British Columbia Zero-Net Energy Building Study
Jack Davis Building
Final Report

CONFIDENTIAL DRAFT FOR COMMENTS BY PROJECT TEAM

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EXECUTIVE SUMMARY

An energy audit of the Jack Davis Building at 1810 Blanshard Street in Victoria, the home of the British Columbia Ministry of Energy and Mines, has been performed. The purpose of the audit was to determine energy saving measures to reduce the building's consumption of natural gas and electricity, as well as investigate steps to further decrease the building's energy balance to the zero-net energy threshold.

Analyzing past utility bills and local weather trends created a baseline of the Jack Davis Building's energy consumption. These energy use patterns were then used as a benchmark to determine the accuracy of the building model, developed using the EE4 building simulation software.

The simulation results indicate that the model closely simulates the actual energy consumption of the Jack Davis Building (natural gas consumption within three percent and electricity consumption within sixteen percent). Thus, the model was used as a tool to aid in determining the merit of proposed energy saving measures.

The scope of energy saving measures was identified through a series of consultations with project stakeholders committed to energy efficiency and the Jack Davis Building. These consultations included personnel from the Alternative Energy Policy Branch, the British Columbia Building Corporation, WSI, and the Institute for Integrated Energy Systems at the University of Victoria. The result of these collaborations was a short list of potential measures, of these, twelve significant energy savings measures and five energy showcase opportunities were analyzed. A summary of the findings is included in the following tables, prioritizing the measures based on simple payback period (Table 1) as well as total energy saving potential (Table 2).

TABLE 1: ENERGY SAVING MEASURES: LISTED IN ORDER OF SIMPLE PAYBACK PERIOD

Energy Saving Measure	**Cost ($)**	**Savings ($/yr)**	**Simple Payback (yr)**	**Notes:**
1. SHW tank insulation	150	290	0.5	
2. Summer set-point temperature	600	450	1.3	
3. Base electricity load	1,500	990 to 4,940 [a]	1.5 to 0.3 [a]	[a] Modest and ambitious savings scenarios
4. Daylighting control	2,000	650	3.1	
5. Occupant-sensing lighting control	2,210	460	4.8	
6. Computer monitors	51,700 [b]	4,100	12.6	[b] Incremental cost
7. Windows with thermal break	60,140 [c]	4,580	13.1	[c] Incremental cost
8. T8 lighting conversion	90,500	6,510	13.9	
9. High-efficiency condensing boilers	116,000	8,110	14.3	
10. Revolving entrance door	16,350 [d]	930	17.6	[d] Incremental cost
11. Ground source heat pump	295,150 [e]	15,660	18.8	[e] Incremental cost
12. Solar hot water heating	12,540	210	59.7	

TABLE 2: ENERGY SAVING MEASURES: LISTED IN ORDER OF TOTAL ENERGY SAVINGS

Energy Saving Measure	**Electricity Savings [1] (kWh/yr)**	**Natural Gas Savings (GJ/yr)**	**Cooling Savings (kWh/yr)**	**Total Energy Savings (GJ/yr)**
1. Ground source heat pump	- 174,060 [2]	2,505	≈ 0	1878
2. High-efficiency condensing boilers	--	842	--	842
3. Windows with thermal break	--	476	- 380	475
4. T8 lighting conversion	171,020	- 203	2,890	423
5. Computer monitors	106,140	- 118	1,410	269
6. Base electricity load - modest projection (reduce by 5%) - ambitious projection (reduce by 25%)	 30,230 151,130	 -- --	 -- --	 109 544
7. Revolving entrance door	--	95	135	96
8. Daylighting control	29,370	- 32	450	75
9. Summer set-point temperature	5,130	--	4,120	33
10. Occupant-sensing lighting control	9,535	- 2	190	32
11. SHW tank insulation	--	30	--	30
12. Solar hot water heating	--	22	--	22

[1] Includes electrical consumption for lights, plug loads, equipment loads but does not include the electrical consumption due to cooling.
[2] A negative savings indicates that an increase in electricity or natural gas consumption was a result of the measure's implementation.

It is evident at the conclusion of this study that the Jack Davis Building is currently operating at a high level of energy efficiency. The initial design of the building, which won the building acclaim upon completion just over ten years ago, is still reaping the benefits of energy efficient construction via low energy expenditures. For this reason, the availability of energy saving measures with short paybacks is scarce; the last gigajoule saved is the hardest to earn.

These findings attest to the significant savings potential of energy-efficient design in new buildings, for which the Jack Davis Building has been an excellent example. This positions the building well as a potential exemplary case for office buildings in the province of British Columbia. Implementing the suggested energy saving measures will ensure that all efforts have been made to reduce energy consumption, the mandatory first step in striving for a zero-net energy building. The measures outlined as "showcase opportunities" provide a potential framework for the next step in approaching energy independence and zero emissions.

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List of Acronyms & Abbreviations

A/C	Air Conditioning
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AHU	Air Handling Unit
BCBC	British Columbia Buildings Corporation
BF	Ballast Factor
BIPV	Building Integrated Photovoltaic
CBIP	Commercial Building Incentives Program
CDD	Cooling Degree Day
COP	Coefficient of Performance
CRT	Cathode Ray Tube
DOE	Department of Energy (USA)
EEB	Energuide for Existing Buildings
GHX	Ground Heat Exchanger
GSHP	Ground Source Heat Pump
HDD	Heating Degree Day
HVAC	Heating, Ventilation and Air Conditioning
IESVic	Institute for Integrated Energy Systems at UVic
JDB	Jack Davis Building
LCD	Liquid Crystal Display
Low-e	Low emissivity
MEM	Ministry of Energy and Mines
NRCan	Natural Resources Canada
PIP	Product Incentive Program (BC Hydro)
PIR	Passive Infrared
PV	Photovoltaic
REDI	Renewable Energy Deployment Incentive (NRCan)
RSI	Unit Thermal Resistance (SI units)
SEER	Seasonal Energy Efficiency Ratio

SHW	Service Hot Water
US	Ultrasonic
VAV	Variable Air Volume
WPPI	Wind Power Production Incentive (NRCan)

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1.0 Introduction

An energy audit of the Jack Davis Building at 1810 Blanshard Street in Victoria, the home of the British Columbia Ministry of Energy and Mines, has been performed. The purpose of the audit was to determine energy saving measures to reduce the building's consumption of natural gas and electricity, as well as to investigate strategies to establish the building as a zero-net energy consumer.

The zero-net energy study of the Jack Davis Building is a collaborative project involving participation from the Ministry of Energy and Mines (MEM), the British Columbia Buildings Corporation (BCBC), the Institute for Integrated Energy Systems at the University of Victoria (IESVic), as well as consultation from external building energy specialists.

The energy study consists of four tasks: 1) Building Energy Audit and System Model development, 2) Identification of Near and Long-term Energy System Options, 3) Feasibility Analysis, and 4) Reporting and Recommendations.

This report is a final summary of the work completed, providing details on all tasks. The report includes information detailing the energy audit process used to determine the current status of the building construction, operation, and energy performance. The energy audit also establishes the current energy consumption level to which the predictions of the building model can be compared. The creation, validation, and results of the building model are also discussed in this report.

The energy audit, model findings, and a series of brainstorming sessions have helped to generate a list of potential energy saving measures. These are presented and analyzed based on the merits of each measure's ability for implementation, near and long-term energy saving potentials, and economic payback period. Measures are also proposed to create a zero-net energy building with the intent of the MEM's Jack Davis Building being an exemplar for office building energy use in British Columbia.

2.0 Background

The Jack Davis Building is an eight-storey building with two levels of underground parking, with a total floor area of 13,585 m^2. The primary use of the building is office space, with the Ministry of Energy and Mines occupying the top five floors with two and a half floors of leased office space below. The bottom floor also accommodates the MEM library and laboratory. The first underground level is sub-divided to include further lab space, rock sample storage, as well as to provide office space for the building superintendent and operations group.

The Jack Davis Building was built in 1994 and has already gained recognition for its energy efficient design. Only minor modifications have been made to the original building, the most significant of which include:

- transformation of a storage room in the first parking level to office space in order to accommodate the building superintendent and operations group,
- the deactivation of daylight control of perimeter lighting,
- the removal of zone level A/C units on mid-level floors due to space use modifications,
- the replacement of two hot water heating tanks, and
- several minor modifications to the configuration of office spaces.

2.1 Building Envelope

The Jack Davis Building has a rectangular footprint with the long axis running East-West. The existing building envelope primarily consists of glass façade (spandrel panels) and low-e glazing. The windows are aluminum framed without thermal breaks, and are operable. Other envelope building materials include acrylic stucco, granite panels, and glass blocks.

Due to the relatively new construction, the exterior (walls and roof) is in good condition with no obvious water damage or apparent failed sealed units.

Table 3 lists the current envelope insulation levels in the building. The RSI-values for the walls include the effects of thermal bridging, and the RSI-values for the windows are for low-e, aluminum-framed windows without thermal breaks.

TABLE 3: EXISTING BUILDING ENVELOPE CHARACTERISTICS

Building Face	Window Area (m^2)	Average RSI-Value Windows (m^2K/W)	Wall Area (m^2)	Average RSI-Value Walls (m^2K/W)	Window & Wall Area (m^2)	Average RSI-Value Walls & Windows (m^2K/W)	Average U-Value Walls & Windows (W/m^2K)
North	1244.6	0.30	1005.8	2.13	2250.4	0.49	2.06
East	316.1	0.31	862.9	2.22	1179.0	0.83	1.20
South	1211.2	0.30	1063.9	2.27	2275.1	0.50	1.99
West	79.9	0.35	960.4	2.27	1040.3	1.61	0.62
Roof	--	--	1621.0	3.57	1621.0	3.57	0.28

2.2 Building Mechanical and Electrical Systems

The Jack Davis Building is equipped with a variable air volume (VAV) air-handling unit (AHU) on each floor. The temperature for each zone is controlled by occupants within a possible range of 20 to 24°C. The control system adjusts the air set-point temperature for each AHU based on the average of the zone settings. Specific zones that require additional conditioning, either due to exceptional heat gains or the need for precise environmental controls, are equipped with individual heat pumps or air conditioning units. The VAV systems all have reheat capabilities via a hot water loop that runs through reheat coils in each VAV box, and supplied by two, high efficiency, natural gas-fired boilers with modulating control. Economizer control allows for utilization of the outdoor air to cool the building when the outdoor air temperature is sufficiently below the return air temperature. Air is exhausted from the building using four relief fans on each floor (two in the NE corner and two in the NW corner of the building). These fans are controlled in tandem with the variable-speed supply air fans and outside air dampers to balance the outside air and exhaust airflow through each floor. Service hot water (SHW) is supplied at 55°C by two, recently installed, natural gas-fired hot water heaters.

The cooling load is met in three stages. Initially, outside air is used with the air handling system having the capability to make supply air 100 per cent outdoor air, thus enabling "free cooling" (economizer control). An increased air flow and decreased cooling temperature difference (15°F instead of the commonly used 20°F) allows for increased use of free cooling capabilities compared to conventional HVAC systems. The second cooling strategy is via direct evaporative cooling built in to each AHU. Finally, the remaining cooling load is met with a chilled water loop supplied by a rotary chiller accompanied by a cooling tower. This three-stage cooling scheme helps reduce chiller run-time during the shoulder months of the cooling season. The cooling equipment is manually disabled during the heating months (October through April). The chiller is equipped with heat reclaim from the condenser to provide heating, although this capability is currently disabled.

Due to the building's short life span, all mechanical equipment is in good state. Table 4 shows a summary of the rated performance values of the primary mechanical equipment.

TABLE 4: EXISTING BUILDING MECHANICAL CHARACTERISTICS

System	Size	Efficiency
Space Heating Boilers (x2)	775 kW	81 %
Chiller	1055 kW	5.8 COP
Cooling Tower	1240 kW	--
Air Handling Unit VAV Fans (typ)	11.25 kW 9000 L/s	80 %
Heat Pump (typ)	8.8 kW (Heating)	3.0 COP 10.0 SEER
DHW Heaters (x2)	58 kW 303 L	80 %

In addition to the HVAC equipment, the Jack Davis Building's electrical network consists primarily of lighting and office equipment loads. The as-built lighting inventory has not been significantly modified since the building's construction and was therefore used to determine the floor specific lighting loads. The building is lit primarily with T12 fluorescent tubes resulting in an average lighting power density of approximately 13.0 W/m^2 (1.2 W/ft^2). Nightly off-sweeps[3] of all office lighting are performed by the lighting control system to ensure lights are turned off during non-working hours.

There was no existing inventory available for office equipment and human occupation; therefore, a survey was performed within this study to develop an inventory. The total number of occupants working in the building was found to be 490, resulting in an average occupancy density of 0.036 persons per m^2 (28 m^2 per person). The total inventory of office equipment (presented in Appendix A) produces a total of 100 kilowatts of heat gain over the entire building. Table 5 shows the floor-by-floor summary of the current occupant and equipment inventory.

TABLE 5: SUMMARY OF OCCUPANT & OFFICE EQUIPMENT HEAT GAIN INVENTORY

Floor	**# Occupants**	**Office Equipment Heat Gain (kW)**
8	36	13.40
4-7 (typ)	65	13.40
3	75	14.36
2	67	12.21
G	23	5.83
P1	7	1.39

[3] Off-sweep refers to the automatic switching off of office lighting by the control system. The off-sweep is preceded with a warning flicker so that in the event that the space is occupied, the occupant can override the lighting shutdown. The lighting off-sweeps for the Jack Davis Building occur at six pm and again every two hours thereafter.

3.0 Existing Energy Use

The natural gas and electricity consumption trends of the Jack Davis Building for the last three years, obtained from gas and electricity bills, are plotted in Figures 1 and 2. Natural gas consumption for the year 2002[4] was 3,497 GJ and the electricity consumption was 1,831,200 kWh (6,592 GJ) for a total building energy consumption of 10,089 GJ or 0.74 GJ/m² of floor area.

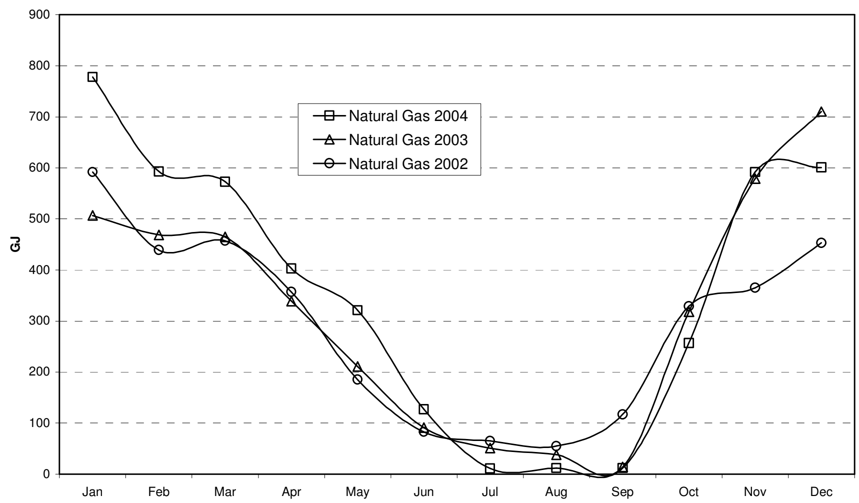

FIGURE 1: JACK DAVIS BUILDING NATURAL GAS CONSUMPTION (2002-2004)

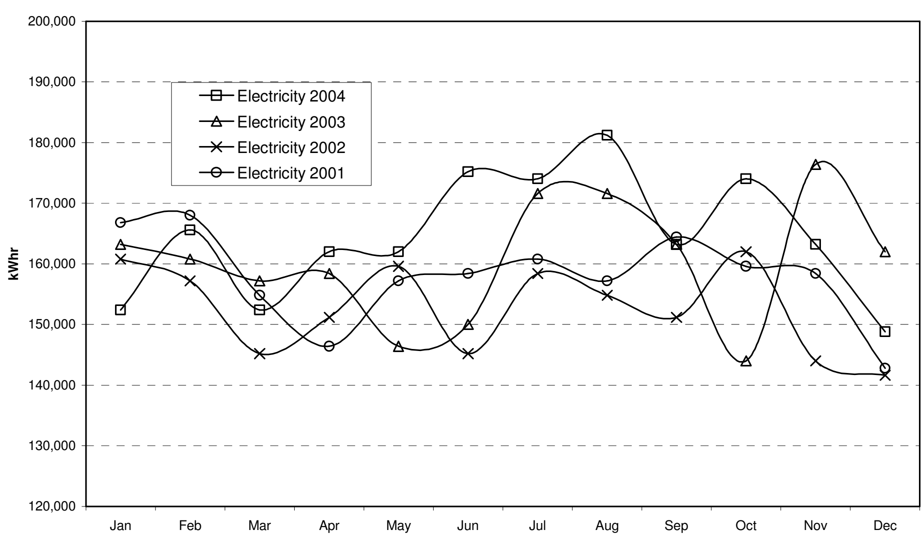

FIGURE 2: JACK DAVIS BUILDING ELECTRICITY CONSUMPTION (2001-2004)

[4] 2002 represents a near average year according to Environment Canada's National Climate Data Archive; for further reference see the heating and cooling degree day graphs included as Appendix B.

As the natural gas is primarily consumed for space heating purposes, it is expected that the consumption will drop during the summer months, revealing the remaining consumption (approximately 50 GJ per month) as being attributable to the service water heating. Similarly, since the cooling load is met using electricity, the peaks during the summer months, particularly apparent for the years 2004 and 2003 which both had unusually warm summers (see Appendix C for cooling degree day comparisons), are attributable to cooling.

3.1 Analysis of Existing Energy Use

Monthly natural gas consumption values normalized for heating degree days (Appendix B) are plotted in Figure 3 for years 2002, 2003, and 2004. The data indicates that while the natural gas consumption in 2002 was as expected (i.e. relatively uniform natural gas consumption per degree day), the 2003 and 2004 consumption figures show significant variations. The reason for these variations is likely the operational problems encountered over this period as a result of modifications made to boiler control as reported by the building's operations supervisor.

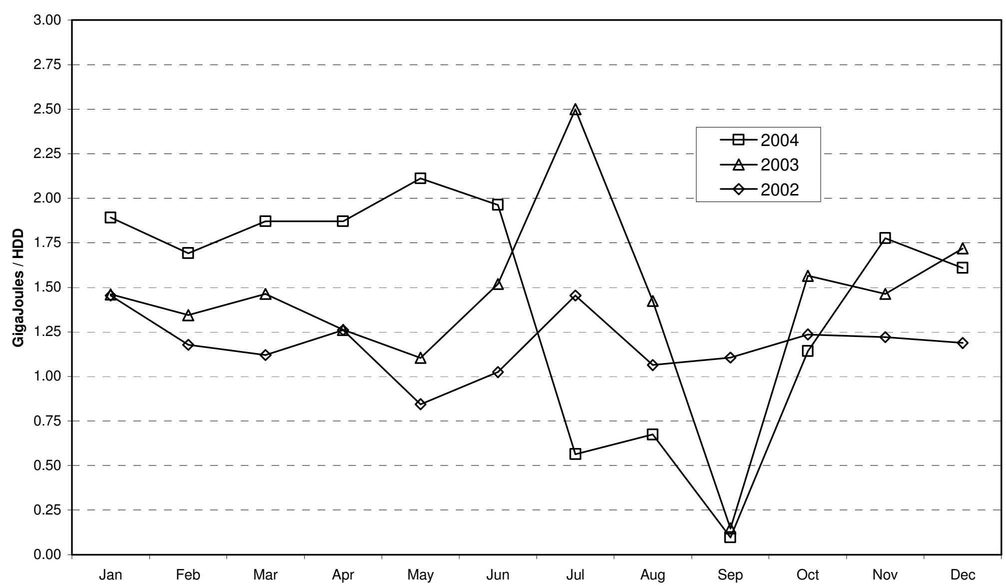

FIGURE 3: NATURAL GAS CONSUMPTION PER HEATING DEGREE DAY (2002-2004)

The monthly peak electrical demand of the building, plotted in Figure 4, shows that peak electrical demands are approximately 400 kW throughout the majority of the year with an increase during the summer months of approximately 125 kW. This difference is attributed to the additional electrical demand placed on the building by the chiller.

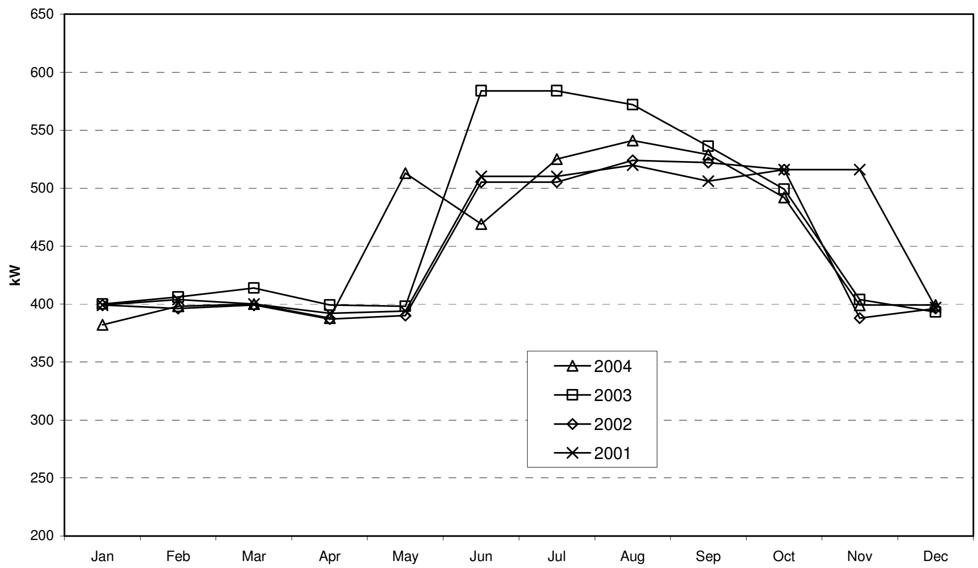

FIGURE 4: MONTHLY PEAK ELECTRICAL DEMAND (2001-2004)

In order to better understand the characteristics of the building's electrical consumption main, lighting, tenant, chiller, elevator and motor loads were monitored and recorded at ten-minute intervals for a week-long study period in late May, 2005. The electrical load profile plots for a two-day period (May 25 to May 26) are shown as Figure 5.

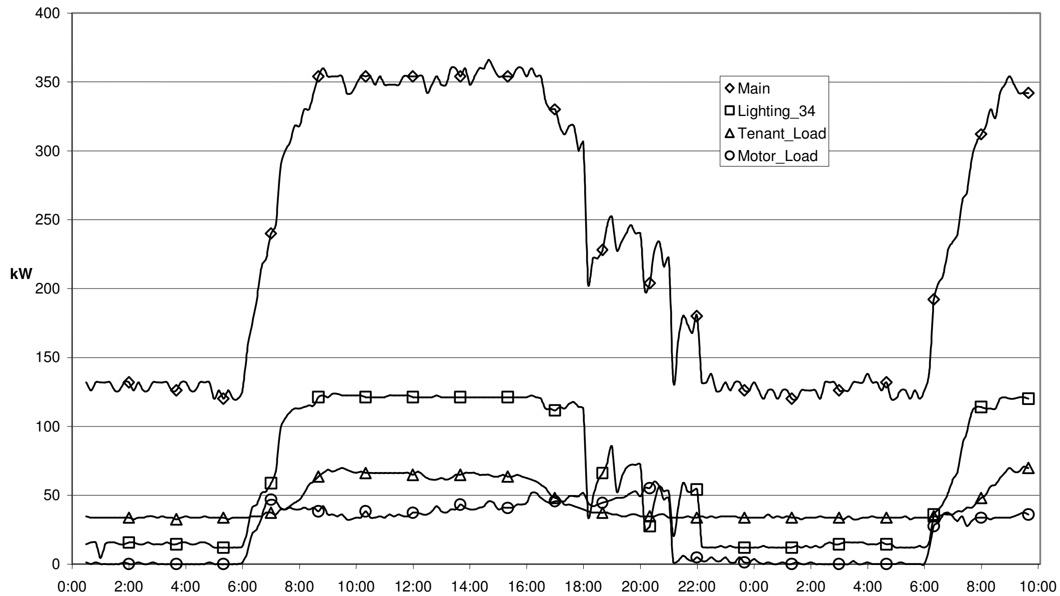

FIGURE 5: ELECTRICITY END-USE LOAD PROFILE
(MAY 25-26, RECORDED AT 10 MIN. INTERVALS)

From the electrical load profiles, several of the building's end-use electrical loads and schedules can be determined or verified. For example:

- the overnight (or base load) of the building is approximately 125 kW,
- the overnight lighting load is approximately 34 kW, 24 percent that of the occupied lighting load (143 kW),
- the tenant load during unoccupied periods (27 kW) is only reduced to 50 percent of the occupied load (53 kW). This could be attributed to workers leaving computers and other office equipment on at night,
- the elevator load is approximately five kW during occupied hours,
- for the study period (late May) the cooling season has not yet begun and therefore the chiller should not be active, the load is zero and therefore verifies this.

It is important to note that these loads, particularly concerning heating/cooling related equipment, are a snapshot of the specified period and are not necessarily constant throughout the year.

3.2 Existing Energy Use Costs

The most recent annual energy costs for the Jack Davis Building, the 2004 calendar year, were $43,550 spent on natural gas and $106,220 on electricity, combining for a total of $149,770 or $11.02/m^2. The combined monthly energy costs are shown in Figure 6.

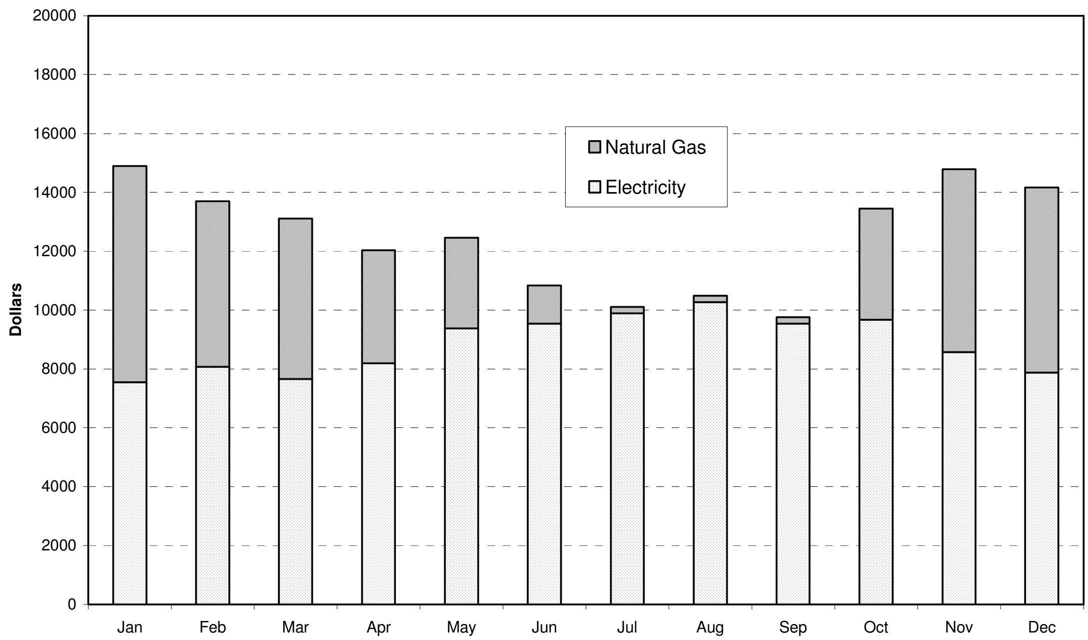

FIGURE 6: COMBINED MONTHLY ENERGY COSTS FOR JDB (2004)

As expected for Victoria's climate, the electricity consumption is slightly elevated during the summer months when the chiller is operating and, during this same period, the natural gas consumption is substantially reduced. The swing in natural gas consumption is due to the inactivity of the boilers during the cooling season, with the only remaining natural gas draw being the service hot water load which is maintained relatively constant all-year round. Overall, the electricity consumption represents over two-thirds of the annual energy cost.

4.0 Building Simulation

A building model was developed to better understand building energy use and to provide a benchmark to which alternative energy design options could be compared. The building simulation program chosen was the EE4 software prepared by Natural Resources Canada. EE4 is an analysis tool that uses the DOE2.1e (v133) simulation engine for compliance checking of the Commercial Buildings Incentive Program (CBIP), but when non-standard operating inputs and schedules are desired, the non-compliance mode can be used for general building simulation purposes. The screening tool provides results on operational energy consumption, cost as well as greenhouse gas emissions.

4.1 Modelling Procedure

To create a building model using EE4 a building tree must be defined, requiring descriptions of the geographical region, building construction, systems and zones, as well as operational schedules and utility rate structures.

The Jack Davis Building model was described by 14 mechanical systems serving 43 thermal zones. Space was configured into thermal zones based on similar heat gain and operational requirements, generally resulting in four perimeter zones (north, east south, and west) and one central zone per level. For each zone, a description of the central heating and cooling systems, heat gains, envelope areas, construction, lighting loads, and equipment performance was entered. A description of the resulting building tree is given as Appendix C.

Since EE4 does not have the capability to simulate the operation of evaporative cooling systems, the predicted energy consumption for cooling was reduced by 25%[5] to reflect the energy savings realized as a result of using evaporative cooling in the Jack Davis Building. As well, a series of electrical loads that were not considered by the model were determined from inventory and operations data, and were included with the final

[5] The 1999 ASHRAE Handbook states that direct evaporative cooling reduces costs by 25 to 40% over mechanical cooling (p. 50.1), for this study the conservative approximation of 25% savings was used.

electrical consumption. These included: elevator loads, fan loads in unconditioned zones, relief fan loads, and exterior lighting loads.

4.2 Modelling Results and Comparison

The resulting simulated energy use is compared to the actual energy use for the Jack Davis Building over an entire year in Table 6.

TABLE 6: COMPARISON OF SIMULATED AND ACTUAL BUILDING ANNUAL ENERGY USE

Energy Source	Simulated (GJ)	Actual (GJ)	% Difference
Electricity	7,671	6,592	+ 16.4 %
Natural Gas	3,396	3,497	- 2.9 %
Combined	11,067	10,089	+ 9.7 %

As the results in Table 6 indicate, the model performs well, over predicting the energy consumption of the building by less than ten percent. Equally as important as the accuracy of the magnitude of the energy consumption is how well the model's profiles match that of the actual building's energy use. The simulated monthly profiles of the natural gas and electricity consumption are considered accurate within acceptable levels. As can be seen in Figures 7 and 8 the actual and predicted monthly energy consumption values present similar profiles. With these results we can be confident that the model provides a sufficiently accurate representation of the Jack Davis Building's operation and energy use.

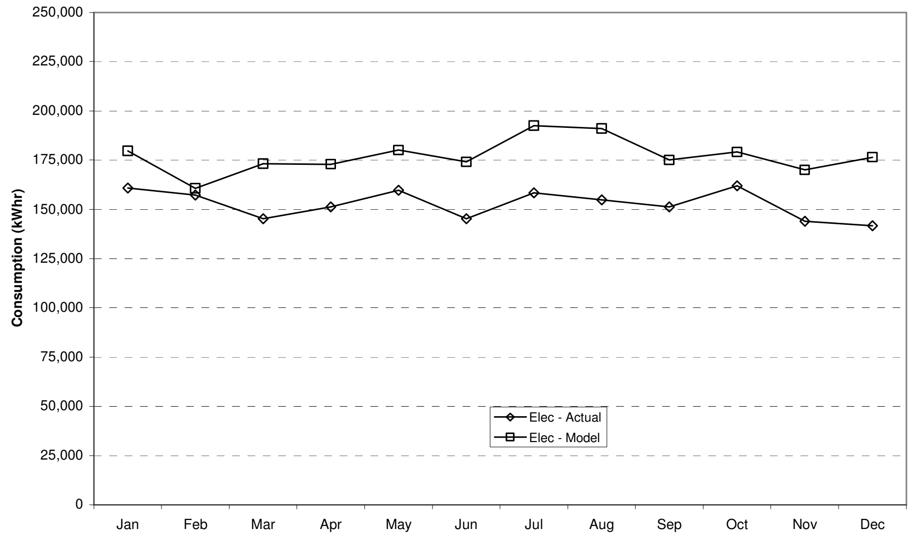

FIGURE 7: COMPARISON OF ELECTRICITY CONSUMPTION: MODEL VS. ACTUAL

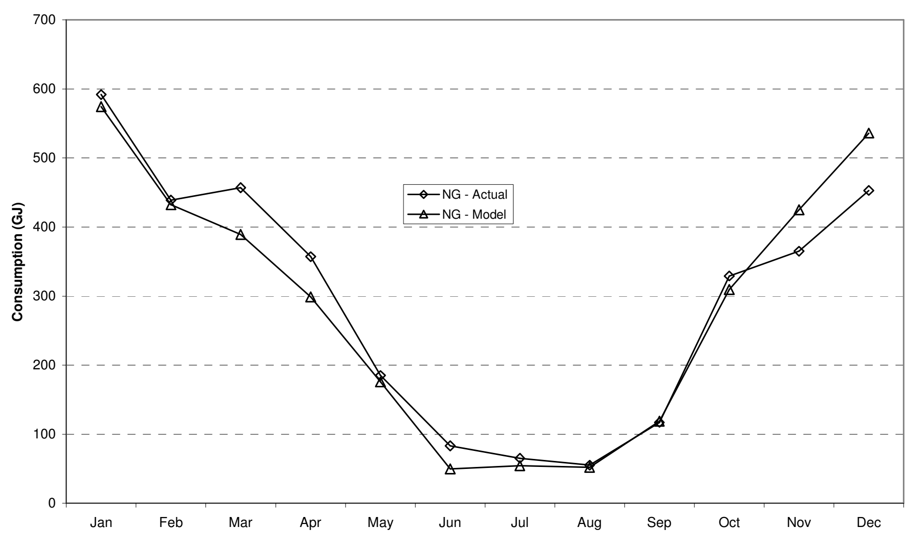

FIGURE 8: COMPARISON OF NATURAL GAS CONSUMPTION: MODEL VS. ACTUAL

The actual energy consumption data from the Jack Davis Building does not allow for the breakdown of energy usage by end-use. An attribute of the EE4 building simulation tool is that it now allows for the loads attributable to various building components to be identified. Figure 9 shows the end-use consumption distribution for electricity consuming loads[6], Figure 10 for natural gas, and finally Figure 11 combines the two for the total power consumption by end-use.

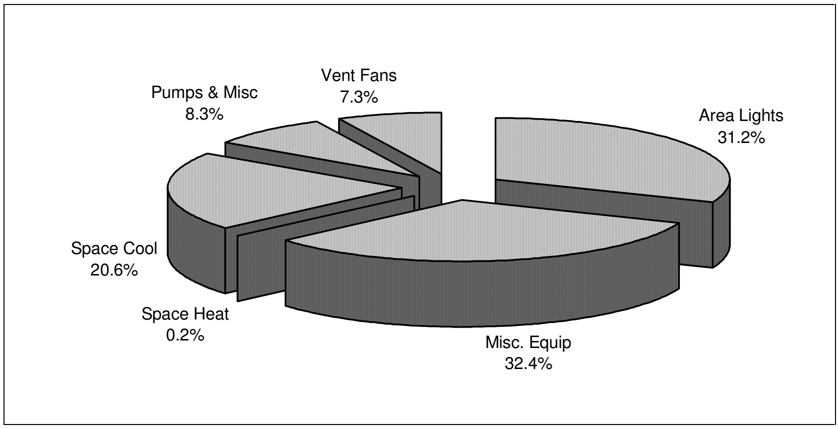

FIGURE 9: SIMULATED ELECTRICITY CONSUMPTION BY END-USE

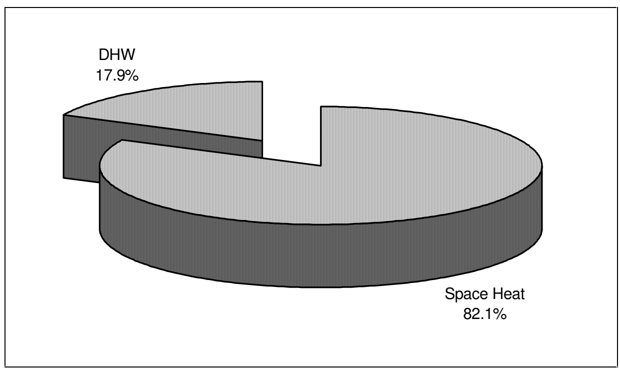

FIGURE 10: SIMULATED NATURAL GAS CONSUMPTION BY END-USE

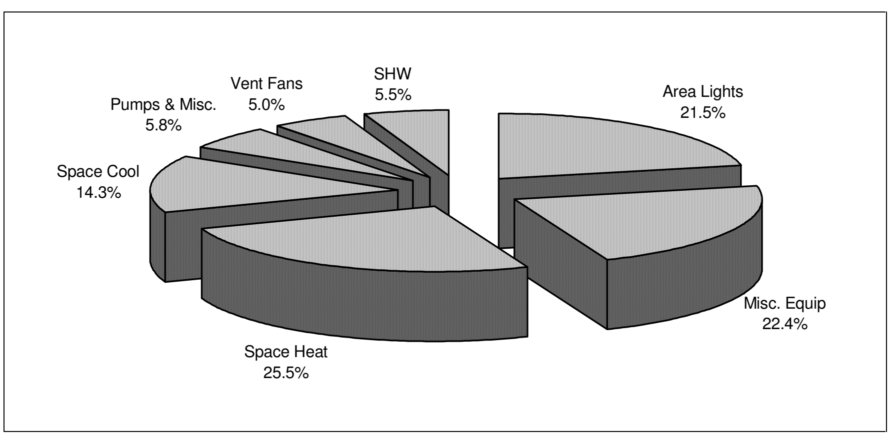

FIGURE 11: SIMULATED POWER CONSUMPTION BY END-USE

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6 Space Cooling includes electrical consumption of cooling equipment as well as heat rejection equipment (i.e. heat pumps & cooling tower).

5.0 Energy Efficiency Options

An investigation to identify energy efficiency opportunities in the Jack Davis Building was conducted. As described previously, consultation with building managers, operators, occupants, and energy specialists led to the identification of a number of potential energy saving modifications to the building's envelope, lighting, HVAC, water, and power generation systems. This section summarizes the result of the audit including the cost and performance of each energy efficiency option.

5.1 Energy Saving Measures

For each energy saving measure the building model was modified to predict the energy and cost savings associated with implementation. The model allowed for a thorough systemic perspective of each proposed measure. For example, replacing an incandescent light bulb with a fluorescent one saves electrical energy, but the reduction in internal heat gain also effects the building's heating and cooling loads, the balance of these factors dictates the merits of the measure. The cost for each measure was estimated using MEANS costing data[7] as well as quotes from local suppliers. In some cases an incremental cost is quoted (only referring to the additional portion of the cost required to update from an existing condition) and in others a full cost quote is provided. The economic merits of each proposed measure was then determined using a simple payback period method. This reflects the number of years it will take, at the determined rate of energy savings, to pay off the initial capital required to implement the measure. The analysis of each of the energy saving measures follows.

5.1.1 Windows with Thermal Break

The current windows adorning the exterior of the Jack Davis Building are aluminum-framed, double-glazed, low-e windows. Aluminum windows are strong, light and durable but the Achilles heal of this type of window design is the heat transfer via the window frame, as aluminum is a very good conductor. The result is a loss of heat to the

[7] 2006 RSMeans Building Construction Cost Data, 64th Edition.

outdoors on cold days and a pathway for heat to enter on hot days requiring increased heating and cooling expenditures to compensate.

Modern aluminum window design has reduced the heat path associated with traditional designs by inserting a “thermal break”. By disrupting the heat transfer pathway by inserting a low conductance material between the exterior and interior of the frame, the U-value for otherwise identical aluminum framed windows has been approximately cut in half (depending on the glass to frame ratio of each window).

As the Jack Davis Building’s current windows are only midway through their 25-year typical life span, it is recommended that modifications be made when the units need replacing (i.e. commonly at time of seal failure). The incremental cost of installing windows with a thermally broken frame is approximately $25 per square metre, translating to an incremental expenditure of $63,700 to replace all existing windows. By implementing this energy saving measure the annual savings in heating and cooling costs have been modelled at 475 GJ or $4,580. Qualifying for the federal Energuide for Existing Buildings (EEB) incentive program contributes another $3,560 towards the project ($7.50 per GJ saved).

Measure: Upgrading existing double-glazed, low-e aluminum windows with advanced units with thermally broken frames.

Annual Cost Savings: $ 4,580

Incremental Cost: $ 60,140

Simple Payback: 13.1 years

5.1.2 Revolving Entrance Door

The main entrance of the Jack Davis Building is a high-traffic area and access to the main lobby is currently accommodated with two swinging doors. An alternative to the swinging door is the revolving door which offers a number of improvements for office buildings, including: reduced infiltration levels (resulting in reduced heating and cooling loads), minimized wind effects on opening pressure, and increased security levels.

A revolving door consists of four “wings” that revolve around a central column. The revolving door, whether in motion or stationary (either in the “x” position or the “+” position), never exposes the conditioned zone completely to the exterior. This configuration allows revolving doors to drastically reduce the amount of outside air introduced into the conditioned zone (typically 2 m^3 per passage opposed to 25 m^3 for swinging doors[8]). Potential energy saving calculations predict that the reduction in infiltration rates for modest rates of traffic[9] lead to savings of approximately $930 per year in reduced energy expenditures (95 GJ reduction in heating and 135 kWh in cooling). The incremental cost of installing a 6’-6” diameter by 6’-10” high revolving door in place of the existing doublewide swinging doors would be approximately $16,350.

Measure: Replace existing doublewide swinging doors of main lobby of Jack Davis Building with a revolving entrance door. **Annual Cost Savings:** $ 930 **Incremental Cost:** $ 16,350 **Simple Payback:** 17.6 years

Alternatively, if it were decided that a revolving door is inappropriate due to accessibility issues (i.e. shipping and receiving), a sliding door would also be affective in reducing infiltration, and thus energy costs. In this case, the implementation of this measure would be reduced to an incremental cost of approximately $5,000. Consequently, the energy saving potential would be greatly reduced as well.

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[8] ASHRAE Fundamentals
[9] Calculations performed for 150 passages per hour, a conservative number for busy office buildings.

5.1.3 T8 Lighting Conversion

At the time of construction of the Jack Davis Building, the lighting system was designed with T12 lighting. Innovations in lighting technology since initial implementation offer further energy savings, namely with the use of energy-efficient T8 lamps.

T8 lamps offer savings in energy consumption of 40% when compared with T12. As well, T8 lighting with low BF (ballast factor) ballasts have a longer life than its T12 counterpart, typically lasting 1.2 to 1.5 times longer, offering further savings in maintenance costs. Additional benefits attributable to T8 lamps are lower start-up and operational noise levels, no flickering, and improved color rendering over T12 lamps.

The overall cost of converting the Jack Davis Building's lighting system from T12 to T8 is in the order of $100,000. To help offset these costs, the BC Hydro's Product Incentive Program (PIP) offers a rebate for each lamp and ballast replaced. Utilizing the PIP rebate for T8 lamps offers savings of $9,500.

Converting to T8 lamps results in lighting energy savings of 171,020 kWh per year (610 GJ/yr), resulting in a cost savings of $8,330 per annum. The reduced internal heat gain associated with lowering the wattage of the lighting system will also affect the overall heating and cooling load of the building. The modification results in a reduction in required cooling energy to the extent of 2,890 kWh/yr (10 GJ/yr), translating to additional savings of $140 per year. The decreased heat gain requires additional heating energy to supplement the loss; therefore, natural gas consumption will increase due to the proposed lighting modification. Heating costs will increase by $1,960 per year (200 GJ/yr) as a result of the reduction in heat gain. Considering the effects on the lighting, cooling, and heating consumptions of the building, the overall savings as a result of converting from T12 to T8 with low BF ballasts is $6,510 per year.

Measure: Replace existing T12 lighting with energy saving T8 lamps with low BF ballasts.

Annual Cost Savings: $ 6,510

Cost: $ 90,500

Simple Payback: 13.9 years

5.1.4 Daylighting Control

Daylighting control refers to the use of light sensing devices to control the amount of artificial light required in an area that receives natural lighting as well. The control over the lighting system can be simple on/off or a gradual dimming.

At the time of construction, the Jack Davis Building was fitted with photocell sensors along the perimeters of floors two through eight. The photocells were connected to the lighting system with overriding on/off control, with the intent of reducing the amount of excess electricity consumed as a result of lighting areas that naturally have sufficient daylighting. As a result of occupant dissatisfaction the sensors were turned off shortly after operation began, never to be revisited.

The problems that led to the disengaging of the daylighting control were: 1) the on/off control was perceived to create a drastic change to lighting levels (most common problem), 2) perceived lack of lighting, and 3) a lack of control over lighting needs. As all of these problems arise from negative occupant perception, it is anticipated that with more inclusive monitoring, the daylighting control could be re-engaged. To reintroduce the daylighting control, it is recommended that a pilot study be performed in which the occupants are educated on the operations and benefits of lighting control. For best results a sample floor should be chosen where the occupants are anticipated to be more receptive to energy reduction measures (i.e. the Alternative Energy Policy Branch of the MEM) and therefore more willing to deal with the slight inconveniences associated with the start up period. With the feedback from this study, it is anticipated that occupants can assist in outlining any operational problems with the daylighting control (i.e. poorly placed photosensors), as well as help define the photosensor set-points that they are most comfortable with.

The rewards of completing a daylighting control study are evident in the potential energy savings associated with reintroducing the existing photosensors. As the lighting consumption in areas with photosensors is typically 30% less than areas without[10], the potential savings for the Jack Davis Building are approximately $650 per year[11]. As the photocells have been active for over ten years, it will also be necessary to re-commission the existing hardware. It is approximated that this will cost $2,000[12].

Measure: Re-introduce daylighting control over perimeter lighting, beginning with a one floor pilot study **Annual Cost Savings:** $ 650 **Cost:** $ 2,000 (Re-commissioning) **Simple Payback:** 3.1 years

It should also be noted that interconnection of the proposed energy saving measures will allow for further detailed energy saving measures. For example, if T8 ballasts were incorporated, the ballasts would then be capable of dimming. If, after the proposed daylighting study is completed, it is found that the occupants are dissatisfied with the on-off operation of the photocells, a dimmer control may be incorporated.

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[10] Lighting Research Centre, www.lrc.rpi.edu/
[11] Savings projection assumes a 30% reduction in perimeter lighting (totaling 32.5 kW) for occupied periods during a typical year (approx 3000 hrs). The projection also considers the inherent change in heating and cooling expenditure incurred due to the loss of internal heat gains associated with turning lights off.
[12] Re-commissioning costs based on the rough figures of 4 sensors/floor, 7 floors, 1 hour/sensor at $60/hour

5.1.5 *Occupant-sensing Lighting Control*

It was determined in the modelling phase of this project that lighting accounts for over 30% of the total electricity consumption of the building. Exploring methods to reduce the lighting load can therefore lead to significant energy savings. One method is to ensure that lights in low-occupancy areas are only on when they are being used. Occupancy sensors connected to the existing lighting system can ensure that the lights are on only when required; if the sensor is not "triggered" within a preset period, the lights will automatically be shut off. Studies on buildings where occupancy sensors have been implemented show that savings on the order of 40% can be expected[13].

Two technologies have emerged for occupancy sensing: passive infrared (PIR) and ultrasonic (US). PIR require a direct line of sight to movement or a heat source and are effective within 15' of the sensor. They are highly resistant to false triggering, do not emit ultrasound or microwaves, can be installed easily by replacing existing switch panels, and are more economical than the ultrasonic varieties. PIR sensors are recommended for small areas but care must be taken to place the sensor appropriately. As they require a direct line of sight to operate effectively, occupant dissatisfaction can easily occur if the sensors are misplaced. PIR sensors with manual override should be considered in the case that occupant dissatisfaction is encountered.

It is recommended that an initial installation of occupancy sensors be implemented in low-traffic areas to preview occupancy satisfaction and savings potential; the building's restrooms are ideal for this scenario. Installation of a PIR sensor will conservatively cost $150 each, this initial cost can be offset by BC Hydro's product incentive program (PIP) that offers a rebate of $12 per sensor. The avoided electrical costs by installing the sensors in all sixteen of the building's restrooms will be approximately 9,725 kWh per year or $470. The reduction in heat gain as a result of reduced lighting loads will result

[13] The Lighting Research Centre performed a 26 case study report on occupancy sensor installations. The result was expected reductions in lighting consumption of 40% (shared space, sporadic use), 30% (shared space, scheduled use) and 25% (private offices, sporadic use) Source: "Overcoming Barriers to Widespread Use of Lighting Controls in Commercial/Industrial Applications – Part 1: Automatic Shut-off Controls".

also in a slight increase to heating costs, this has been predicted to be 2 GJ or $20 per year.

If the initial implementation of occupancy sensors performs as expected, it is recommended that further implementation be pursued. Ideal candidates are shared-use, infrequently occupied locations such as lunchrooms, photocopy rooms, and storerooms. A light logger should be employed to identify the locations with the most illuminated hours during unoccupied periods.

> **Measure:** Install PIR occupant sensors for lighting control in each of the 16 washrooms of the Jack Davis Building.
>
> **Annual Cost Savings:** $ 460
>
> **Cost:** $ 2,210
>
> **Simple Payback:** 4.8 years

5.1.6 Ground Source Heat Pump

Ground source heat pump (GSHP) systems are continually gaining greater acceptance in BC as a replacement to fossil fuel fired heating and cooling systems for commercial buildings. GSHP systems offer significant reductions in energy consumption and greenhouse gas emissions due to their increased COP (commonly offering a heating energy produced to electricity consumed ratio of over three) and a transfer away from fossil fuel combustion technologies.

A ground source heat pump (GSHP) system consists of a ground-loop heat exchanger (GHX) coupled with a heat pump. The low-grade energy supplied by the earth is up-graded by a water-to-water heat pump to a temperature that is suitable for residential heating. The GHX provides a thermal link between the heat pump and the near constant year round temperature of the earth, via a system of buried pipes and a circulating heat transfer fluid. The ground acts as a heat source (during the heating season) or a sink (during the cooling season) to maintain the desired temperature of the conditioned space.

At the Jack Davis Building the space required for a GHX system is limited. The cement pad on the north side of the site (an area of approximately 200 m^2) has been identified as the most promising site available. The limited space requires that a compact vertical borehole GHX system be installed. The site-specific geo-thermal properties are often the defining factor in determining the feasibility of GSHP systems. For this study, general figures were used based on local geology, but if installation of the proposed system is considered, a borehole and in-situ property test are essential to a thorough feasibility study[14].

An initial cost estimate of installing the proposed GSHP system reveals an installed cost of approximately $523,400[15]. It is anticipated that a GSHP system will result in avoided heating and cooling costs of $15,660 per year[16]. The proposed reduction would also qualify the project for $14,090 in Energuide for Existing Building incentive funds ($7.50 per GJ saved). As the proposed GSHP system would act as a combined heating and cooling system, the installation would eliminate the need for some existing equipment (i.e. boilers, chiller, and cooling tower); it is anticipated that the incremental replacement savings would offset an additional amount of $214,200.

Measure: Install GSHP system with vertical borehole heat exchanger to meet building's heating and cooling needs.

Annual Cost Savings: $ 15,660

Incremental Cost: $ 295,150

Simple Payback: 18.8 years

[14] A rough approximation of cost for a basic feasibility test would be in the order of an additional $7,000. This would include soil/hydrology analysis (≈ 60hrs @ $70/hr) and the drilling of two sample bore holes (≈ 105m (x2) @ $12/m). Cost based on RETScreen recommendations and approximations.

[15] Cost based on RETScreen analysis, includes costs for heat pumps, well and circulating pumps, circulating fluid, drilling and grouting, heat exchange loop pipes, system balancing, and contingencies, all designed to meet the building's heating load as described by historical consumption information.

[16] Heating saving projections based on a 2500 GJ reduction in natural gas consumption and 174,060 kWh increase in electrical consumption. Cooling savings are approximately neutral as the current cooling system (evaporative cooler, chiller, and cooling tower) offer similar efficiencies as a heat pump in cooling mode.

5.1.7 High-Efficiency Condensing Boilers

The cornerstone of the heating system in the Jack Davis Building is two 775 kW hot water boilers. In an attempt to save energy, the possibility of replacing the existing hot water boilers with high-efficiency condensing boilers is explored. The existing boilers, operating at 80% thermal efficiency, are in good condition and only mid-way through their lifespan. Retrofitting the existing boiler with condensing units would only be legitimized if the energy savings associated with the high efficiencies of condensing boilers (up to 95%) offset the high initial capital costs.

Condensing boilers use high efficiency heat exchangers to decrease the combustion exhaust temperatures to a point where condensation occurs, increasing overall efficiency by salvaging the latent heat of vaporization that is typically lost out the flue of traditional boilers. Vital to the operation of a condensing boiler is a return water temperature low enough to condense the flue gases, temperatures at or below 50°C are typically sufficient. The existing heating system at the Jack Davis Building returns water from the zone heating coils at temperatures of 80°C. For condensing boilers to be considered with the existing heating system, the return water loop must also be modified in order to reduce returning water temperatures. The costs of this additional modification may be partially offset by utilizing this heat (via a heat exchanger) to preheat the service hot water.

The cost of two condensing boilers[17] is $91,200, the additional costs of implementation and modification of the existing system (removing existing boilers, reducing return water temperatures and providing drainage for condensate) would increase this value to $122,400. The Energuide for Existing Buildings (EEB) incentive provided by the federal government will contribute $7.50 per GJ saved for the retrofit to condensing boilers. This equates to a contribution of $6,320 towards the proposed energy saving measure. It is projected that the increased efficiency of the proposed system would reduce natural gas consumption by 840 GJ per year, saving $8,110 per year on heating costs.

[17] Quote provided for two (2) Fulton Vantage 3,000,000 Btu/hr (761 kW) condensing boilers available in BC through Equipco Ltd. (604-522-5590)

Measure: Replace existing hot water boilers with high-efficiency condensing units. **Annual Cost Savings:** $ 8,110 **Cost:** $ 116,000 **Simple Payback:** 14.3 years

5.1.8 Solar Hot Water Heating

Installing a solar hot water heating system offers the benefit of offsetting natural gas consumption and greenhouse gas emissions currently attributable to the service hot water (SHW) loads of the Jack Davis Building. Modelling results of the Jack Davis Building show that approximately 18 percent of the annual natural gas consumption is attributable to SHW loads[18], resulting in a total of 625 GJ or $6,030 per year.

A solar water heating system consists of a solar collector, a heat exchange loop, hot water storage, a control system, and the associated conduits. The current SHW system location, on the roof of the JDB, makes for easy adaptability to a solar collector system. Thermomax has a proven product that is distributed locally[19] and would be suitable for this application. A suitably sized system consists of two collectors (3 m^2 each), consisting of 30 evacuated-tubes each, mounted to the roof on south-facing brackets with a closed heat-exchange loop circulating glycol fluid to the storage tank.

Previous interest in solar heating by BCBC has made available a used solar water heating system, in excellent condition, from a similar building. As used equipment is not valid for federal funding via the Renewable Energy Deployment Incentive (REDI), the implementation of a new system was also priced for comparison. Removal, transfer, and installation of the existing system would cost approximately $12,540. To purchase and

[18] The EE4 model approximates the hot water consumption of the Jack Davis building based on a typical space function for open-plan office buildings of 90 Watts per occupant.
[19] Thermomax Industries Ltd, Victoria. Contact Information: 250-721-4360 or www.solarthermal.com

install a new system would cost $20,750. The installation of a new system would be eligible for REDI's 25% incentive, reducing the cost to $15,560. It is therefore recommended to proceed with the used solar hot water heating system.

The annual contribution to the SHW load by each Thermomax collector is 3,000 kWh for an installation in Victoria[20]. The two collectors can therefore provide 6,000 kWh/yr (22 GJ/yr) translating into annual cost savings of $210.

Measure: Install Thermomax solar water collector system (complete with mounting, insulation, storage, conduits, and controls) to supplement the existing SHW system on the roof of the Jack Davis Building.

Annual Cost Savings: $ 210

Cost: $ 12,540

Simple Payback: 59.7 years

5.1.9 SHW Tank Insulation

A potential low-cost energy saving measure is the addition of supplemental insulation to service hot water tanks to reduce standby heat losses. The SHW tanks at the Jack Davis Building are particularly susceptible to heat loss, as they are located on the roof in an unconditioned enclosure.

Typical standby losses of gas water heaters are approximately 6.5% of stored capacity per hour[21]. Adding a layer of jacket insulation (typically a min of 2" or 5cm for this application) can reduce standby heat losses by 25 to 40%. Using the conservative estimate of 25%, the overall expenditure on DHW-attributed natural gas for the Jack Davis Building can be reduced by nearly 5% by installing supplemental tank insulation. This equates to annual savings of 30 GJ or $290.

[20] Refer to Thermomax solar collector System Sizing Guide (included as Appendix D)
[21] The input capacity of the installed SHW tanks at the Jack Davis Building is 199,000 Btu/hr or 58 kW.

As mentioned previously, fiberglass insulation is available at low-cost with material expenditures of approximately $20 per tank. As care must be taken when installing jacket insulation to allow for adequate flue ventilation on natural gas-fired DHW tanks, it is recommended that a professional be employed.

> **Measure:** Install two-inch, insulation jackets on existing DHW tanks.
>
> **Annual Cost Savings:** $ 290
>
> **Cost:** $ 150
>
> **Simple Payback:** 0.5 years

5.1.10 Base Electricity Load

Monitoring of electricity use at the Jack Davis Building has revealed that consumption during unoccupied periods, at 125 kW, is abnormally high. Initial metering at the branch level has narrowed the load attribution primarily to lighting and 120V house/plug loads. This information has flagged that over-consumption is occurring, but does not allow for the sources of the excessive consumption to be clearly identified. Collecting electrical consumption information during unoccupied periods at the individual panel level would allow for these sources to be isolated.

To implement this panel-level study would involve employing two electricians for an overnight period to manually collect consumption information from the building's electrical panels. The cost of this measure would be approximately $1,500. Projections show that if modest energy saving measures result from this study (i.e. a 5% reduction in electricity consumption during unoccupied periods) yearly savings of 30,230 kWh or

$990 could be realized[22]. If ambitious savings are projected (i.e. a 25% reduction), avoided costs of 151,130 kWh or $4,940 could be realized.

As the electrical consumption of the Jack Davis building during occupied periods is typical when compared to other buildings, it is anticipated that a significant portion of the energy saving measures identified by this study will not be design or equipment based, but operational in nature. For this reason, it is anticipated that the implementation of such measures (i.e. educating occupants to turn off lights, computers, printers, etc. when not in use) will be low-cost by nature, barring surprises.

Measure: Perform study to identify panel-level electricity consumption during unoccupied periods.

Potential Annual Cost Savings: $ 990 (Modest Savings Scenario, 5%)
$ 4,940 (Ambitious Savings Scenario, 25%)

Cost: $ 1,500

Simple Payback: 1.5 years (Modest Savings Scenario, 5%)
0.3 years (Ambitious Savings Scenario, 25%)

5.1.11 Summer Set-point Temperature

Currently the operative temperature of the Jack Davis Building is maintained at 22°C all year round. It is widely acknowledged in the HVAC industry that the building temperature may be increased in the summer months as a result of the reduced levels of occupant clothing. By maintaining the building at slightly elevated temperatures during the summer months the amount of cooling required can be reduced, without sacrificing occupant comfort, at no significant extra cost.

[22] As the energy saving measures are not yet known, the impact that a reduction in electrical consumption has on other building systems (i.e. the effect of reduced heat gain on heating and cooling requirements) are unpredictable. The actual savings may therefore be increased or decreased based on the findings.

Acceptable ranges of operative temperatures for which occupant comfort is satisfied falls within a range of varying humidity and temperature. For winter months, ASHRAE[23] publishes an acceptable range within 20 to 24°C for conditions common in the Jack Davis Building. For summer months this range is raised to between 22 and 26°C. It is therefore possible to raise the summer set-point temperature from the current setting at 22°C to 24°C without sacrificing occupant comfort. Implementing this proposed energy saving measure will reduce electricity consumption, by reducing both chiller and ventilation fan operation, by 9,250 kWh per year translating into cost savings of $450. To adjust the global set-point temperature of the building would require modest modifications to the building's control programs, anticipated to cost in the order of $600[24].

Measure: Increase the summer set point temperature from 22°C to 24°C.
Annual Cost Savings: $ 450
Cost: $ 600
Simple Payback: 1.3 years

5.1.12 Computer Monitors

Liquid Crystal Display (LCD) monitors offer a number of savings over the traditional Cathode Ray Tube (CRT) computer monitor. The primary saving is power consumption, as the LCD monitor consumes one-third the energy of a CRT monitor with equivalent screen size. Other benefits of switching to LCD monitors include: a longer life span (double that of a CRT monitor), space savings (LCD typically consume 75% less desk space), and health benefits (LCD are flicker free, anti-glare and produce no electromagnetic radiation). Associated drawbacks with the conversion to LCD monitors are: initial cost (LCD monitors are still significantly higher than the established CRT

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[23] ASHRAE Fundamentals, Section 8.19 "Acceptable Ranges of Operative Temperature and Humidity for Persons Clothed in Typical Summer and Winter Clothing, at Light, Mainly Sedentary, Activity"
[24] Cost estimate provided by WSI, building system operators of the Jack Davis Building.

monitors) and the increased heating load resulting from reduced internal gains. This last factor is often not considered with LCD analysis, but can have significant effects on operational costs, particularly in northern climates where the heating load far exceeds the annual cooling load.

An inventory of the Jack Davis Building performed for this study yielded a current total of 502 monitors. Of these monitors, those operated by the provincial ministries are currently slated for renewal as they are nearing the end of their lifespan. To replace each of these monitors with LCDs would require an additional expenditure of approximately $51,700. The reduction in electrical consumption associated with this modification would be 106,140 kWh per year, resulting in a cost savings of $5,240 per annum. As well, the coinciding alteration to the internal heat gain levels within the building results in a reduction in cooling energy requirements of 1,410 kWh ($70 per year) and an increase in heating energy requirements of 120 GJ ($1,140 per year). The net savings as a result of implementing this energy saving measure is thus approximately $4,100 per year.

Measure: Replace all existing CRT monitors in the building (totaling 502) with LCD monitors at time of renewal.

Annual Cost Savings: $ 4,100 (if current computer use schedule maintained)

Incremental Cost: $ 51,700

Simple Payback: 12.6 years

5.1.13 Communication Strategy

It has been apparent throughout this project that the success of many of the energy saving measures rely heavily on a high level of communication with the occupants of the Jack Davis Building. Many of the measures requires an initial level of tolerance by occupants as well as an increased level of understanding in how the technology works and what the intentions are for its implementation.

For operational measures such as daylighting control, occupancy sensors, set point temperature, and reduced occupant-driven electrical consumption it is recommended that a communication strategy with those directly affected accompany the implementation. Some key issues to a successful communication strategy are:

- *Relevancy*: knowing how the project impacts the occupants is essential for promoting motivation,
- *Transparency*: share goals and results to promote inclusion,
- *Accessibility*: have a clear leader who is approachable and provides a protocol for communication,
- *Simplicity*: keep the message simple, face-to-face meetings and memos with a few clear bullets will make message easy to digest and avoid confusion.

5.2 Energy Showcase Opportunities

The intent of this project was twofold, to identify potential energy saving measures to reduce the amount of energy consumed by the Jack Davis Building, and also to identify measures that may not fit into the project payback limitations of the British Columbia Buildings Corporation but can lead the building towards the designation of a zero-net emitter. The latter measures are discussed here and are designated as energy showcase opportunities.

The following energy saving measures all have simple payback periods beyond 25 years. This does not necessarily declare these projects as unfit to pursue as the simple payback strategy does not consider many factors (i.e. reduced maintenance costs, reduced emissions, security through independent generation) and therefore, does not promote renewable energy projects in the most enticing manner. For this reason, the proposed energy showcase opportunities are presented in a format that emphasizes benefits and potential drawbacks (without simple paybacks) leaving the decision making process open to dynamic factors such as increasing fossil fuel costs, energy security, and emission reduction strategies.

5.2.1 Green Roof

Green roofs, or living roofs, are organic building elements designed to enhance the performance of buildings and the satisfaction of occupants. Green roofs are already common in Europe and are continually gaining acceptance in North America. Adding vegetation to the roof cover of a building offers a number of benefits, including: greatly increased roof membrane longevity (i.e. two to three times), decreased heat loss, reduced stormwater run-off, stormwater filtration, moderation of temperatures associated with the urban heat island effect, sound insulation, air cleaning, as well as general aesthetic pleasure for occupants and adjacent buildings.

The green roof consists of a several layers of construction. Initially, a high quality water proofing and root repellant layer carpets the existing roof and is then covered by a drainage system and filter cloth. The next layer is the growing medium (soil), which consists of lightweight substrates specifically designed for the application, and then the plant cover. Plant selection varies depending on climate and desired maintenance; some possibilities include indigenous grasses, herbs, and shrubs. There are two predominant types of green roofs, extensive and intensive. Consisting of similar layer construction the difference between the two is that extensive installations have minimal irrigation and thin soil beds resulting in saturated increased roof loads of only 70 to 170 kg per m^2. Intensive green roofs have deep soil beds (more favourable for plant growth) and irrigation systems resulting in an installed, saturated weight of 280 to 970 kg per m^2.

Canadian buildings with similar characteristics to the JDB have verified the savings potential of green roofs. Monitoring of installed green roofs have yielded reduced heat gains of 95% and heat losses of 26% through the roof as a result of installing a 6" (15 cm) vegetative cover. If installed on the available roof space of the JDB[25] the increased insular qualities alone would account for savings of $130 (15 GJ) per year.

A survey of similar installations has resulted in an installed cost of $125 per square metre[26] of green roofing. This would result in a total expenditure of $106,000 for a green roof covering all available area at the Jack Davis Building. As this price qualifies this energy saving measure as a "concept item" the value of doubling roof life and the intrinsic values associated with greening the working environment must be considered heavily before proceeding[27].

5.2.2 Photovoltaic Electricity Generation

Generating electricity on-site at the Jack Davis Building using photovoltaic (PV) panels would allow the building to achieve a degree of energy independence. Although the technology behind PV electricity generation is proven, its place in the competitive electricity generation market is still developing. Installing PV panels on the roof of the Jack Davis Building provides the opportunity to support renewable energy generation and offset greenhouse gas emissions, in a highly visible manner, while providing a dependable power supply with energy pricing security in the eye of a volatile energy market.

At the heart of a PV system is a network of solar panels, each comprised of an array of electricity generating PV cells. The electricity produced is of the DC variety and, therefore, an inverter is required to convert the electricity to AC power, as used throughout the building. The proposed system has been designed and can be installed by

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[25] Excluding roof area occupied by walkways and equipment rooms, the available roof space on the Jack Davis Building is approximately 850 m^2.

[26] "Design Guidelines for Green Roofs", Peck, S. & M. Kuhn, Canadian Mortgage and Housing Corporation (CMHC) Research Publication, available at http://www.cmhc-schl.gc.ca

[27] It must be noted that a structural study was not performed to determine whether or not the roof of the JDB was capable of supporting the additional weight of a green roof, in order to proceed, a detailed structural assessment must be performed.

a local supplier[28], and will provide 10 kW of electricity. This will contribute 12,400 kWh of electricity to the building over a typical year, displacing $605 in electricity costs. The system will be grid-tied, meaning that no on-site storage is required as the existing electricity grid will be used in the case that there is either an excess or deficiency of electricity to the building[29]. The current net-metering policy of the utility, BC Hydro, allows for excess electricity to be absorbed by the grid and the producer is given a credit to offset the purchasing of equivalent quantities of electricity[30].

The cost of installing a 10 kW PV system (including panels, stand, inverter, controls, and grid tie) will be approximately $ 120,000. This initial cost will be slightly reduced through incentives available through the Energuide for Existing Buildings (EEB) program. At $7.50 per avoided GJ, the incentive will contribute $340 towards the proposed energy saving measure.

5.2.3 Wind Turbine Electricity Generation

Utilizing turbines to harvest the energy of the wind has become the most cost-effective method of producing renewable electricity. The cost-effectiveness of small wind turbines (10 kW to 300 kW) has been proven in off-grid and rural applications, but is still in the initial market stages for urban use[31].

The opportunity for clean energy generation presented by small wind turbines is offset by a number of hurdles for urban settings. The inhibitors to widespread use include: turbulent winds due to complex topologies and wind shadows from other buildings/structures, noise and aesthetic issues, as well as a lack of developed municipal policies surrounding rooftop installations.

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[28] SPS/Carmanah of Victoria, www.spsenergy.com
[29] As the proposed PV system has only been designed to contribute a small fraction of the building's base electricity load (less than 10%), it is rarely expected that the grid will be required for storage.
[30] See BC Hydro Net Metering Service, Schedule 1289 for further details. Available at http://www.bchydro.com/info/ipp/ipp8842.html
[31] In Canada, the University of Toronto and True-North Power Systems are undertaking a joint pilot study on urban renewables exploring the feasibility of personal sized, inner city "urbines". Details available at www.truenorthpower.com

The general rule-of-thumb for wind turbine installation is that a minimum mean wind speed of 8 m/s is required. Initial investigations reveal that the mean wind speed in Victoria is 4 m/s[32]. As urban wind flows are particularly difficult to predict, it is recommended that further study by completed to determine a site-specific wind speed. Installation of a wind anemometer would provide useful information for little cost, as a wind monitor is already in the possession of the Alternative Energy Policy branch and ready for installation.

If a small wind turbine installation is deemed feasible, based on further wind speed analysis, initial calculations show that a 50 kW[33] wind turbine would cost approximately $165,000 and contribute 37,500 kWh of electricity per year[34]. This would result in annual cost savings of $1,830.

5.2.4 Fuel Cell Electricity Production with Cogeneration

Solid oxide fuel cells (SOFC), overlooked for transportation applications due to high operating temperatures[35], show great potential for meeting the electrical and heating (using cogeneration) requirements of buildings. Fuel cell combined heat and power (CHP) systems offer excellent emissions reductions and part load efficiencies with favourable thermal to electric ratios and low maintenance, but are still hampered by high costs and short life-spans. Availability of commercially viable products is limited, as stationary power production using fuel cells is still an emerging market. Several companies have small units (1 to 5 kW) aimed at the residential sector that are nearing market availability, but large fuel cells for stationary electricity generation are still in the developmental stages.

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[32] General information for Victoria determined using Environment Canada's Wind Energy Atlas (www.windatlas.ca).
[33] A 50 kW system is the maximum generation allowed under the current BC Hydro net-metering policy.
[34] Electricity generation calculated for mean wind speeds of 4 m/s, if local wind speeds were discovered to be greater than this, generation values would increase.
[35] SOFC exhaust gas temperatures can be in excess of 800°C.

As SOFC fuel cells are not capable of being regularly turned on and off due to the material effects of drastic thermal cycling, it is recommended that they be operated at all times. It is therefore recommended to size SOFC electrical generators to meet the base electrical load of the building, for the Jack Davis Building this would be approximately 125 kW. A suitable SOFC generator[36], operating on pipeline natural gas, is currently being field tested and has been shown to provide 125 kW of electrical power at 45% efficiency and 100 kW of thermal power at 40% electricity (for a combined efficiency of 85%). An initial cost analysis was performed to show the potential feasibility of such units for the Jack Davis Building once the technology has matured.

The early adoption cost of SOFC systems is being approximated at $5,000 per kW. Installation of a 125 kW SOFC cogeneration system at the Jack Davis Building would therefore cost approximately $650,000. Initial calculations reveal that with the system running year round, the electrical and heating contributions to the building's energy supply (1,095,000 kWh and 3,900 GJ respectively) would offset costs of approximately $90,000 per year[37]. Unfortunately, the lack of information that surrounds fuel cells in their testing stages restricts predictions of the fuel (NG) consumption required of the SOFC system. It is expected that this cost will offset the savings significantly if not eclipse them.

5.2.5 Biodiesel-fueled Electricity Production with Cogeneration

The Jack Davis Building is equipped with a 350 kW diesel generator situated in a parking-level enclosure and supplied with a 2,500 litre belowground storage tank. The generator acts as an emergency backup and is currently operated for only 20 hours per year for maintenance purposes. The availability of an on-site generator provides a unique opportunity for distributed generation of electricity and therefore a study was performed

[36] Siemens Westinghouse model SFC-200. Further information available at http://www.powergeneration.siemens.com/en/fuelcells/commercialization/index.cfm

[37] Savings will depend heavily on the operating scenario chosen for the fuel cell cogen system (i.e. electrical or thermal load following).

to increase operation of the generator using a renewable fuel source (biodiesel) and capturing waste heat to offset heating costs in a cogeneration arrangement.

Biodiesel can be used blended with petroleum-based diesel (B20, a twenty percent biodiesel blend is common) or used in its pure form or "neat". Biodiesel can be substituted for common diesel in most engines with little or no cost and provides a number of benefits, including increased safety (biodiesel is considered a non-hazardous/ non-flammable material for transport and storage and biodegrades 5 times faster than petroleum) and reduced emissions over conventional #2 diesel.

The following study examined the feasibility of running the existing Kohler generator, modified for cogeneration via a preheat heat exchange with the building's hydronic heating system, to meet 10 percent of the Jack Davis building's electrical consumption. Under this scenario the cogen/biodiesel system will offset 180,000 kWh of purchased electricity and 590 GJ of hot water heating requirements resulting in an annual savings of $14,480. Operation of the generator for 730 hrs will result in the consumption of 61,700 litres of biodiesel (B20) resulting in an annual cost of $58,600[38].

It can be seen with this study that the operational costs outweigh the operational savings of the cogen/biodiesel system (the system will never pay itself back). As the on-site natural gas heating system and the purchased hydro-electricity are both relatively clean and inexpensive energy sources the implementation of a cogen/biodiesel system would not be economically feasible.

[38] As British Columbia does not have any commercial scale biodiesel production, the gas must be imported from out of province. The Vancouver Island Biodiesel Evaluation Study completed in September 2005 by Wise Energy (www.vibesproject.ca) quotes per litre prices of $0.95 for B20 and $1.10 for B100.

6.0 Summary and Conclusions

Table 7 offers a complete list of the energy saving measures investigated for this study.

TABLE 7: ENERGY SAVING MEASURES

Energy Saving Measure	**Total Energy Savings (GJ/yr)**	**Cost ($)**	**Savings ($/yr)**	**Simple Payback (yr)**
Windows with thermal break	475	60,140	4,580	13.1
Revolving entrance door	96	16,350	930	17.6
T8 lighting conversion	423	90,500	6,510	13.9
Daylighting control	75	2,000	650	3.1
Occupant-sensing lighting control	32	2,210	460	4.8
Ground source heat pump	1878	295,150	15,660	18.8
High-efficiency condensing boilers	842	116,000	8,110	14.3
Solar hot water heating	22	12,540	210	59.7
SHW tank insulation	30	150	290	0.5
Base electricity load	109 to 544	1,500	990 to 4,940	1.5 to 0.3
Summer set-point temperature	33	600	450	1.3
Computer monitors	269	51,700	4,100	12.6

The analysis of the proposed energy saving measures revealed that significant energy savings are possible. Determining which measures to implement depends on one of two criteria: the simple payback of the measure or the avoided energy consumption. Table 8 shows the cost and energy savings potential of three scenarios proposed as selection criteria for measure implementation: all measures with a payback of under ten, fifteen, or twenty years.

TABLE 8: THREE SCENARIOS FOR IMPLEMENTATION OF ENERGY SAVING MEASURES

Selection criteria:	**Combined Cost ($)**	**Combined Savings ($/yr)**	**Combined Simple Payback Period (yr)**	**Combined Energy Savings (GJ)**
Simple payback under 10 years	6,460	2,840	2.3	279
Simple payback under 15 years	324,800	26,140	12.4	2,288
Simple payback under 20 years	636,300	42,730	14.9	4,262

It can be seen from Table 8 that the energy saving measures with a payback period under ten years do not result in a large amount of energy savings. The reason for this is that the design of the Jack Davis Building was, and still is, very energy efficient. Forward thinking design won the building accolades upon inception, and the effects of the energy-efficient design are still being realized. For this reason, the possibility of further energy savings of great significance will require a considerable investment of time (for financial payback) and money.

If implemented, the energy saving measures outlined in this report will result in the lowering of the building's annual energy consumption. Reducing the base load is of vital importance in the quest for a zero emission building, as the final gigajoules towards energy independence can be very costly. This can be seen in the study of energy showcase opportunities identified in Section 5.2.

As well, consideration of the present value of money versus the future cost of implementation may reveal more favourable payback periods than are projected with the simple payback period criteria. The costs and projected payback periods of the energy showcase opportunities will vary with time depending on a number of dynamic factors: diminishing life span of the existing equipment, technological advances, and the ever-increasing cost of energy. Measures that do not appear feasible at the present time should be monitored, as changing circumstances will continually offer new opportunities for energy efficiency.

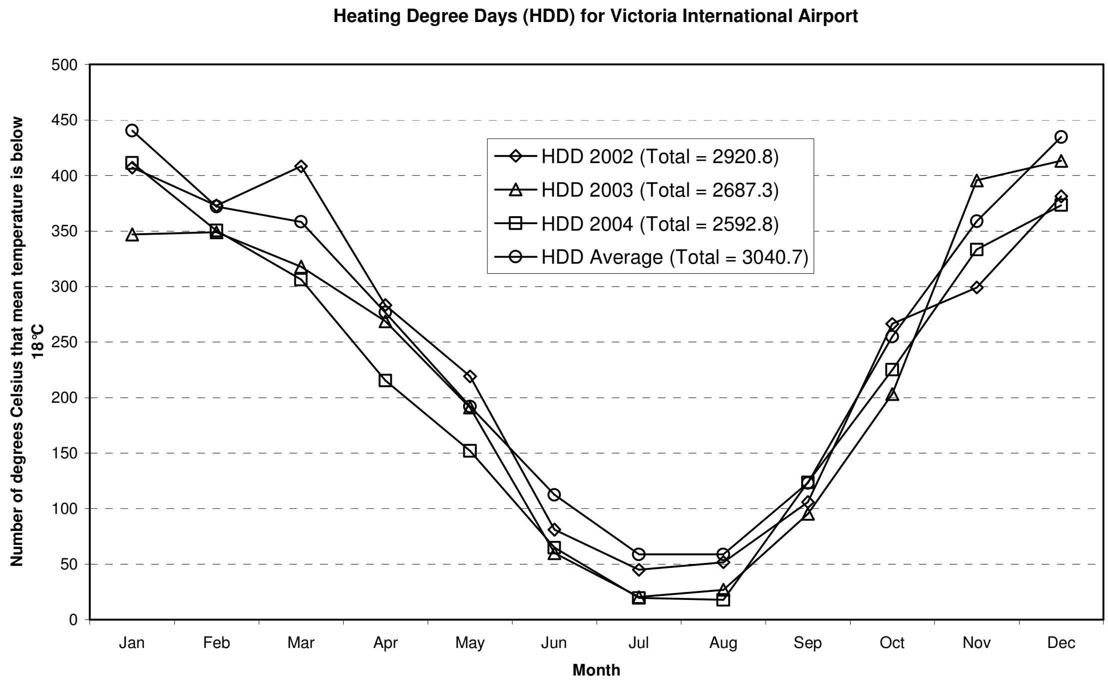
List of Appendices

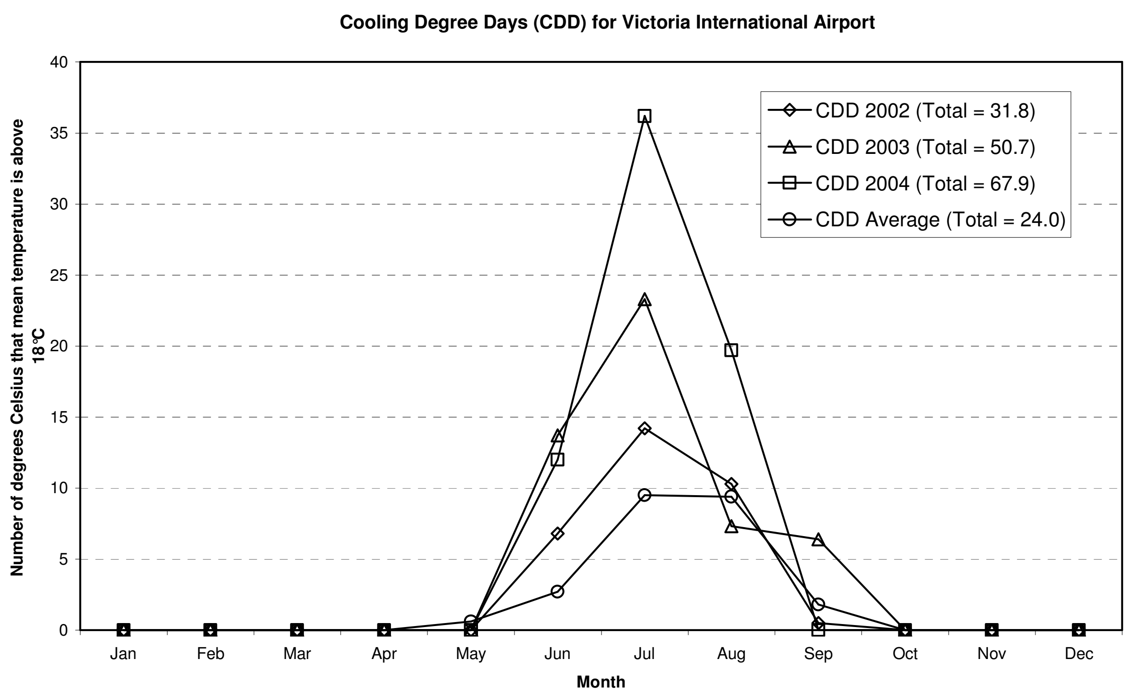
Appendix A: Office Equipment Heat Gain Inventory

Office Equipment					
Device	**Size**	**Operation**	**Heat Gain (W/unit)**	**Total # Units**	**Total Heat Gain (W)**
Laptop Computer		Continuous	65	0	0
Desktop Computer		Continuous	65	490	31850
Computer Monitor (Liquid Crystal Display)	Small (13" - 15")	Continuous	55	0	0
Computer Monitor - LCD	Small (13" - 15")	Energy Saver		0	0
Computer Monitor - LCD	Medium (16" - 18")	Continuous		0	0
Computer Monitor - LCD	Medium (16" - 18")	Energy Saver		0	0
Computer Monitor - LCD	Large (19" - 20")	Continuous		0	0
Computer Monitor - LCD	Large (19" - 20")	Energy Saver		0	0
Computer Monitor (Cathode Ray Tube)	Small (13" - 15")	Continuous	55	17	935
Computer Monitor (CRT)	Small (13" - 15")	Energy Saver	0	0	0
Computer Monitor (CRT)	Medium (16" - 18")	Continuous	70	203	14210
Computer Monitor (CRT)	Medium (16" - 18")	Energy Saver	0	0	0
Computer Monitor (CRT)	Large (19" - 20")	Continuous	80	282	22560
Computer Monitor (CRT)	Large (19" - 20")	Energy Saver	0	0	0
Desktop Light				0	0
Laser Printer	Small Desktop	Continuous	130	0	0
Laser Printer	Small Desktop	1 page per min.	75	88	6600
Laser Printer	Small Desktop	Idle	10	0	0
Laser Printer	Desktop	Continuous	215	0	0
Laser Printer	Desktop	1 page per min.	100	65	6500
Laser Printer	Desktop	Idle	35	0	0
Laser Printer	Small Office	Continuous	320	0	0
Laser Printer	Small Office	1 page per min.	160	10	1600
Laser Printer	Small Office	Idle	70	0	0
Laser Printer	Large Office	Continuous	550	0	0
Laser Printer	Large Office	1 page per min.	275	15	4125
Laser Printer	Large Office	Idle	125	0	0
Photocopier	Desktop	Continuous	400	0	0
Photocopier	Dektop	1 page per min.	85	6	510
Photocopier	Desktop	Idle	20	0	0
Photocopier	Office	Continuous	1100	0	0
Photocopier	Office	1 page per min.	400	8	3200
Photocopier	Office	Idle	300	0	0
Facsimile Machine	Desktop	Continuous	30	21	630
Facsimile Machine	Desktop	Idle	15	1	15
Image Scanner	Desktop	Continuous	25	0	0
Image Scanner	Desktop	Idle	15	0	0
Coffee Maker	small		295	14	4130
Vending Machine	indoor/outdoor, Dixie Narco	continuous	290	1	290
Microwave Oven	small	1/2 hr per day	14	10	140
Microwave Oven	large	1/2 hr per day		0	0

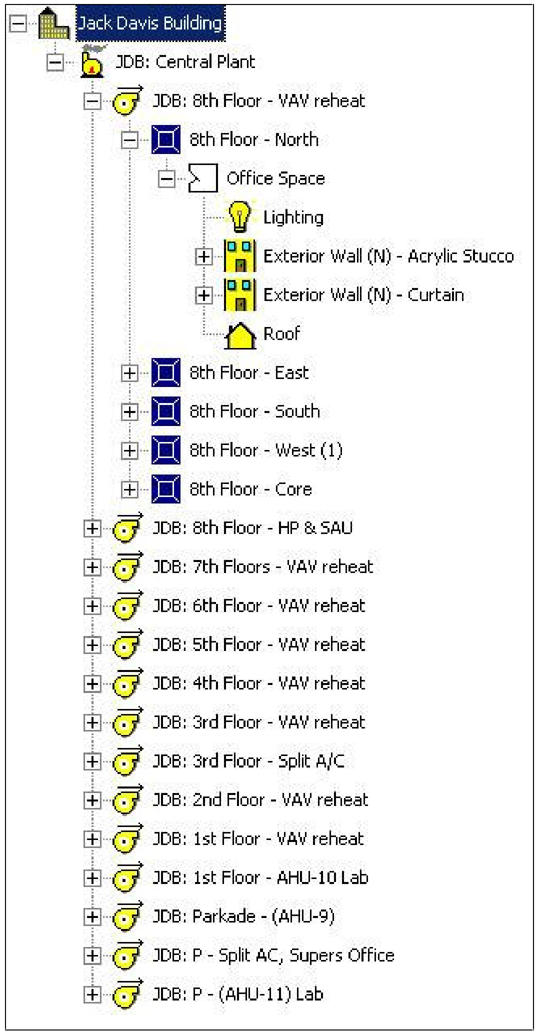
Refrigerator	small (bar, one door, no freezer)	continuous	40	1	40
Refrigerator	Medium (2 door, top freezer)	continuous	78	2	156
Refrigerator	Full Size (2 door, top freezer)	continuous	164	13	2132
Toaster	small, 2 slice	1/2 hr per day	12	2	24
				TOTAL (kW)	**99.647**

Appendix B: Heating and Cooling Degree Days for Victoria International Airport





Appendix C: EE4 Building Tree: Jack Davis Building



Appendix D: Thermomax Solar Collector System Sizing Guide

THERMOMAX
SOLAR COLLECTORS

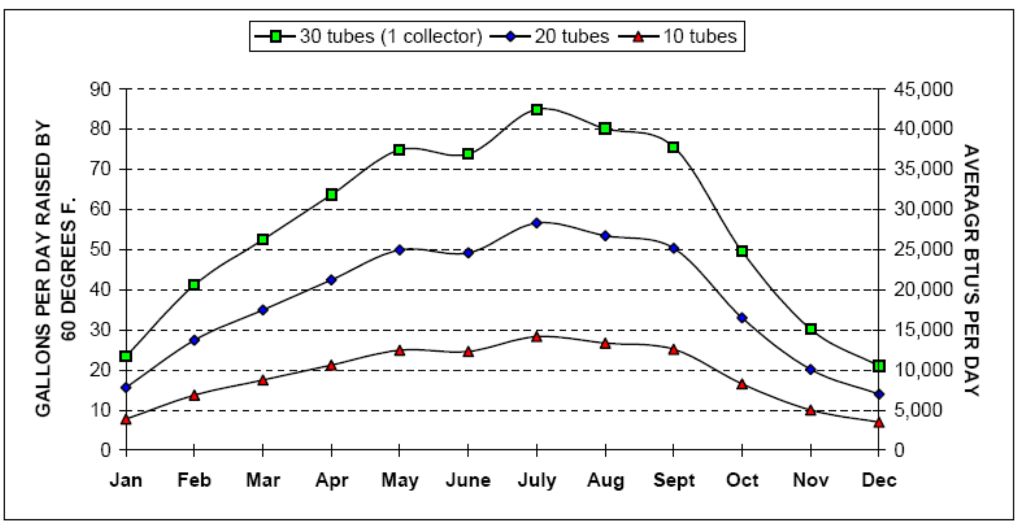
Victoria, BC

System Sizing Guide

Latitude:	49 Degrees
System Tilt	49 Degrees
Orientation	180 Degrees

	Mean daily Radiation *		Average Daily Thermomax Output ** BTU's and US Gallons heated by 60F					
	MJ/ sq.m	BTU/ sq.m	10 Tubes 1 square meter		20 Tube Collector 2 square meters		30 Tube Collector 3 square meters	
			BTU	Gallons	BTU	Gallons	BTU	Gallons
Jan	5.886	5,583	3,908	8	7,816	16	11,724	23
Feb	10.335	9,803	6,862	14	13,724	27	20,586	41
Mar	13.180	12,501	8,751	18	17,502	35	26,253	53
Apr	15.991	15,167	10,617	21	21,234	42	31,852	64
May	18.802	17,834	12,484	25	24,967	50	37,451	75
June	18.542	17,587	12,311	25	24,622	49	36,933	74
July	21.339	20,240	14,168	28	28,336	57	42,504	85
Aug	20.129	19,092	13,365	27	26,729	53	40,094	80
Sept	18.983	18,005	12,604	25	25,208	50	37,811	76
Oct	12.450	11,809	8,266	17	16,532	33	24,799	50
Nov	7.574	7,184	5,029	10	10,058	20	15,086	30
Dec	5.270	4,999	3,499	7	6,998	14	10,497	21
Annual Mean	14.054	13,330	9,331	19	18,662	37	27,993	56
Annual Totals BTU		4,866,579	3,406,605	6,813	6,813,211	13,626	10,219,816	**20,440**
					Gallons Heated in 25 years			**510,991**

* Radiation figures from "Solar Radiation Data Analysis for Canada 1967-1976"
** Collector efficiency 70% of average daily radiation.



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