note that the low and high scenarios were *both* lower than for the medium scenario. This unusual outcome is a result of the peculiar dramatic jump in the "high" gas forecast starting in year 22, which exacerbated the increase in gas costs.

Another building type that may have specific concerns would be strip malls that still use single-pane windows (outside of Vancouver), but that is considered poor practice so it hasn't been met with a lot of resistance in Vancouver. Since it is considered common practice to have at least double pane windows, developers and owners likely will accept the more stringent requirement. (This is the perfect reason for regulating a minimum and not relying on the market to self-regulate itself.)

LIFE-CYCLE ECONOMIC ANALYSIS PARAMETERS

Per Andrew Pape-Salmon's request, we applied three sets of life-cycle cost (LCC) criteria based on gas and electricity price forecasts from the 13-Jan-2004 version of the Energy Price Forecast spreadsheet provided by Andrew Pape-Salmon. The scenarios included:

1. "Medium scenario" using the medium forecasts with an 8% discount rate over a 25-year period[15],
2. "High scenario" using the high forecasts with a 4% discount rate over a 20-year period; this would provide for the most optimistic LCC indicators, and
3. "Low scenario" using the high forecasts with a 12% discount rate over a 20-year period; this would provide for the most conservative LCC indicators.

We did not *directly* apply the price forecasts for non-residential electricity or for natural gas (residential and commercial); only the electricity forecasts for MURBs were directly applied. We instead applied the annual escalation indicated by the price forecasts to current posted rate tariffs. One reason for this is because the price forecasts provided did not apply to large commercial customers—only residential and "small commercial"). Note that gas provided to MURBs is typically on a common meter under a small or large commercial rate tariff, depending on the annual consumption. Most commercial building archetypes included in our analyses typically are not considered small.

For electricity, the level of energy and demand for each month can significantly affect the average blended rate. For a LEED-Canada study EnerSys is finalizing, application of the BC Hydro 1200-series tariffs for different typical building types resulted in blended rates ranging from \$0.048/kWh to \$0.058/kWh. In comparison, a typical strip mall store on the small commercial rate structure averaged \$0.065/kWh. This is significantly different from the 2004 rates shown in the provided price forecasts.

[15] Price forecasts were projected for only 22 years instead of 25 years; the same arithmetic trend is continued for years 23 to 25 in the LCC analysis.

Hence, we applied the appropriate BC Hydro, Aquila Networks Canada (formerly West Kootenay Power), and Terasen Gas rate tariffs, current as of January 2004:

- BC Hydro (Lower Mainland, Northern Interior) – Tariff 1210. Commercial customers typically fall under any of four 1200-series rate structures; the 1210 tariff represents a representative medium level between the two most popular 1200 and 1211 structures.

  Energy (kWh):
  - 1st 14800 kWh @ $0.0649/kWh
  - All remaining kWh @ $0.0312/kWh

  Demand (kW):
  - 1st 35 kW @ $0.0/kW
  - 2nd 115 kW @ $3.07/kW
  - All remaining kW @ $6.12/kW
  - 50% ratchet

- Aquila (Southern Interior) – Schedule 21(b), with discount (b) for delivery and metering voltage.

  Energy (kWh):
  - 1st 8000 kWh @ $0.06644/kWh
  - 2nd 92000 kWh @ $0.05045/kWh
  - All remaining kWh @ $0.03746/kWh

  Demand (kW):
  - 1st 40 kW @ $0.0/kW
  - All remaining kW @ $4.95/kW
  - 75% ratchet

- Terasen (Lower Mainland):
  Rate 2 for <2000 GJ/year @ $9.699/GJ
  Rate 3 for >2000 GJ/year @ $9.128/GJ

- Terasen (Southern Interior or "Inland" service):
  Rate 2 for <2000 GJ/year @ $9.588/GJ
  Rate 3 for >2000 GJ/year @ $9.031/GJ

- Terasen (Northern Interior or "Columbia" service):
  Rate 2 for <2000 GJ/year @ $9.726/GJ
  Rate 3 for >2000 GJ/year @ $9.163/GJ

Note that we did not input minimum monthly charges, as they do not affect the LCC analysis since they are constant regardless of what energy measure is implemented.

In addition, we provided for $10/tonne of avoided CO_2 emissions. The emissions for natural gas were based on 49.9 kg/GJ for natural gas, provided by Innes Hood. At $10/tonne, this equates to an adder of $0.50/GJ. Marginal electricity emissions were based on 0.373 kg/kWh, derived by Compass Resource Management using a recent benchmarking study by the Northwest Power Planning Council (http://www.nwcouncil.org/energy/powerplan/grac/052202/gassimple.htm). This value was cited in the study "The Costs and Benefits of Hydronic Heating in New Multifamily Residential Construction in the Lower Mainland of British Columbia" completed in December 2003 for Terasen Gas, Natural Resources Canada and The City of Vancouver. At $10/tonne, this equates to 0.373 ¢/kWh.

Finally, we provided for the incremental cost or savings associated with increases or decreases in heating and cooling equipment capacities at $15/MBtuh and $500/ton. These represent marginal equipment capacity costs and are consistently applied for all cases, although they may range significantly from project to project. These costs are derived from confirmation from dozens of design teams who participated in integrated energy performance workshops conducted by EnerSys. (Energy performance workshops represent forums where LCC analysis is conducted on various energy management options during key stages of a new building design.)

APPENDIX B:

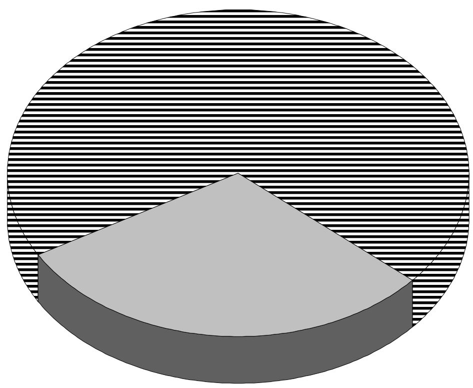
REPBC LIFE-CYCLE ECONOMIC ANALYSIS OF ASHRAE 90.1-2001 STIPULATIONS

REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

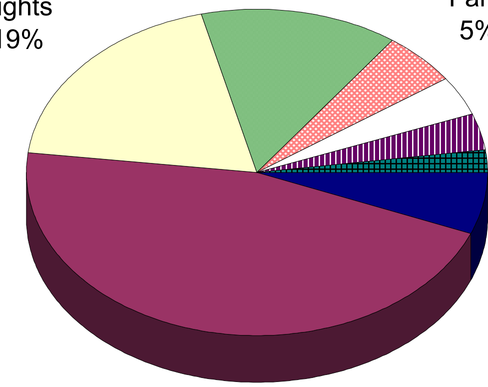
Small Office, Gas VAV ASHRAE Reference - Energy Efficiency Case
Summerland, BC

Wall R-Value Requirements, Commercial Steel Frame Construction (5.3.1.2)

ENERGY BILL: $45,405, RESULTING IN SAVINGS OF $2,009 (4.2%)



Divided by Utility Source



Divided by End-Use

END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling	4,485	1.5%					4,485	1.5%	174	0.8%
Heating	769	10.6%	13,028	12.2%			13,797	12.1%	1,328	12.2%
Lights	11,226	0.0%					11,226	0.0%	549	0.0%
Equip.	7,888	0.0%					7,888	0.0%	404	0.0%
Fans	3,122	1.0%					3,122	1.0%	150	0.9%
Refrig							0		0	
Ext. Lts	2,003	0.0%					2,003	0.0%	117	0.0%
Elev.	2,213	0.1%					2,213	0.1%	101	0.0%
DHW			671	0.0%			671	0.0%	67	0.0%
Cook							0		0	
TOTAL	31,707	0.6%	13,699	11.7%			45,405	4.2%	2,889	6.1%
Total $ Savings	$197		$1,812				$2,009		187.4	
Fuel Savings:	2.2 MWh		180 GJ		0 Mlbs		$0.50 /m²		46.7 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,367	1,319	48.3 (3.5%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	30	29	1.2 (3.9%)
Cooling (tons output)	67.1	64.9	2.2 (3.3%)
Fans & Pumps (hp)	59	59	0.3 (0.4%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO_2 Savings (kg/m²):	2.435	Net Capital $/m²:	$2.14

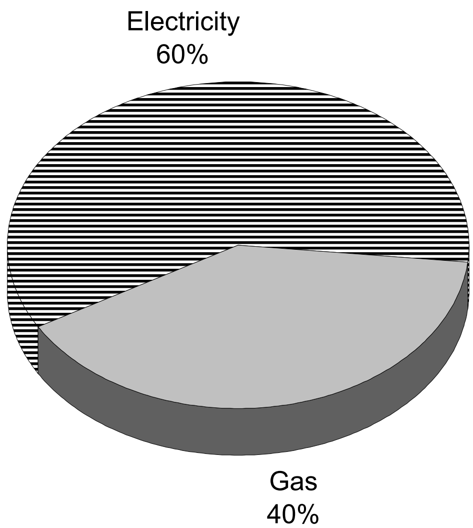
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$10,450
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$2,009*
Net Capital Cost	*$8,598*
LCC - NPV:	***-$3.32/m²***
Range ($/m²):	***-8.85 to -1.66***

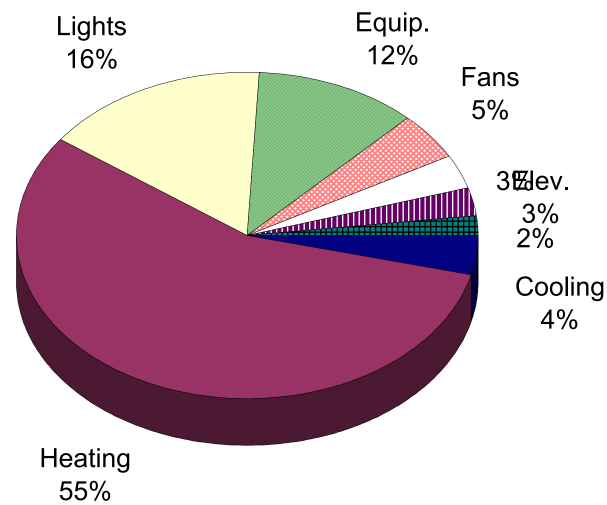
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Small Office, Gas VAV ASHRAE Reference - Energy Efficiency Case
Prince George, BC

Wall R-Value Requirements, Commercial Steel Frame Construction (5.3.1.2)
ENERGY BILL: $47,519, RESULTING IN SAVINGS OF $2,564 (5.1%)



Divided by Utility Source



Divided by End-Use

Legend / END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling	3,711	-0.3%					3,711	-0.3%	135	-1.8%
Heating	962	9.9%	18,362	11.9%			19,324	11.8%	1,956	11.9%
Lights	10,054	-0.1%					10,054	-0.1%	549	0.0%
Equip.	7,005	-0.1%					7,005	-0.1%	404	0.0%
Fans	3,043	0.3%					3,043	0.3%	157	0.6%
Refrig							0		0	
Ext. Lts	1,736	-0.1%					1,736	-0.1%	116	0.0%
Elev.	2,004	-0.2%					2,004	-0.2%	101	0.0%
DHW			643	0.0%			643	0.0%	67	0.0%
Cook							0		0	
TOTAL	28,514	0.3%	19,005	11.6%			47,519	5.1%	3,485	7.0%
Total $ Savings	$74		$2,490				$2,564		263.6	
Fuel Savings:	1.6 MWh		258 GJ		0 Mlbs		$0.64 /m²		65.7 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	2,129	2,056	72.1 (3.4%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	47	45	1.7 (3.6%)
Cooling (tons output)	66.6	67.2	-0.6 -(0.8%)
Fans & Pumps (hp)	74	76	-1.6 -(2.2%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	3.355	Net Capital $/m²:	$2.40

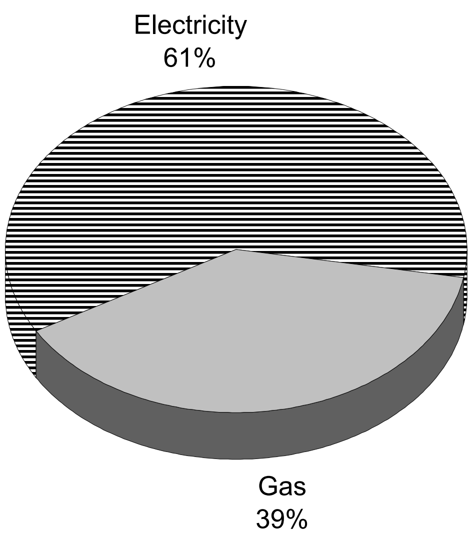
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$10,450
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$2,564*
Net Capital Cost	*$9,625*
LCC - NPV:	***-$4.49/m²***
Range ($/m²):	***-11.82 to -2.39***

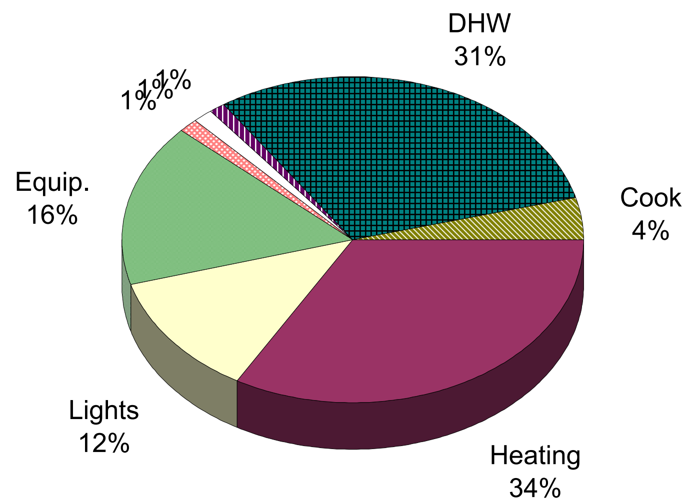
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

High-Rise MURB, Conventional Shell, Electric Resistance - Energy Efficiency Case
Vancouver, BC

Wall R-Value Requirements, Residential Steel Frame Construction (5.3.1.2)
ENERGY BILL: $161,325, RESULTING IN SAVINGS OF $4,202 (2.5%)



Divided by Utility Source



Divided by End-Use

END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling							0		0	
Heating	39,790	9.6%	17,139	0.0%			56,930	6.9%	4,112	5.6%
Lights	25,524	0.0%					25,524	0.0%	1,496	0.0%
Equip.	16,475	0.0%	9,745	0.0%			26,220	0.0%	1,978	0.0%
Fans	2,563	0.0%					2,563	0.0%	150	0.0%
Refrig							0		0	
Ext. Lts	3,069	0.0%					3,069	0.0%	180	0.0%
Elev.	2,365	0.0%					2,365	0.0%	139	0.0%
DHW			35,712	0.0%			35,712	0.0%	3,710	0.0%
Cook	8,942	0.0%					8,942	0.0%	524	0.0%
TOTAL	**98,728**	**4.1%**	**62,596**	**0.0%**			**161,325**	**2.5%**	**12,288**	**2.0%**
Total $ Savings	**$4,202**		**$0**				**$4,202**		**246.3**	
Fuel Savings:	68.4 MWh		0 GJ		0 Mlbs		**$0.33 /m²**		**19.2 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	537	537	0.0 (0.0%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	1,173	1,090	82.8 (7.1%)
Cooling (tons output)	0.0	0.0	0.0 (0.0%)
Fans & Pumps (hp)	9	9	0.0 (0.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²): 1.990	Net Capital $/m²: $2.29

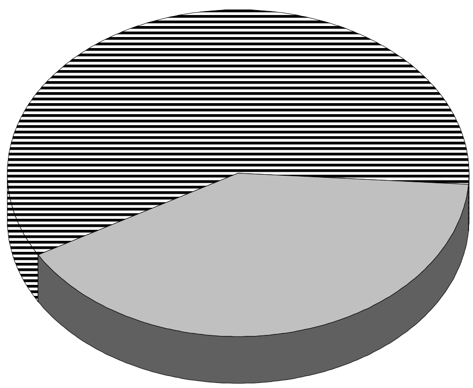
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$30,640
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$4,202*
Net Capital Cost	*$29,398*
LCC - NPV:	***-$1.85/m²***
Range ($/m²):	***-3.61 to -0.629***

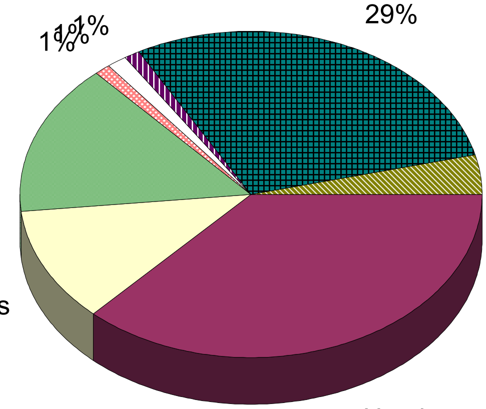
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

High-Rise MURB, Conventional Shell, Electric Resistance - Energy Efficiency Case
Summerland, BC

Wall R-Value Requirements, Residential Steel Frame Construction (5.3.1.2)
ENERGY BILL: $170,221, RESULTING IN SAVINGS OF $3,544 (2.0%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling							0		0	
	Heating	42,358	7.7%	22,643	0.0%			65,001	5.2%	4,858	4.1%
	Lights	25,524	0.0%					25,524	0.0%	1,496	0.0%
	Equip.	16,475	0.0%	9,646	0.0%			26,122	0.0%	1,978	0.0%
	Fans	2,571	0.0%					2,571	0.0%	151	0.0%
	Refrig							0		0	
	Ext. Lts	3,068	0.0%					3,068	0.0%	180	0.0%
	Elev.	2,365	0.0%					2,365	0.0%	139	0.0%
	DHW			36,627	0.0%			36,627	0.0%	3,843	0.0%
	Cook	8,942	0.0%					8,942	0.0%	524	0.0%
	TOTAL	**101,304**	**3.4%**	**68,917**	**0.0%**			**170,221**	**2.0%**	**13,168**	**1.6%**
Total $ Savings		**$3,544**		**$0**				**$3,544**		**207.7**	
Fuel Savings:		57.7 MWh		0 GJ		0 Mlbs		**$0.28 /m²**		**16.2 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	785	785	0.0 (0.0%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	1,551	1,453	98.3 (6.3%)
Cooling (tons output)	0.0	0.0	0.0 (0.0%)
Fans & Pumps (hp)	9	9	0.0 (0.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	1.678	Net Capital $/m²:	$2.27

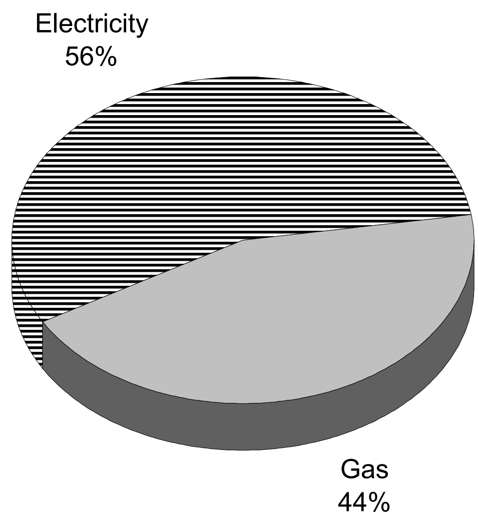
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$30,640
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$3,544*
Net Capital Cost	*$29,165*
LCC - NPV:	***-$1.22/m²***
Range ($/m²):	***-2.71 to -0.189***

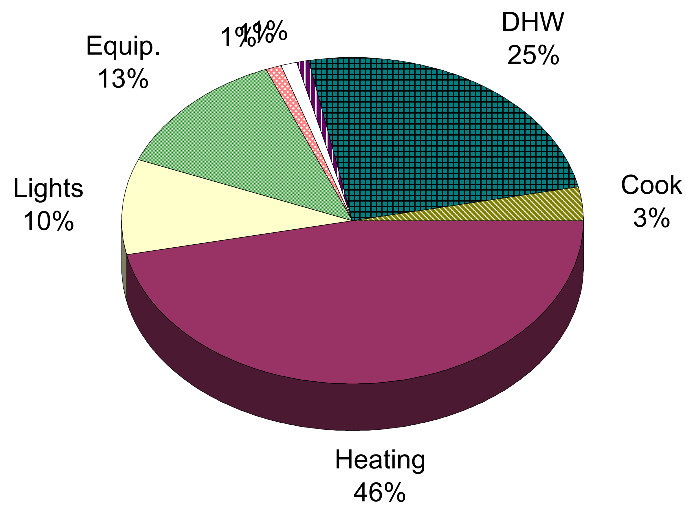
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

High-Rise MURB, Conventional Shell, Electric Resistance - Energy Efficiency Case
Prince George, BC

Wall R-Value Requirements, Residential Steel Frame Construction (5.3.1.2)
ENERGY BILL: $198,653, RESULTING IN SAVINGS OF $6,963 (3.4%)



Divided by Utility Source



Divided by End-Use

END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling							0		0	
Heating	51,953	9.2%	40,793	4.1%			92,746	7.0%	7,267	6.3%
Lights	25,524	0.0%					25,524	0.0%	1,496	0.0%
Equip.	16,475	0.0%	9,780	0.0%			26,255	0.0%	1,978	0.0%
Fans	2,627	0.0%					2,627	0.0%	154	0.0%
Refrig							0		0	
Ext. Lts	3,060	0.0%					3,060	0.0%	179	0.0%
Elev.	2,365	0.0%					2,365	0.0%	139	0.0%
DHW			37,135	0.0%			37,135	0.0%	3,843	0.0%
Cook	8,942	0.0%					8,942	0.0%	524	0.0%
TOTAL	**110,945**	**4.5%**	**87,708**	**1.9%**			**198,653**	**3.4%**	**15,579**	**3.0%**
Total $ Savings	**$5,240**		**$1,724**				**$6,963**		**485.5**	
Fuel Savings:	85.3 MWh		178 GJ		0 Mlbs		**$0.54 /m²**		**37.9 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,853	1,324	529.4 (28.6%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	1,785	2,645	-859.8 -(48.2%)
Cooling (tons output)	0.0	0.0	0.0 (0.0%)
Fans & Pumps (hp)	9	9	0.0 (0.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	3.176	Net Capital $/m²:	$2.78

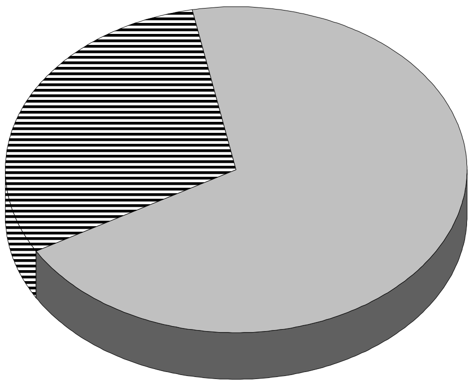
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$30,640
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$6,963*
Net Capital Cost	*$35,596*
LCC - NPV:	***-$3.83/m²***
Range ($/m²):	***-7.60 to -1.87***

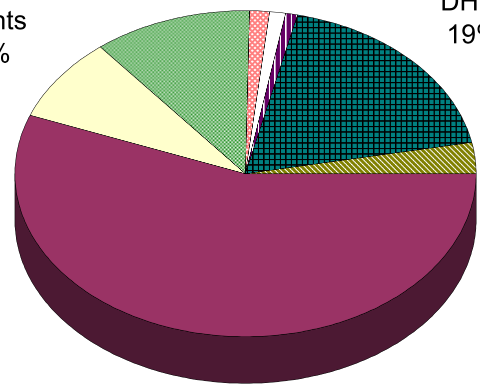
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Low-Rise MURB, Conventional Shell, On/Off Boiler - Energy Efficiency Case
Prince George, BC

Wall R-Value Requirements, Residential Wood Frame Construction (5.3.1.2)
ENERGY BILL: $65,775, RESULTING IN SAVINGS OF $1,512 (2.2%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling							0		0	
	Heating			31,962	4.5%			31,962	4.5%	3,308	4.5%
	Lights	8,306	0.0%					8,306	0.0%	487	0.0%
	Equip.	5,525	0.0%	3,260	0.0%			8,785	0.0%	661	0.0%
	Fans	1,345	1.0%					1,345	1.0%	79	1.0%
	Refrig							0		0	
	Ext. Lts	1,020	0.0%					1,020	0.0%	60	0.0%
	Elev.	788	0.0%					788	0.0%	46	0.0%
	DHW			10,589	0.0%			10,589	0.0%	1,096	0.0%
	Cook	2,981	0.0%					2,981	0.0%	175	0.0%
	TOTAL	**19,964**	**0.1%**	**45,811**	**3.2%**			**65,775**	**2.2%**	**5,911**	**2.6%**
Total $ Savings		**$13**		**$1,499**				**$1,512**		**155.9**	
Fuel Savings:		0.2 MWh		155 GJ		0 Mlbs		**$0.35 /m²**		**36.5 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,437	1,392	45.3 (3.1%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	0.0	0.0	0.0 (0.0%)
Fans & Pumps (hp)	5	5	0.1 (1.5%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²): 1.830	Net Capital $/m²: $10.74

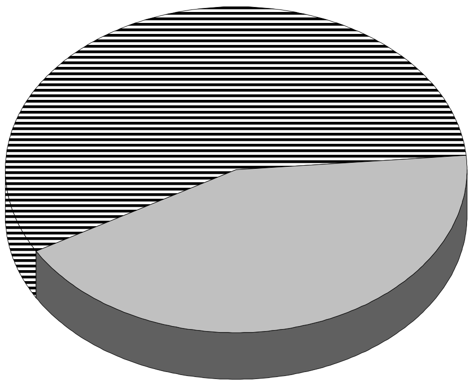
Economic Analysis (FAILS)

Incremental Costs ($)	
Equip. & Labor	$46,585
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$1,512*
Net Capital Cost	*$45,906*
LCC - NPV:	***$6.94/m²***
Range ($/m²):	***2.83 to 8.10***

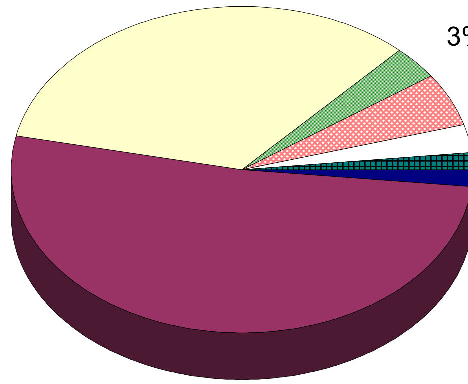
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Big Box Retail, Gas Packaged ASHRAE Case - Energy Efficiency Case
Vancouver, BC

Wall R-Value Requirements (5.3.1.2)
ENERGY BILL: $54,055, RESULTING IN SAVINGS OF $25,471 (32.0%)



Divided by Utility Source



Divided by End-Use

Legend	Electricity		Natural Gas		Central Steam		TOTAL COSTS		ANNUAL ENERGY	
END-USE	$	Savings	$	Savings	$	Savings	$	Svgs	GJ	Svgs
Cooling	1,732	24.4%					1,732	24.4%	71	7.5%
Heating			22,475	50.3%			22,475	50.3%	2,335	50.3%
Lights	22,004	-0.2%					22,004	-0.2%	1,521	0.0%
Equip.	2,127	-0.2%					2,127	-0.2%	147	0.0%
Fans	3,303	40.8%					3,303	40.8%	233	41.6%
Refrig							0		0	
Ext. Lts	1,680	-1.6%					1,680	-1.6%	127	0.0%
Elev.							0		0	
DHW			733	0.0%			733	0.0%	76	0.0%
Cook							0		0	
TOTAL	**30,847**	**8.2%**	**23,208**	**49.5%**			**54,055**	**32.0%**	**4,509**	**36.0%**
Total $ Savings	**$2,756**		**$22,715**				**$25,471**		**2,531.3**	
Fuel Savings:	47.7 MWh		2,359 GJ		0 Mlbs		**$6.09 /m²**		**605.5 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	2,178	1,385	793.1 (36.4%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	81.6	57.5	24.1 (29.6%)
Fans & Pumps (hp)	39	25	14.0 (36.3%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	32.422	Net Capital $/m²:	$58.49

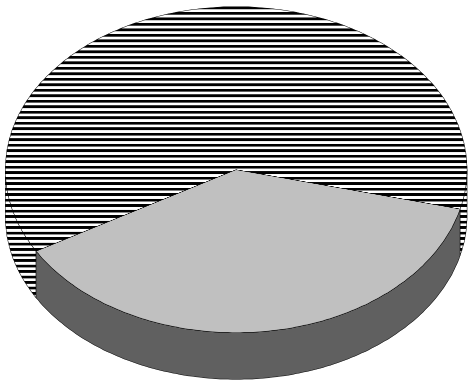
Economic Analysis (MARGINAL)

Incremental Costs ($)	
Equip. & Labor	$268,500
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$25,471*
Net Capital Cost	*$244,529*
LCC - NPV:	***-$8.12/m²***
Range ($/m²):	***-75.02 to 12.10***

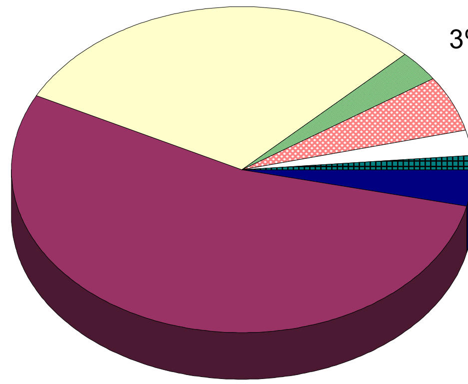
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Big Box Retail, Gas Packaged ASHRAE Case - Energy Efficiency Case
Summerland, BC

Wall Mass Wall R-Value Requirements (5.3.1.2)
ENERGY BILL: $71,210, RESULTING IN SAVINGS OF $31,625 (30.8%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	4,757	26.9%					4,757	26.9%	181	22.7%
	Heating			26,163	48.8%			26,163	48.8%	2,745	48.8%
	Lights	29,260	2.4%					29,260	2.4%	1,521	0.0%
	Equip.	2,829	2.4%					2,829	2.4%	147	0.0%
	Fans	5,291	44.0%					5,291	44.0%	283	43.7%
	Refrig							0		0	
	Ext. Lts	2,185	1.4%					2,185	1.4%	127	0.0%
	Elev.							0		0	
	DHW			726	0.0%			726	0.0%	76	0.0%
	Cook							0		0	
	TOTAL	44,321	13.2%	26,889	48.1%			71,210	30.8%	5,080	36.2%
Total $ Savings		$6,719		$24,905				$31,625		2,885.9	
Fuel Savings:		75.7 MWh		2,613 GJ		0 Mlbs		$7.56 /m²		690.3 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	2,852	1,874	977.3 (34.3%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	124.3	87.4	36.9 (29.7%)
Fans & Pumps (hp)	48	29	18.5 (38.5%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	37.949	Net Capital $/m²:	$56.30

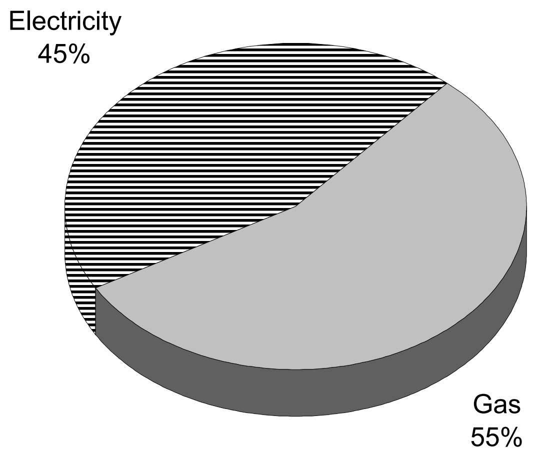
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$268,500
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$31,625*
Net Capital Cost	*$235,382*
LCC - NPV:	***-$27.91/m²***
Range ($/m²):	***-106.03 to -2.45***

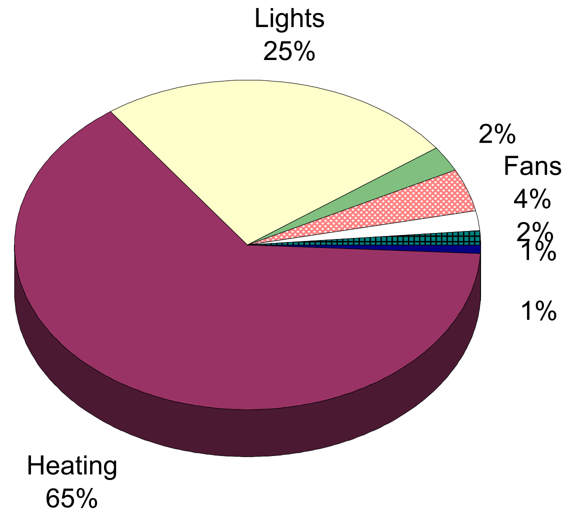
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Big Box Retail, Gas Packaged ASHRAE Case - Energy Efficiency Case
Prince George, BC

Mass Wall R-Value Requirements (5.3.1.2)
ENERGY BILL: $69,063, RESULTING IN SAVINGS OF $42,505 (38.1%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	1,520	40.1%					1,520	40.1%	52	25.0%
	Heating			37,424	50.3%			37,424	50.3%	3,873	50.3%
	Lights	22,026	-0.7%					22,026	-0.7%	1,521	0.0%
	Equip.	2,129	-0.7%					2,129	-0.7%	147	0.0%
	Fans	3,550	52.2%					3,550	52.2%	251	53.2%
	Refrig							0		0	
	Ext. Lts	1,677	-2.5%					1,677	-2.5%	126	0.0%
	Elev.							0		0	
	DHW			736	0.0%			736	0.0%	76	0.0%
	Cook							0		0	
	TOTAL	**30,904**	**13.1%**	**38,160**	**49.8%**			**69,063**	**38.1%**	**6,046**	**41.1%**
Total $ Savings		**$4,676**		**$37,829**				**$42,505**		**4,218.1**	
Fuel Savings:		84.1 MWh		3,915 GJ		0 Mlbs		**$10.17 /m²**		**1,009.0 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	3,942	2,456	1,485.2 (37.7%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	91.7	57.3	34.4 (37.5%)
Fans & Pumps (hp)	49	25	23.9 (48.5%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	54.238	Net Capital $/m²:	$73.34

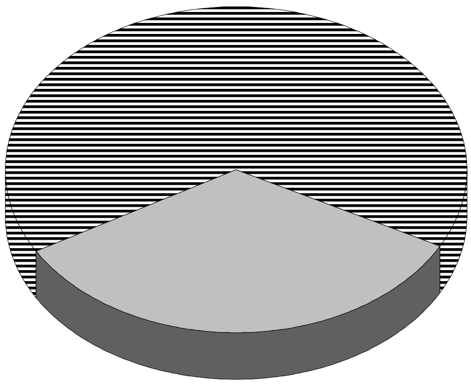
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$346,100
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$42,505*
Net Capital Cost	*$306,611*
LCC - NPV:	***-$37.85/m²***
Range ($/m²):	***-149.38 to -4.10***

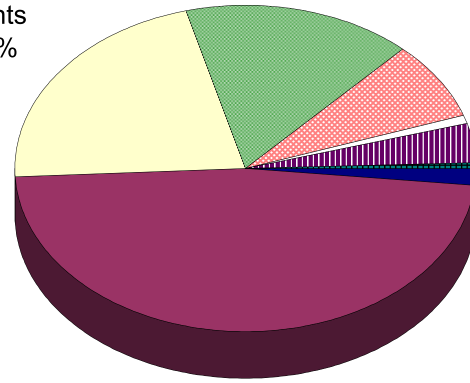
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Large Office, Gas VAVS Budget Case - Energy Efficiency Case
Vancouver, BC

Glazing, Commercial (5.3.2)
ENERGY BILL: $200,195, RESULTING IN SAVINGS OF $15,112 (7.0%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	8,609	-5.6%					8,609	-5.6%	266	-8.2%
	Heating	3,401	14.3%	67,252	18.8%			70,653	18.6%	7,187	18.8%
	Lights	52,355	0.0%					52,355	0.0%	3,296	0.0%
	Equip.	35,765	0.0%					35,765	0.0%	2,423	0.0%
	Fans	20,095	-3.3%					20,095	-3.3%	1,206	-1.7%
	Refrig							0		0	
	Ext. Lts	1,426	0.0%					1,426	0.0%	121	0.0%
	Elev.	10,650	0.5%					10,650	0.5%	604	0.0%
	DHW			640	0.0%			640	0.0%	67	0.0%
	Cook							0		0	
	TOTAL	132,302	-0.4%	67,892	18.7%			200,195	7.0%	15,169	9.7%
Total $ Savings		-$496		$15,608				$15,112		1,625.5	
Fuel Savings:		1.1 MWh		1,621 GJ		0 Mlbs		$0.63 /m²		67.5 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	6,928	6,409	518.6 (7.5%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	152	141	11.4 (7.5%)
Cooling (tons output)	372.6	402.8	-30.3 -(8.1%)
Fans & Pumps (hp)	321	377	-56.0 -(17.5%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	3.378	Net Capital $/m²:	$10.63

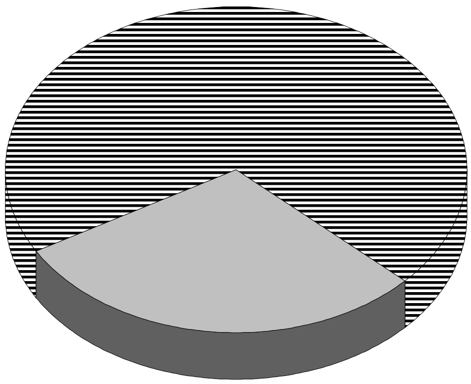
Economic Analysis (MARGINAL)

Incremental Costs ($)	
Equip. & Labor	$248,800
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$15,112*
Net Capital Cost	*$255,985*
LCC - NPV:	***$3.94/m²***
Range ($/m²):	***-3.51 to 5.98***

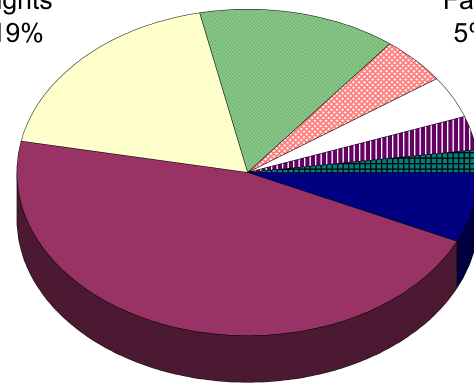
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Small Office, Gas VAV ASHRAE Reference - Energy Efficiency Case
Summerland, BC

Glazing, Commercial (5.3.2)
ENERGY BILL: $46,875, RESULTING IN SAVINGS OF $3,750 (7.4%)



Divided by Utility Source



Divided by End-Use

Legend	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling	5,545	15.7%					5,545	15.7%	205	16.4%
Heating	730	19.3%	13,319	13.2%			14,049	13.6%	1,358	13.3%
Lights	11,300	1.2%					11,300	1.2%	549	0.0%
Equip.	7,942	0.8%					7,942	0.8%	404	0.0%
Fans	3,143	8.4%					3,143	8.4%	145	6.0%
Refrig							0		0	
Ext. Lts	2,007	0.2%					2,007	0.2%	117	0.0%
Elev.	2,218	0.3%					2,218	0.3%	101	0.0%
DHW			671	0.0%			671	0.0%	67	0.0%
Cook							0		0	
TOTAL	32,885	5.0%	13,990	12.7%			46,875	7.4%	2,946	8.0%
Total $ Savings	$1,716		$2,034				$3,750		257.3	
Fuel Savings:	15.5 MWh		202 GJ		0 Mlbs		$0.93 /m²		64.1 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,401	1,270	131.2 (9.4%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	31	20	10.3 (33.5%)
Cooling (tons output)	80.2	69.6	10.6 (13.2%)
Fans & Pumps (hp)	79	71	8.4 (10.7%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO_2 Savings (kg/m²):	3.944	Net Capital $/m²:	$5.93

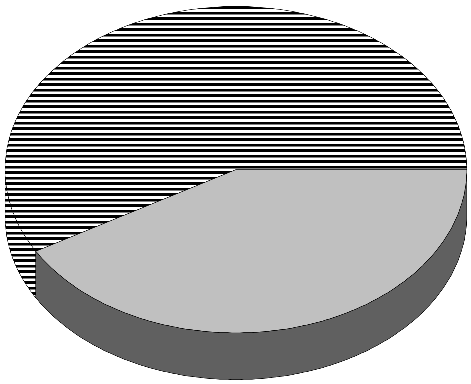
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$31,200
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$3,750*
Net Capital Cost	*$23,802*
LCC - NPV:	***-$4.91/m²***
Range ($/m²):	***-13.12 to -1.66***

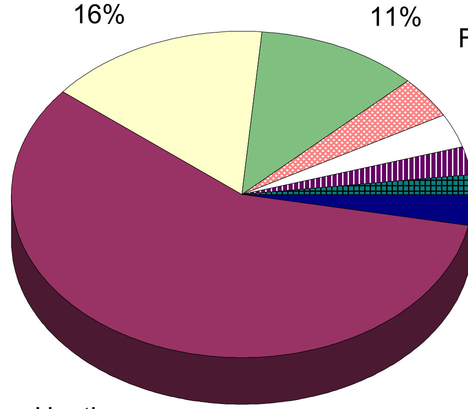
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Small Office, Gas VAV ASHRAE Reference - Energy Efficiency Case
Prince George, BC

Glazing, Commercial (5.3.2)
ENERGY BILL: $47,787, RESULTING IN SAVINGS OF $3,284 (6.4%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	3,257	19.2%					3,257	19.2%	105	18.3%
	Heating	1,021	5.8%	19,231	10.8%			20,253	10.6%	2,048	10.8%
	Lights	10,097	-0.2%					10,097	-0.2%	549	0.0%
	Equip.	7,038	-0.2%					7,038	-0.2%	404	0.0%
	Fans	2,790	6.3%					2,790	6.3%	145	5.4%
	Refrig							0		0	
	Ext. Lts	1,743	-0.5%					1,743	-0.5%	116	0.0%
	Elev.	1,966	-1.7%					1,966	-1.7%	101	0.0%
	DHW			643	0.0%			643	0.0%	67	0.0%
	Cook							0		0	
	TOTAL	27,913	3.3%	19,874	10.5%			47,787	6.4%	3,535	7.4%
Total $ Savings		$951		$2,333				$3,284		280.8	
Fuel Savings:		10.9 MWh		242 GJ		0 Mlbs		$0.82 /m²		70.0 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	2,160	1,909	250.8 (11.6%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	47	59	-11.8 -(24.9%)
Cooling (tons output)	72.9	59.8	13.1 (17.9%)
Fans & Pumps (hp)	65	57	8.1 (12.4%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	4.017	Net Capital $/m²:	$5.25

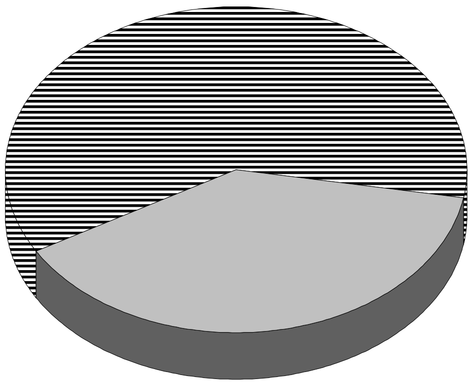
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$31,200
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$3,284*
Net Capital Cost	*$21,083*
LCC - NPV:	***-$3.98/m²***
Range ($/m²):	***-12.03 to -1.19***

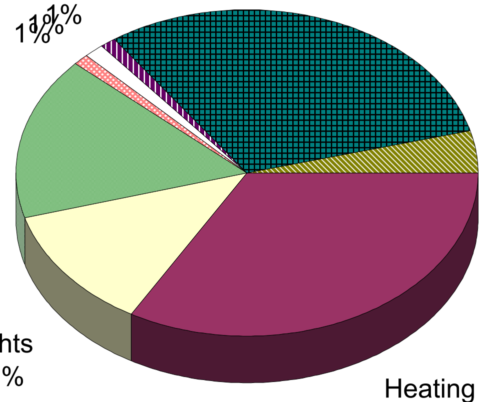
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

High-Rise MURB, Conventional Shell, Electric Resistance - Energy Efficiency Case
Vancouver, BC

Glazing, Residential (5.3.2)
ENERGY BILL: $160,499, RESULTING IN SAVINGS OF $14,371 (8.2%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling							0		0	
	Heating	38,940	27.0%	17,164	-0.1%			56,103	20.4%	4,065	17.1%
	Lights	25,524	0.0%					25,524	0.0%	1,496	0.0%
	Equip.	16,475	0.0%	9,745	0.0%			26,220	0.0%	1,978	0.0%
	Fans	2,563	0.0%					2,563	0.0%	150	0.0%
	Refrig							0		0	
	Ext. Lts	3,069	0.0%					3,069	0.0%	180	0.0%
	Elev.	2,365	0.0%					2,365	0.0%	139	0.0%
	DHW			35,712	0.0%			35,712	0.0%	3,710	0.0%
	Cook	8,942	0.0%					8,942	0.0%	524	0.0%
	TOTAL	**97,878**	**12.8%**	**62,621**	**0.0%**			**160,499**	**8.2%**	**12,241**	**6.4%**
Total $ Savings		**$14,393**		**-$22**				**$14,371**		**841.2**	
Fuel Savings:		234.3 MWh		-2 GJ		0 Mlbs		**$1.12 /m²**		**65.6 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	537	538	-0.2 (0.0%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	1,345	1,005	339.4 (25.2%)
Cooling (tons output)	0.0	0.0	0.0 (0.0%)
Fans & Pumps (hp)	9	9	0.0 (0.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	6.808	Net Capital $/m²:	$9.31

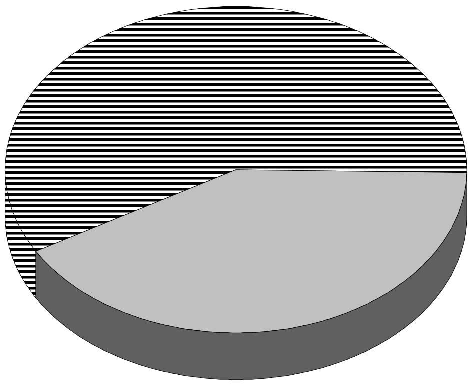
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$124,400
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$14,371*
Net Capital Cost	*$119,311*
LCC - NPV:	***-$4.87/m²***
Range ($/m²):	***-10.89 to -0.690***

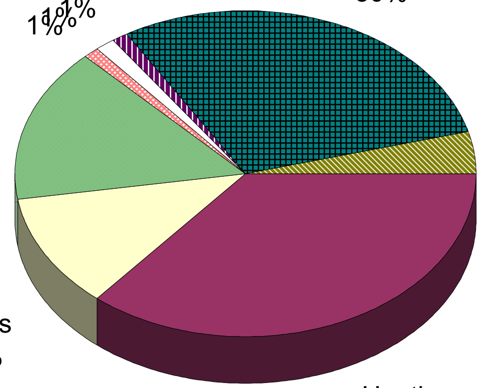
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

High-Rise MURB, Conventional Shell, Electric Resistance - Energy Efficiency Case
Summerland, BC

Glazing, Residential (5.3.2)
ENERGY BILL: $167,106, RESULTING IN SAVINGS OF $11,799 (6.6%)



Divided by Utility Source



Divided by End-Use

Legend		Electricity		Natural Gas		Central Steam		TOTAL COSTS		ANNUAL ENERGY	
	END-USE	$	Savings	$	Savings	$	Savings	$	Svgs	GJ	Svgs
	Cooling							0		0	
	Heating	39,225	23.1%	22,662	-0.1%			61,887	16.0%	4,677	12.9%
	Lights	25,524	0.0%					25,524	0.0%	1,496	0.0%
	Equip.	16,475	0.0%	9,646	0.0%			26,122	0.0%	1,978	0.0%
	Fans	2,571	0.0%					2,571	0.0%	151	0.0%
	Refrig							0		0	
	Ext. Lts	3,068	0.0%					3,068	0.0%	180	0.0%
	Elev.	2,365	0.0%					2,365	0.0%	139	0.0%
	DHW			36,627	0.0%			36,627	0.0%	3,843	0.0%
	Cook	8,942	0.0%					8,942	0.0%	524	0.0%
	TOTAL	98,170	10.7%	68,936	0.0%			167,106	6.6%	12,987	5.1%
Total $ Savings		$11,814		-$15				$11,799		690.8	
Fuel Savings:		192.3 MWh		-2 GJ		0 Mlbs		$0.92 /m²		53.9 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	785	785	0.0 (0.0%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	1,602	1,287	315.5 (19.7%)
Cooling (tons output)	0.0	0.0	0.0 (0.0%)
Fans & Pumps (hp)	9	9	0.0 (0.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	5.589	Net Capital $/m²:	$6.90

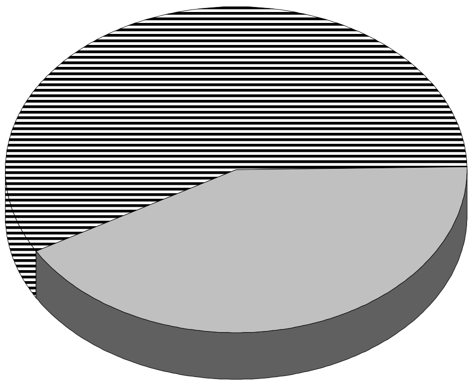
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$93,200
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$11,799*
Net Capital Cost	*$88,467*
LCC - NPV:	***-$4.74/m²***
Range ($/m²):	***-9.68 to -1.31***

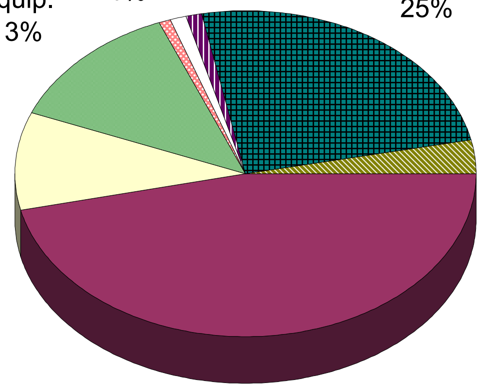
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

High-Rise MURB, Conventional Shell, Electric Resistance - Energy Efficiency Case
Prince George, BC

Glazing, Residential (5.3.2)
ENERGY BILL: $218,420, RESULTING IN SAVINGS OF $15,359 (6.6%)



Divided by Utility Source



Divided by End-Use

END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling							0		0	
Heating	56,565	20.5%	42,840	1.9%			99,404	13.4%	7,188	10.3%
Lights	29,696	0.0%					29,696	0.0%	1,496	0.0%
Equip.	19,335	0.0%	10,448	0.0%			29,784	0.0%	1,978	0.0%
Fans	3,479	0.0%					3,479	0.0%	154	0.0%
Refrig							0		0	
Ext. Lts	3,974	0.0%					3,974	0.0%	179	0.0%
Elev.	3,179	0.0%					3,179	0.0%	139	0.0%
DHW			38,194	0.0%			38,194	0.0%	3,843	0.0%
Cook	10,709	0.0%					10,709	0.0%	524	0.0%
TOTAL	**126,938**	**10.3%**	**91,482**	**0.9%**			**218,420**	**6.6%**	**15,501**	**5.1%**
Total $ Savings	**$14,543**		**$816**				**$15,359**		**827.6**	
Fuel Savings:	206.8 MWh		83 GJ		0 Mlbs		**$1.20 /m²**		**64.6 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,853	1,624	229.5 (12.4%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	1,840	1,935	-95.2 -(5.2%)
Cooling (tons output)	0.0	0.0	0.0 (0.0%)
Fans & Pumps (hp)	9	9	0.0 (0.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	6.339	Net Capital $/m²:	$7.50

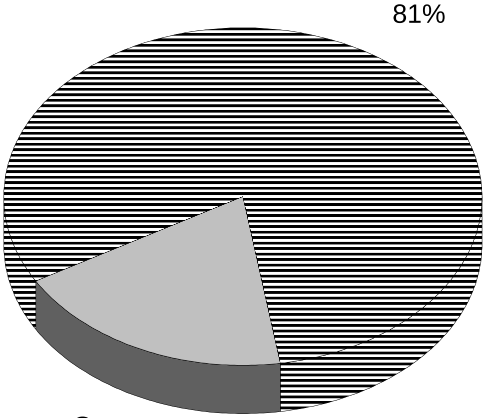
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$98,200
Annual O&M	$0 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$15,359*
Net Capital Cost	*$96,186*
LCC - NPV:	***-$7.52/m²***
Range ($/m²):	***-14.36 to -3.09***

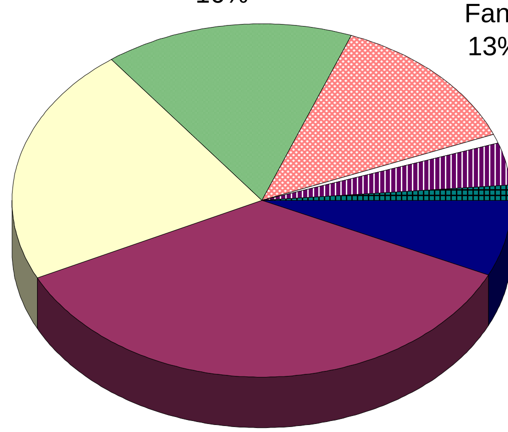
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Small Office, Gas WSHP ASHRAE - Energy Efficiency Case
Vancouver, BC

Water-Source Heat Pumps with Two-Position Valve Interlock (6.3.2.2)
ENERGY BILL: $72,723, RESULTING IN SAVINGS OF $821 (1.1%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	6,444	1.5%					6,444	1.5%	344	1.5%
	Heating	9,336	-0.1%	13,214	-3.6%			22,550	-2.1%	1,800	-2.6%
	Lights	17,412	-0.1%					17,412	-0.1%	1,099	0.0%
	Equip.	12,052	-0.1%					12,052	-0.1%	808	0.0%
	Fans	9,422	11.6%					9,422	11.6%	643	12.1%
	Refrig							0		0	
	Ext. Lts	525	-0.3%					525	-0.3%	42	0.0%
	Elev.	3,640	0.0%					3,640	0.0%	201	0.0%
	DHW			678	0.0%			678	0.0%	67	0.0%
	Cook							0		0	
	TOTAL	58,830	2.1%	13,893	-3.4%			72,723	1.1%	5,004	0.9%
Total $ Savings		$1,283		-$462				$821		47.8	
Fuel Savings:		25.8 MWh		-45 GJ		0 Mlbs		$0.10 /m²		6.0 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,795	1,805	-10.2 -(0.6%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	940	940	-0.6 -(0.1%)
Cooling (tons output)	125.5	124.5	0.9 (0.7%)
Fans & Pumps (hp)	84	77	6.7 (8.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	0.920	Net Capital $/m²:	$1.58

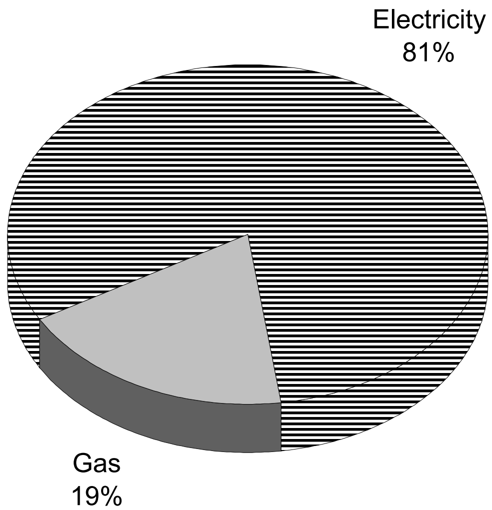
Economic Analysis (FAILS)

Incremental Costs ($)	
Equip. & Labor	$12,960
Annual O&M	$300 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$521*
Net Capital Cost	*$12,660*
LCC - NPV:	***$0.573/m²***
Range ($/m²):	***0.568 to 0.875***

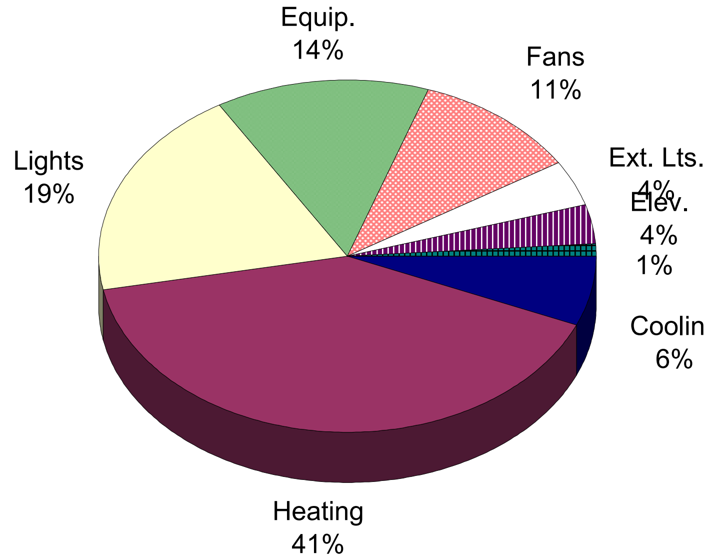
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Small Office, Gas WSHP ASHRAE - Energy Efficiency Case
Summerland, BC

Water-Source Heat Pumps with Two-Position Valve Interlock (6.3.2.2)
ENERGY BILL: $96,581, RESULTING IN SAVINGS OF $1,071 (1.1%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	8,561	1.2%					8,561	1.2%	363	1.3%
	Heating	12,773	-0.2%	17,593	-2.6%			30,366	-1.6%	2,330	-2.0%
	Lights	21,810	-0.1%					21,810	-0.1%	1,099	0.0%
	Equip.	15,290	-0.1%					15,290	-0.1%	808	0.0%
	Fans	11,593	11.2%					11,593	11.2%	621	11.6%
	Refrig							0		0	
	Ext. Lts	3,851	-0.1%					3,851	-0.1%	233	0.0%
	Elev.	4,439	0.0%					4,439	0.0%	201	0.0%
	DHW			671	0.0%			671	0.0%	67	0.0%
	Cook							0		0	
	TOTAL	78,317	1.9%	18,264	-2.5%			96,581	1.1%	5,721	0.7%
Total $ Savings		$1,517		-$447				$1,071		41.7	
Fuel Savings:		23.9 MWh		-44 GJ		0 Mlbs		$0.13 /m²		5.2 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	2,086	2,089	-3.5 -(0.2%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	1,091	1,091	-0.6 -(0.1%)
Cooling (tons output)	134.7	134.2	0.5 (0.4%)
Fans & Pumps (hp)	82	75	6.6 (8.1%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	0.835	Net Capital $/m²:	$1.59

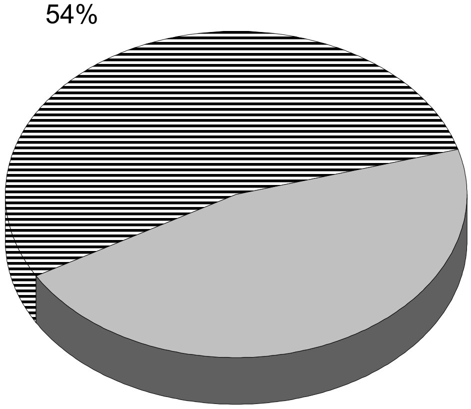
Economic Analysis (FAILS)

Incremental Costs ($)	
Equip. & Labor	$12,960
Annual O&M	$300 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$771*
Net Capital Cost	*$12,772*
LCC - NPV:	***$0.198/m²***
Range ($/m²):	***0.014 to 0.614***

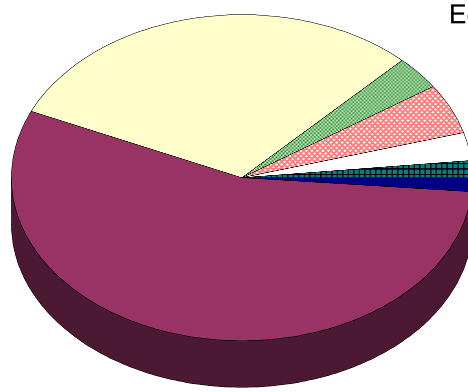
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Big Box Retail, Gas Packaged ASHRAE Case - Energy Efficiency Case
Vancouver, BC

Mandatory Automatic Lighting Shut-off (9.2.1.1)
ENERGY BILL: $55,545, RESULTING IN SAVINGS OF $258 (0.5%)



Divided by Utility Source



Divided by End-Use

END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling	1,698	3.3%					1,698	3.3%	68	5.4%
Heating			24,844	-3.1%			24,844	-3.1%	2,581	-3.1%
Lights	20,999	4.6%					20,999	4.6%	1,425	6.3%
Equip.	2,147	-0.9%					2,147	-0.9%	147	0.0%
Fans	3,426	-0.8%					3,426	-0.8%	239	0.1%
Refrig							0		0	
Ext. Lts	1,697	-1.1%					1,697	-1.1%	127	0.0%
Elev.							0		0	
DHW			733	0.0%			733	0.0%	76	0.0%
Cook							0		0	
TOTAL	**29,968**	**3.2%**	**25,577**	**-3.0%**			**55,545**	**0.5%**	**4,663**	**0.5%**
Total $ Savings	**$998**		**-$741**				**$258**		**22.5**	
Fuel Savings:	27.6 MWh		-77 GJ		0 Mlbs		**$0.06 /m²**		**5.4 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,466	1,491	-25.4 -(1.7%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	58.4	57.7	0.7 (1.2%)
Fans & Pumps (hp)	25	25	0.2 (0.7%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	1.547	Net Capital $/m²:	$1.08

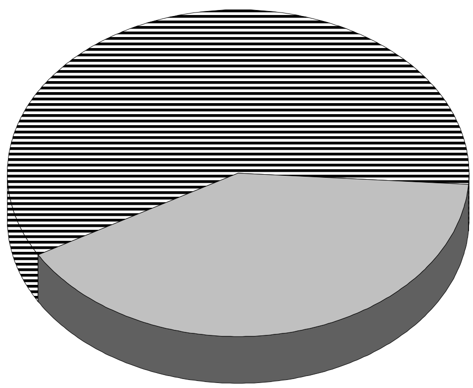
Economic Analysis (FAILS)

Incremental Costs ($)	
Equip. & Labor	$4,500
Annual O&M	$90 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$168*
Net Capital Cost	*$4,529*
LCC - NPV:	***$0.195/m²***
Range ($/m²):	***0.444 to 1.082***

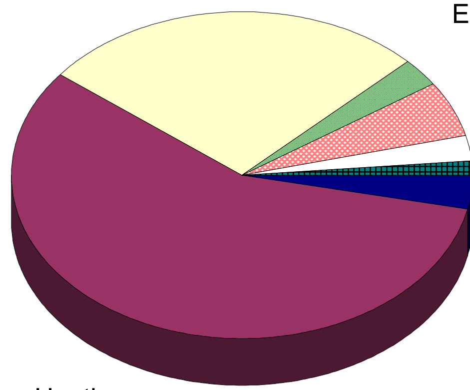
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Big Box Retail, Gas Packaged ASHRAE Case - Energy Efficiency Case
Summerland, BC

Mandatory Automatic Lighting Shut-off (9.2.1.1)
ENERGY BILL: $72,265, RESULTING IN SAVINGS OF $855 (1.2%)



Divided by Utility Source



Divided by End-Use

Legend	Electricity		Natural Gas		Central Steam		TOTAL COSTS		ANNUAL ENERGY	
END-USE	$	Savings	$	Savings	$	Savings	$	Svgs	GJ	Svgs
Cooling	4,722	2.2%					4,722	2.2%	178	3.0%
Heating			28,487	-2.5%			28,487	-2.5%	2,989	-2.5%
Lights	27,831	5.0%					27,831	5.0%	1,425	6.3%
Equip.	2,836	-0.1%					2,836	-0.1%	147	0.0%
Fans	5,472	-0.2%					5,472	-0.2%	293	-0.1%
Refrig							0		0	
Ext. Lts	2,190	-0.2%					2,190	-0.2%	127	0.0%
Elev.							0		0	
DHW			726	0.0%			726	0.0%	76	0.0%
Cook							0		0	
TOTAL	43,052	3.5%	29,213	-2.5%			72,265	1.2%	5,235	0.5%
Total $ Savings	$1,558		-$703				$855		26.7	
Fuel Savings:	27.9 MWh		-74 GJ		0 Mlbs		$0.20 /m²		6.4 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,931	1,954	-23.3 -(1.2%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	89.3	88.7	0.6 (0.7%)
Fans & Pumps (hp)	30	30	0.1 (0.3%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²): 1.610	Net Capital $/m²: $1.08

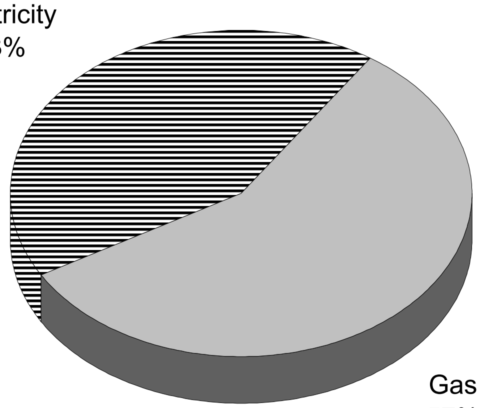
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$4,500
Annual O&M	$90 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$765*
Net Capital Cost	*$4,535*
LCC - NPV:	***-$1.59/m²***
Range ($/m²):	***-1.53 to -0.815***

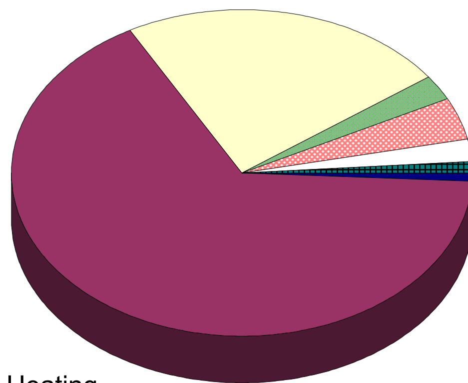
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Big Box Retail, Gas Packaged ASHRAE Case - Energy Efficiency Case
Prince George, BC

Mandatory Automatic Lighting Shut-off (9.2.1.1)
ENERGY BILL: $70,223, RESULTING IN SAVINGS OF $96 (0.1%)



Divided by Utility Source



Divided by End-Use

Legend	Electricity		Natural Gas		Central Steam		TOTAL COSTS		ANNUAL ENERGY	
END-USE	$	Savings	$	Savings	$	Savings	$	Svgs	GJ	Svgs
Cooling	1,524	2.6%					1,524	2.6%	50	4.6%
Heating			39,391	-2.3%			39,391	-2.3%	4,077	-2.3%
Lights	21,014	4.6%					21,014	4.6%	1,425	6.3%
Equip.	2,149	-0.9%					2,149	-0.9%	147	0.0%
Fans	3,717	-1.4%					3,717	-1.4%	261	-0.5%
Refrig							0		0	
Ext. Lts	1,693	-1.0%					1,693	-1.0%	126	0.0%
Elev.							0		0	
DHW			736	0.0%			736	0.0%	76	0.0%
Cook							0		0	
TOTAL	30,096	3.1%	40,127	-2.2%			70,223	0.1%	6,163	0.1%
Total $ Savings	$963		-$867				$96		6.8	
Fuel Savings:	26.8 MWh		-90 GJ		0 Mlbs		$0.02 /m²		1.6 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	2,498	2,514	-15.7 -(0.6%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	58.6	58.1	0.6 (0.9%)
Fans & Pumps (hp)	26	26	0.0 (0.0%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	1.321	Net Capital $/m²:	$1.07

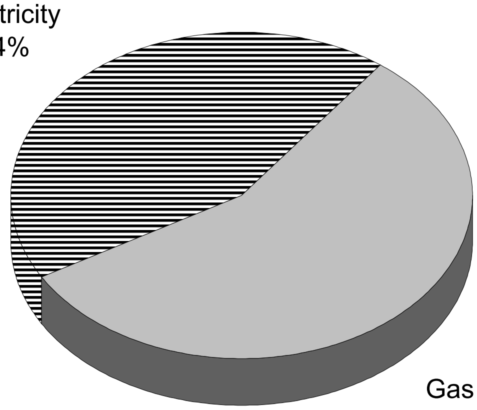
Economic Analysis (FAILS)

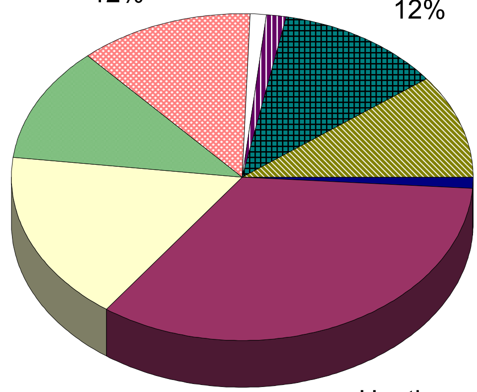
Incremental Costs ($)	
Equip. & Labor	$4,500
Annual O&M	$90 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$6*
Net Capital Cost	*$4,457*
LCC - NPV:	***$0.609/m²***
Range ($/m²):	***0.73 to 1.894***

REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Extended Care, ASHRAE Gas Budget Case - Energy Efficiency Case
Vancouver, BC

Exhaust Heat Recovery (6.3.6.1)
ENERGY BILL: $66,541, RESULTING IN SAVINGS OF $22,053 (24.9%)





Divided by Utility Source **Divided by End-Use**

END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
Cooling	1,081	-2.7%					1,081	-2.7%	65	-3.3%
Heating			19,573	53.9%			19,573	53.9%	2,033	53.9%
Lights	14,084	0.6%					14,084	0.6%	1,013	0.0%
Equip.	2,129	0.6%	5,167	0.0%			7,295	0.2%	689	0.0%
Fans	9,776	-10.6%					9,776	-10.6%	726	-11.4%
Refrig							0		0	
Ext. Lts	840	0.7%					840	0.7%	63	0.0%
Elev.	1,149	0.6%					1,149	0.6%	82	0.0%
DHW			6,781	0.0%			6,781	0.0%	704	0.0%
Cook			5,961	0.0%			5,961	0.0%	619	0.0%
TOTAL	29,059	-3.0%	37,482	37.9%			66,541	24.9%	5,994	27.8%
Total $ Savings	-$845		$22,898				$22,053		2,302.4	
Fuel Savings:	-21.1 MWh		2,379 GJ		0 Mlbs		$4.75 /m²		495.7 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,371	949	422.0 (30.8%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	25.4	25.9	-0.4 -(1.6%)
Fans & Pumps (hp)	45	50	-5.1 -(11.3%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²): 23.854	Net Capital $/m²: $12.46

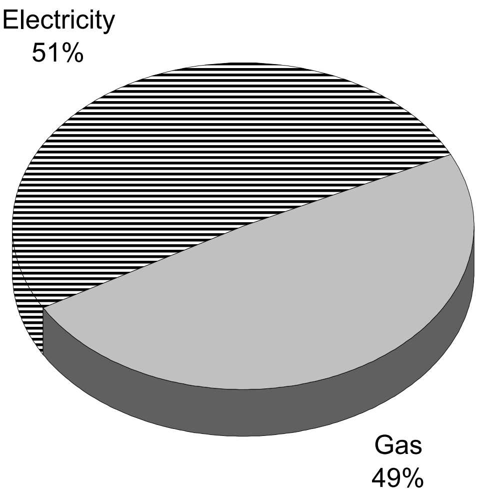
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$64,000
Annual O&M	$1,280 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$20,773*
Net Capital Cost	*$57,876*
LCC - NPV:	***-$35.17/m²***
Range ($/m²):	***-90.31 to -20.51***

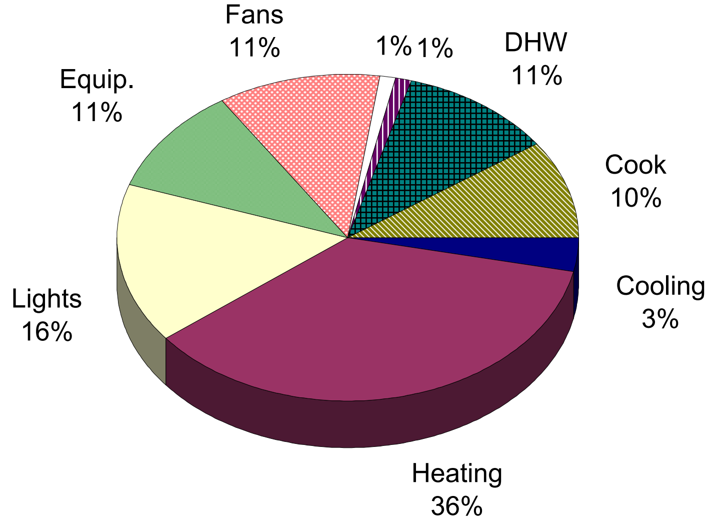
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Extended Care, ASHRAE Gas Budget Case - Energy Efficiency Case
Summerland, BC

Exhaust Heat Recovery (6.3.6.1)
ENERGY BILL: $81,924, RESULTING IN SAVINGS OF $22,826 (21.8%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	4,870	3.6%					4,870	3.6%	213	0.7%
	Heating			22,253	51.5%			22,253	51.5%	2,335	51.5%
	Lights	18,748	1.0%					18,748	1.0%	1,013	0.0%
	Equip.	2,837	1.0%	5,114	0.0%			7,951	0.4%	689	0.0%
	Fans	12,868	-10.2%					12,868	-10.2%	730	-11.1%
	Refrig							0		0	
	Ext. Lts	1,080	0.8%					1,080	0.8%	63	0.0%
	Elev.	1,540	1.1%					1,540	1.1%	82	0.0%
	DHW			6,713	0.0%			6,713	0.0%	704	0.0%
	Cook			5,901	0.0%			5,901	0.0%	619	0.0%
	TOTAL	41,942	-1.8%	39,982	37.1%			81,924	21.8%	6,449	27.2%
Total $ Savings		-$760		$23,586				$22,826		2,403.4	
Fuel Savings:		-19.9 MWh		2,475 GJ		0 Mlbs		$4.91 /m²		517.4 MJ/m²	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	1,741	1,219	521.6 (30.0%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	78.1	68.9	9.2 (11.7%)
Fans & Pumps (hp)	47	52	-5.3 -(11.4%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²):	24.992	Net Capital $/m²:	$11.11

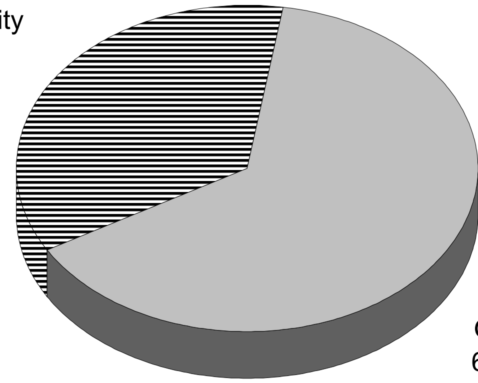
Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$64,000
Annual O&M	$1,280 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$21,546*
Net Capital Cost	*$51,593*
LCC - NPV:	***-$38.34/m²***
Range ($/m²):	***-95.31 to -23.13***

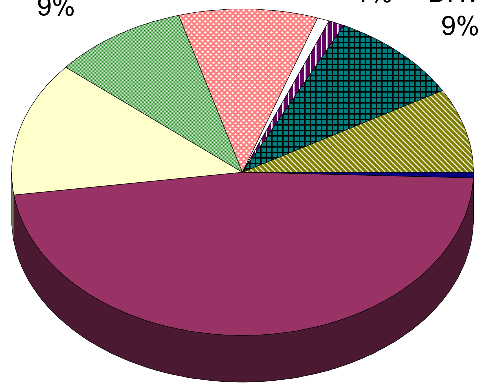
REPBC ASHRAE 90.1-2001 Life-Cycle Economic Analysis

Extended Care, ASHRAE Gas Budget Case - Energy Efficiency Case
Prince George, BC

Exhaust Heat Recovery (6.3.6.1)
ENERGY BILL: $80,973, RESULTING IN SAVINGS OF $32,176 (28.4%)



Divided by Utility Source



Divided by End-Use

Legend	END-USE	Electricity $	Electricity Savings	Natural Gas $	Natural Gas Savings	Central Steam $	Central Steam Savings	TOTAL COSTS $	TOTAL COSTS Svgs	ANNUAL ENERGY GJ	ANNUAL ENERGY Svgs
	Cooling	887	-2.9%					**887**	**-2.9%**	**48**	**-3.6%**
	Heating			33,938	49.3%			**33,938**	**49.3%**	**3,512**	**49.3%**
	Lights	14,089	0.6%					**14,089**	**0.6%**	**1,013**	**0.0%**
	Equip.	2,129	0.6%	5,185	0.0%			**7,315**	**0.2%**	**689**	**0.0%**
	Fans	9,973	-9.4%					**9,973**	**-9.4%**	**740**	**-10.1%**
	Refrig							**0**		**0**	
	Ext. Lts	833	0.7%					**833**	**0.7%**	**63**	**0.0%**
	Elev.	1,150	0.6%					**1,150**	**0.6%**	**82**	**0.0%**
	DHW			6,806	0.0%			**6,806**	**0.0%**	**704**	**0.0%**
	Cook			5,983	0.0%			**5,983**	**0.0%**	**619**	**0.0%**
	TOTAL	**29,061**	**-2.8%**	**51,912**	**38.8%**			**80,973**	**28.4%**	**7,471**	**30.9%**
Total $ Savings		**-$779**		**$32,955**				**$32,176**		**3,340.9**	
Fuel Savings:		-19.4 MWh		3,411 GJ		0 Mlbs		**$6.93 /m²**		**719.2 MJ/m²**	

Maximum HVAC Contribution During Peak*

HVAC END-USE	Demand Base	Demand ECM	Peak Load Reduction
Fossil Heat (kBtuh out)	2,904	2,029	875.0 (30.1%)
Steam Heat (kBtuh out)	0	0	0.0 (0.0%)
Electric Heat (kBtuh out)	0	0	0.0 (0.0%)
Cooling (tons output)	24.0	24.3	-0.3 -(1.2%)
Fans & Pumps (hp)	47	51	-4.9 -(10.4%)

*Coincident with building; thus, values do not necessarily reflect absolute maximums.

CO2 Savings (kg/m²): 35.083	Net Capital $/m²: $10.98

Economic Analysis (PASSES)

Incremental Costs ($)	
Equip. & Labor	$64,000
Annual O&M	$1,280 /year
Cooling System**	$500 /ton
Heating System**	$15 /kBtuh
Fans & Pumps**	$0 /hp
Net Savings/Year	*$30,896*
Net Capital Cost	*$51,019*
LCC - NPV:	***-$60.05/m²***
Range ($/m²):	***-140.51 to -38.26***

APPENDIX C:

REPBC LIFE-CYCLE ECONOMIC ANALYSIS
DETAILED SUMMARY OF ASHRAE 90.1-2001 STIPULATIONS

Summary of ASHRAE 90.1-2001 Life-Cycle Cost Assessment

Table C-1. ASHRAE 90.1-2001 Stipulations for Coastal Region

	ASHRAE 90.1 Stipulation*	Financial Impacts ($/m²)	Energy & Other Impacts	Segment Most Affected	Standard Issue/Comments	Market Acceptance
PASS	Exhaust Heat Recovery (6.3.6.1)	Net Capital Cost: $12.46 Net Maint. Cost: $0.28 Electricity Savings: -$0.18/yr Gas Savings: $4.93/yr NPV SAVINGS: $35.17/yr	Electricity Savings: -4.55 kWh/m² Gas Savings: 512.06 MJ/m² GHG Savings: 23.85 kg/m² CO2	Health care, Laboratories, Schools (gyms, theatres)	Required on air handlers with over 70% outside air, over 5000 cfm and with no exhaust source above 75% of the supply; not common practice.	Except for laboratories, most applicable air handlers do not have exhaust heat recovery; even some labs do not provide for heat recovery.
PASS	Glazing, Residential (5.3.2)	Net Capital Cost: $9.31 Net Maint. Cost: $0.00 Electricity Savings: $1.12/yr Gas Savings: -$0.00/yr NPV SAVINGS: $4.87/yr	Electricity Savings: 18.3 kWh/m² Gas Savings: -0.18 MJ/m² GHG Savings: 6.81 kg/m² CO2	High-rise apartments and hotels	For buildings with high glazing percentages (i.e., >40%), Standard calls for overall U-value that is common but not always installed.	Some residential towers already provide for low-e glazing, particularly within the City of Vancouver, but most do not.
PASS	Wall R-value requirements, residential steel frame construction (5.3.1.2)	Net Capital Cost: $2.29 Net Maint. Cost: $0.00 Electricity Savings: $0.33/yr Gas Savings: $0.00/yr NPV SAVINGS: $1.85/yr	Electricity Savings: 5.33 kWh/m² Gas Savings: 0.00 MJ/m² GHG Savings: 1.99 kg/m² CO2	High-rise apartments and hotels	Overall wall R-value and insulation requirements exceed level provided for most designs.	It is very rare for apartments and hotels with steel-frame or curtain wall construction to provide the required R-7.5 (~1.5") continuous insulation.
PASS	Condenser Heat Recovery for Service Water (6.3.6.2)	*N/A - see Appendix A*	*N/A - see Appendix A*	Large hotels, miscellaneous (e.g., convention complex)	Applies to facilities with large cooling and domestic hot water loads; most likely located in major urban centres.	Most high profile large commercial projects for which this provision would apply are likely to consider this provision.
MARGINAL	Mass wall R-value requirements (5.3.1.2)	Net Capital Cost: $58.49 Net Maint. Cost: $0.00 Electricity Savings: $0.66/yr Gas Savings: $5.43/yr NPV SAVINGS: $8.12/yr	Electricity Savings: 11.4 kWh/m² Gas Savings: 564.39 MJ/m² GHG Savings: 32.42 kg/m² CO2	Retail, Warehouse, Schools (e.g., gym, shops), Churches	Overall wall R-value and insulation requirements exceed levels provided for most designs with solid masonry walls.	Relatively low-budget designs with concrete block construction typically are uninsulated; hence, applies to a significant portion of the market.
MARGINAL	Glazing, Commercial (5.3.2)	Net Capital Cost: $10.63 Net Maint. Cost: $0.00 Electricity Savings: -$0.02/yr Gas Savings: $0.65/yr NPV SAVINGS: -$3.94/yr	Electricity Savings: 0.05 kWh/m² Gas Savings: 67.33 MJ/m² GHG Savings: 3.38 kg/m² CO2	High-rise office	For buildings with high glazing percentages (i.e., >40%), Standard calls for overall U-value that is common but not always installed.	A large portion of this segment already provides for low-e glazing.

Summary of ASHRAE 90.1-2001 Life-Cycle Cost Assessment

FAIL	Mandatory Automatic lighting shut-off (9.2.1.1)	Net Capital Cost: $1.08 Net Maint. Cost: $0.02 Electricity Savings: $0.24/yr Gas Savings: -$0.18/yr NPV SAVINGS: -$0.19/yr	Electricity Savings: 6.61 kWh/m² Gas Savings: -18.40 MJ/m² GHG Savings: 1.55 kg/m² CO2	Retail	Retail outlets over 5,000 square feet are required to have automatic controls to shut off all interior lighting.	Applies most to relatively low-budget designs without direct digital controls (e.g., big box retail).
FAIL	Water-source heat pumps must have two-position valve interlock (6.3.2.2)	Net Capital Cost: $1.58 Net Maint. Cost: $0.04 Electricity Savings: $0.16/yr Gas Savings: -$0.06/yr NPV SAVINGS: -$0.57/yr	Electricity Savings: 3.22 kWh/m² Gas Savings: -5.64 MJ/m² GHG Savings: 0.92 kg/m² CO2	All building types with water-to-air heat pumps on circulation loop with pump over 10 hp	Two-position valves on units are readily available at a nominal cost, but are not standard equipment yet.	Eventual market transformation anticipated since manufacturers will continue to provide compatible units due to influence of ASHRAE.

**Only includes requirements that are not "common practice" (i.e., already followed by ~20% or more of new commercial construction)*

Table C-2. ASHRAE 90.1-2001 Stipulations for Southern Interior

	ASHRAE 90.1 Stipulation*	Financial Impacts $(\$/m^2)$	Energy & Other Impacts	Segment Most Affected	Standard Issue/Comments	Relavent Policies and Measures
PASS	Exhaust Heat Recovery (6.3.6.1)	Net Capital Cost: $11.11 Net Maint. Cost: $0.28 Electricity Savings: -$0.16/yr Gas Savings: $5.08/yr NPV SAVINGS: $38.34/yr	Electricity Savings: -4.28 kWh/m^2 Gas Savings: 532.80 MJ/m^2 GHG Savings: 24.99 kg/m^2 CO2	Health care, Laboratories, Schools (gyms, theatres)	Required on air handlers with over 70% outside air, over 5000 cfm and with no exhaust source above 75% of the supply; not common practice.	Except for laboratories, most applicable air handlers do not have exhaust heat recovery; even some labs do not provide for heat recovery.
	Mass wall R-value requirements (5.3.1.2)	Net Capital Cost: $56.30 Net Maint. Cost: $0.00 Electricity Savings: $1.61/yr Gas Savings: $5.96/yr NPV SAVINGS: $27.91/yr	Electricity Savings: 18.1 kWh/m^2 Gas Savings: 625.12 MJ/m^2 GHG Savings: 37.95 kg/m^2 CO2	Retail, Warehouse, Schools (e.g., gym, shops), Churches	Overall wall R-value and insulation requirements exceed levels provided for most designs with solid masonry walls.	Relatively low-budget designs with concrete block construction typically are uninsulated; hence, applies to a significant portion of the market.
	Glazing, Commercial (5.3.2)	Net Capital Cost: $5.93 Net Maint. Cost: $0.00 Electricity Savings: $0.43/yr Gas Savings: $0.51/yr NPV SAVINGS: $4.91/yr	Electricity Savings: 3.85 kWh/m^2 Gas Savings: 50.24 MJ/m^2 GHG Savings: 3.94 kg/m^2 CO2	High-rise office	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.	A large portion of this segment already provides for low-e glazing.
	Glazing, Residential (5.3.2)	Net Capital Cost: $6.90 Net Maint. Cost: $0.00 Electricity Savings: $0.92/yr Gas Savings: -$0.00/yr NPV SAVINGS: $4.74/yr	Electricity Savings: 15.0 kWh/m^2 Gas Savings: -0.12 MJ/m^2 GHG Savings: 5.59 kg/m^2 CO2	High-rise apartments and hotels	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.	Some residential towers already provide for low-e glazing, particularly within the City of Vancouver, but most do not.
	Wall R-value requirements, commercial steel frame construction (5.3.1.2)	Net Capital Cost: $2.14 Net Maint. Cost: $0.00 Electricity Savings: $0.05/yr Gas Savings: $0.45/yr NPV SAVINGS: $3.32/yr	Electricity Savings: 0.54 kWh/m^2 Gas Savings: 44.76 MJ/m^2 GHG Savings: 2.44 kg/m^2 CO2	Any building type with steel frame wall construction	Overall wall R-value and insulation requirements exceed level provided for many designs.	It is very rare for steel-frame or curtain wall construction to provide the required R-3.5 (~1") continuous insulation.
	Mandatory Automatic lighting shut-off (9.2.1.1)	Net Capital Cost: $1.08 Net Maint. Cost: $0.02 Electricity Savings: $0.37/yr Gas Savings: -$0.17/yr NPV SAVINGS: $1.59/yr	Electricity Savings: 6.68 kWh/m^2 Gas Savings: -17.64 MJ/m^2 GHG Savings: 1.61 kg/m^2 CO2	Retail	Retail outlets over 5,000 square feet are required to have automatic controls to shut off all interior lighting.	Applies most to relatively low-budget designs without direct digital controls (e.g., big box retail).

Summary of ASHRAE 90.1-2001 Life-Cycle Cost Assessment

	Wall R-value requirements, residential steel frame construction (5.3.1.2)	Net Capital Cost: $2.27 Net Maint. Cost: $0.00 Electricity Savings: $0.28/yr Gas Savings: $0.00/yr NPV SAVINGS: $1.22/yr	Electricity Savings: 4.50 kWh/m² Gas Savings: 0.00 MJ/m² GHG Savings: 1.68 kg/m² CO2	High-rise apartments and hotels	Overall wall R-value and insulation requirements exceed level provided for most designs.	It is very rare for apartments and hotels with steel-frame or curtain wall construction to provide the required R-7.5 (~1.5") continuous insulation.
	Condenser Heat Recovery for Service Water (6.3.6.2)	*N/A - see Appendix A*	*N/A - see Appendix A*	Large hotels, miscellaneous (e.g., convention complex)	Applies to facilities with large cooling and domestic hot water loads; most likely located in major urban centres.	Most high profile large commercial projects for which this provision would apply are likely to consider this provision.
FAIL	Water-source heat pumps must have two-position valve interlock (6.3.2.2)	Net Capital Cost: $1.59 Net Maint. Cost: $0.04 Electricity Savings: $0.19/yr Gas Savings: -$0.06/yr NPV SAVINGS: -$0.20/yr	Electricity Savings: 2.98 kWh/m² Gas Savings: -5.52 MJ/m² GHG Savings: 0.83 kg/m² CO2	All building types with water-to-air heat pumps on circulation loop with pump over 10 hp	Two-position valves on units are readily available at a nominal cost, but are not standard equipment yet.	Eventual market transformation anticipated since manufacturers will continue to provide compatible units due to influence of ASHRAE.

**Only includes requirements that are not "common practice" (i.e., already followed by ~20% or more of new commercial construction)*

Summary of ASHRAE 90.1-2001 Life-Cycle Cost Assessment

Table C-3. ASHRAE 90.1-2001 Stipulations for Northern Interior

	ASHRAE 90.1 Stipulation*	Financial Impacts ($/m²)	Energy & Other Impacts	Segment Most Affected	Standard Issue/Comments	Relavent Policies and Measures
PASS	Exhaust Heat Recovery (6.3.6.1)	Net Capital Cost: $10.98 Net Maint. Cost: $0.28 Electricity Savings: -$0.17/yr Gas Savings: $7.09/yr NPV SAVINGS: $60.05/yr	Electricity Savings: -4.17 kWh/m² Gas Savings: 734.27 MJ/m² GHG Savings: 35.08 kg/m² CO2	Health care, Laboratories, Schools (gyms, theatres)	Required on air handlers with over 70% outside air, over 5000 cfm and with no exhaust source above 75% of the supply; not common practice.	Except for laboratories, most applicable air handlers do not have exhaust heat recovery; even some labs do not provide for heat recovery.
PASS	Mass wall R-value requirements (5.3.1.2)	Net Capital Cost: $58.64 Net Maint. Cost: $0.00 Electricity Savings: $1.10/yr Gas Savings: $8.92/yr NPV SAVINGS: $51.02/yr	Electricity Savings: 19.8 kWh/m² Gas Savings: 923.63 MJ/m² GHG Savings: 53.49 kg/m² CO2	Retail, Warehouse, Schools (e.g., gym, shops), Churches	Overall wall R-value and insulation requirements exceed levels provided for most designs with solid masonry walls.	Relatively low-budget designs with concrete block construction typically are uninsulated; hence, applies to a significant portion of the market.
PASS	Glazing, Residential (5.3.2)	Net Capital Cost: $7.50 Net Maint. Cost: $0.00 Electricity Savings: $1.13/yr Gas Savings: $0.06/yr NPV SAVINGS: $7.52/yr	Electricity Savings: 16.1 kWh/m² Gas Savings: 6.49 MJ/m² GHG Savings: 6.34 kg/m² CO2	High-rise apartments and hotels	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.	Some residential towers already provide for low-e glazing, particularly within the City of Vancouver, but most do not.
PASS	Wall R-value requirements, commercial steel frame construction (5.3.1.2)	Net Capital Cost: $2.40 Net Maint. Cost: $0.00 Electricity Savings: $0.02/yr Gas Savings: $0.62/yr NPV SAVINGS: $4.49/yr	Electricity Savings: 0.41 kWh/m² Gas Savings: 64.21 MJ/m² GHG Savings: 3.36 kg/m² CO2	Any building type with steel frame wall construction	Overall wall R-value and insulation requirements exceed level provided for many designs..	It is very rare for steel-frame or curtain wall construction to provide the required R-3.5 (~1") continuous insulation.
PASS	Glazing, Commercial (5.3.2)	Net Capital Cost: $5.25 Net Maint. Cost: $0.00 Electricity Savings: $0.24/yr Gas Savings: $0.58/yr NPV SAVINGS: $3.98/yr	Electricity Savings: 2.72 kWh/m² Gas Savings: 60.18 MJ/m² GHG Savings: 4.02 kg/m² CO2	High-rise office	For buildings with high glazing percentages, Standard calls for overall U-value that is common but not always installed.	A large portion of this segment already provides for low-e glazing.
PASS	Wall R-value requirements, residential steel frame construction (5.3.1.2)	Net Capital Cost: $2.78 Net Maint. Cost: $0.00 Electricity Savings: $0.41/yr Gas Savings: $0.13/yr NPV SAVINGS: $3.83/yr	Electricity Savings: 6.65 kWh/m² Gas Savings: 13.91 MJ/m² GHG Savings: 3.18 kg/m² CO2	High-rise apartments and hotels	Overall wall R-value and insulation requirements exceed level provided for most designs.	It is very rare for apartments and hotels with steel-frame or curtain wall construction to provide the required R-7.5 (~1.5") continuous insulation.

Summary of ASHRAE 90.1-2001 Life-Cycle Cost Assessment

FAIL	Mandatory Automatic lighting shut-off (9.2.1.1)	Net Capital Cost: $1.07 Net Maint. Cost: $0.02 Electricity Savings: $0.23/yr Gas Savings: -$0.21/yr NPV SAVINGS: -$0.61/yr	Electricity Savings: 6.41 kWh/m² Gas Savings: -21.48 MJ/m² GHG Savings: 1.32 kg/m² CO2	Retail	Retail outlets over 5,000 square feet are required to have automatic controls to shut off all interior lighting.	Applies most to relatively low-budget designs without direct digital controls (e.g., big box retail).
FAIL	Wall R-value requirements, residential wood frame construction (5.3.1.2)	Net Capital Cost: $10.74 Net Maint. Cost: $0.00 Electricity Savings: $0.00/yr Gas Savings: $0.35/yr NPV SAVINGS: -$6.94/yr	Electricity Savings: 0.05 kWh/m² Gas Savings: 36.31 MJ/m² GHG Savings: 1.83 kg/m² CO2	Low-rise apartments	Standard calls for higher insulation levels than typical practice.	It is very rare to provide the prescriptively required R-7.5 (~1.5") continuous insulation, although 2"x6" construction may satisfy the overall R-value requirement, depending on the cladding system.

**Only includes requirements that are not "common practice" (i.e., already followed by ~20% or more of new commercial construction)*