DEVELOPMENT OF GENERIC OFFICE BUILDING ENERGY MEASURES

Final Report

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1. INTRODUCTION

1.1 Background

Public Works and Government Services Canada have expressed an interest in developing energy efficiency and renewable energy guidelines applicable to office building projects. The objective of the guideline development would be to illustrate what could be done to reduce energy use in PWGSC buildings by as much as 60 to 70%.

1.2 Objective and Scope

The objective of this project was to illustrate what could be done, and at what cost, to reduce energy use, in new small and large office buildings as much as 60 to 70% compared to the Model National Energy Code for Buildings, 1997 (MNECB).

The scope of the work was to involve:

- selecting appropriate office building models to represent both small and large buildings;
- constructing DOE 2.1 E model representations for the base cases to be in accordance with the MNECB;
- identifying energy measures which would need to be implemented in the base case to achieve energy savings;
- analyzing the energy and economic performance of the energy measures applied one at a time to the base cases;
- rank-ordering the measure results by simple payback period and selecting groups of measures (i.e. measure sets) with lower payback periods, with the intent of saving anywhere from 25% to 60% of the base case energy use.
- modelling the measure sets, applied to the model buildings, again using DOE 2.1 E, and calculating the life cycle costs associated with each case;
- draw conclusions and recommendations, based on the results, on how PWGSC should proceed to implement the reports findings;
- prepare a separate Guideline targetted to decision makers in Public Works which lays out the results of the investigation.

2. DESCRIPTIONS OF THE MODEL BUILDINGS, BASE CASE ENERGY CRITERIA, ENERGY MEASURES

2.1 The Model Buildings

Two generic office building models, one 45,000 ft.^{2}, the other 260,000 ft.^{2} were employed in this study. The two buildings provide different opportunities to significantly reduce energy use. Table 2.1 summarizes detail for these two model buildings and the applicable energy criteria in accordance with the Model National Energy Code for Buildings (MNECB). These buildings were the base cases to which all subsequent design modifications to the buildings were compared.

2.2 MNECB Energy Criteria for Base Case Buildings

2.3 Energy Measures

The following measures were initially considered for application to the model buildings, in one or more of the cases, in subsequent modelling:

- perimeter daylighting in the large office;
- energy efficient fans, pumps and motors;
- variable speed pumps;
- displacement ventilation (100% OD air) with heat recovery and radiant heating/cooling panels;
- ground-source heat pump system in the large office;
- solar wall integrated into architecture of model building (ventilation air pre-heat);
- photovoltaics for power supply;
- solar thermal service water heating;
- microturbine for power generation with heat recovery;
- energy efficiency measures for elevators;
- office equipment with very low idle power use/smart controls;
- occupancy sensors on lighting;
- automatic solar shading;
- demand ventilation (CO_2 control) perhaps in combination with garden plants for CO_2 control;
- passive solar shading;
- water-source heat pump thermal storage in the small office.

DOE 2.1E does not model solar technologies. We used Watsun PV for the purpose of PV modelling. The DOE 2.1E weather file provided hour-by-hour values for solar radiation, temperature and wind speed which was converted by a utility program to a Watsun PV input file. Watsun PV then provided the electrical output from the PV array on an hour-by-hour basis. This was then combined in an EXCEL spreadsheet with electrical loads from the DOE 2.1E model runs and the grid demand calculated.

2.4 Other Energy Measures

While the list of energy measures analyzed in this investigation is extensive, there are others which deserve mention and future consideration. These are briefly described below.

Desiccant cooling

A desiccant dehumidifier can be added to an existing vapour compression cooling system to control humidity separately from sensible cooling of the air. In this system a solid desiccant material is impregnated in a ceramic wheel. As the air passes through the wheel, the desiccant absorbs the moisture in the air. As the wheel continues to rotate, heat is added by a gas burner or waste heat from say a microturbine, to reactivate or dry the desiccant and the process is repeated. Desiccant dehumidification can be beneficial where there is a high latent load (or moisture load) in comparison to a sensible cooling (or lowering the air temperature) load. When used in combination with an existing air conditioning system, the existing cooling equipment or plant can have a smaller cooling capacity hence capital savings. The greater the amount of outdoor air supplied to a building the greater the energy savings with a desiccant cooling unit.

Evaporative cooling

In evaporative cooling, the evaporation of water provides the cooling effect. There are different configurations, some better suited to dry climates. For climates, like Canada's, with moderate humidity levels, either an indirect or combination indirect/direct evaporative cooling system can be used with conventional direct expansion cooling equipment. In the indirect method, the air to be cooled does not come in direct contact with the evaporating water but through a heat exchanger surface. In the direct method, water evaporates directly into the airstream reducing its dry bulb temperature. The two processes can be combined in two stages. The first stage (indirect) sensibly cools the air which then passes through the second stage (direct) to be cooled directly in contact with the water. A conventional cooling coil provides additional cooling/dehumidification as required. Indirect/direct evaporative cooling systems are claimed to be able to provide 40 to 50% energy savings in moderate humidity climates.

Displacement Ventilation with Heat Pumps

Displacement ventilation (100% outdoor air) has been modelled here as part of a radiant panel heating and cooling system. The water-to-air heat pumps modelled in both the small and large office, as part of the ground source system, require that air be recirculated in the zones over the coils in both heating and cooling operation. However, if the water-to-air heat pumps were replaced with water-to-water heat pumps, the same radiant panel heating and cooling distribution system could be used with 100% outdoor air and significant fan energy savings would result.

TABLE 2.1: MNECB Criteria for Office Buildings - Ottawa

	Low-rise Office (45,000 ft^2)	**High-rise Office (260,000 ft^2)**
Description of Building	Gas heating/with cooling Walls - Brick, batt and rigid insulation Built-up roof, rigid insulation double glazed, grey tint, aluminum/ thermal break SHGC = 0.54/No sash	Gas heating/with cooling Walls - Brick, batt and rigid insulation Built-up roof, rigid insulation double glazed, grey tint, aluminum/thermal break SHGC = 0.54/No sash
Energy Code	MNECB - 1997	MNECB - 1997
Lighting load	17.8 W/m^2	17.8 W/m^2
Equip/Appliance Load	7.5 W/m^2	7.5 W/m^2
Elevator Load	1 × 30 kW	4 × 30 kW
Occupant Density	25 m^2/person	25 m^2/person
Schedules	Compliance supplement (7.0)	Compliance supplement (7.0)
Percent Fenestration (%)	40	40
Fenestration U-value (W/m^2-C)	3.2	3.2
Opaque wall U-value (W/m^2-C)	0.55	0.55
Roof U-value (W/m^2-C)	0.47	0.47
Below grade wall (RSI) -unfinished	No insulation	No insulation
Perimeter Floor Insulation (RSI)	No insulation	No insulation
Floor above unheated space (U-value) - conc. slab	0.47	0.47
Infiltration	0.25 $l/s/m^2$ exterior wall	0.25 $l/s/m^2$ exterior wall
Outdoor air	0.4 $l/s/m^2$ floor area	0.4 $l/s/m^2$ floor area
HVAC system	Individual zone packaged rooftop DX air cooled (EER=8.9) with economizer Gas-fired central boiler	Individual floor VAV with central make up air gas-fired preheat Chilled water (COP = 5.2) Cooling tower/economizer Hydronic radiation heating with gas-fired central boiler
SHW system	Peak demand 90 W/person Electric storage heater	Peak demand 90 W/person Electric storage heater

3.INDIVIDUAL MEASURE ANALYSIS

3.1Introduction

This chapter reports on the results of the individual measure analysis. A total of 26 energy efficiency/renewable energy measures were applied to the base case model small office building and DOE 2.1E simulations undertaken. Similarly, 28 energy efficiency/renewable energy measures were applied to the large office building model and DOE 2.1E energy analysis performed.

All initial simulations were performed using Ottawa weather data. The base case small and large office buildings were defined in Chapter 2, Table 2.1. Applicable energy criteria, in accordance with the Model National Energy Code for Buildings, were applied to both buildings. All subsequent design modifications were compared, one by one, to the resulting base case.

3.2Results

Included in this chapter are a series of tables containing the results of the individual measure analysis. Table 3.1 contains the results for the small office building; Table 3.2 for the large office building.

Each table contains results for both the base case building and for each of the individual measures applied to the base case building. Component energy use (GJ) is presented together with a total energy use for each case. Other sections of the tables present electricity use and demand totals, natural gas consumption and energy charges based on Ottawa energy rates as of November 1, 2000. Total energy savings are provided together with an estimate of the incremental cost of each measure and the associated simple payback period

3.2.1Small Office

In the small office building, a number of energy measures have simple payback periods under 5 years (10), between 5 and 10 years (7) and between 10 and 15 years (3). The remaining measures (6), particularly the renewable measures, have much longer payback periods.

Individual measures with whole building energy savings of 10% or greater include:

(a) triple-glazed windows (21%);
(b) ground-source heat pump (34%);
(c) low-E argon filled, vinyl-framed windows (13%);
(d) water-loop heat pump system (16%);
(e) radiant panel heating and cooling (18%);
(f) condensing boiler (13%).

3.2.1Large Office

In Table 3.2, it is evident that a number of measures have simple payback periods under 5 years (8), between 5 and 10 years (7), and between 10 and 15 years (2). As with the small office, the renewable energy measures have much longer simple payback periods.

Individuals measures with whole building energy savings of 10% or greater include:

(a) triple-glazed windows (18%);
(b) low-E argon-filled, vinyl-framed windows (12%);
(c) ground-source heat pump (32%);
(d) condensing boiler (14%).

Appendix A contains descriptions of many of the less commonly applied measures.

Table 3.1: Individual Measure Analysis for Small Office Building

MEASURE #	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
DESCRIPTION	Base case	Lighting power density of 11.5 W/m^2	Perimeter daylighting with light dimming	Occupancy sensors for lighting	Active solar shading	Add low-E coating to windows	Add low-E coating and argon fill to windows	Add low-E coating, argon fill, and vinyl frames to windows	Triple-glazed low-e coated, argon filled, vinyl framed windows	Increase wall insulation by ΔRSI = 0.9
ENERGY USED (GJ)										
Space Heating	1,613	1,782	1,760	1,740	1,574	1,357	1,313	1,169	885	1,498
Space Cooling	235	206	212	212	222	219	220	221	227	236
Domestic Hot Water	158	158	158	158	158	158	158	158	158	158
Interior Lighting	784	508	572	568	784	784	784	784	784	784
Equipment/Appliances	422	422	422	422	422	422	422	422	422	422
Fans	311	308	304	308	323	289	287	283	276	309
Pumps	22	23	22	22	22	20	19	18	16	21
Elevators	151	151	151	151	151	151	151	151	151	151
Total	*3,695*	*3,556*	*3,600*	*3,579*	*3,655*	*3,399*	*3,353*	*3,205*	*2,918*	*3,577*
ELECTRICITY										
Metered Peak Demand (kW)	283	248	249	253	275	274	274	273	272	282
Metered Consumption (kWh)	597,076	513,708	531,861	531,171	596,631	583,963	582,176	579,362	575,211	595,112
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-
NATURAL GAS										
Metered Consumption (m^3)	41,246	45,570	45,004	44,495	40,222	36,306	33,551	29,884	22,613	38,302
ENERGY CHARGES ($)										
Electric (Consumption)	26,212	22,552	23,349	23,318	26,192	25,636	25,558	25,434	25,252	26,125
Electric (Demand)	19,233	16,500	17,038	16,914	19,293	18,633	18,634	18,589	18,648	19,222
Natural Gas	20,016	22,070	21,797	21,561	19,521	17,665	16,354	14,605	11,111	18,613
Total	*65,461*	*61,122*	*62,184*	*61,793*	*65,006*	*61,934*	*60,546*	*58,628*	*55,011*	*63,960*
ANNUAL SAVINGS ($)	0	4,339	3,277	3,668	455	3,527	4,915	6,833	10,450	1,501
SAVINGS (%)										
Energy Consumption	-	3.7	2.5	3.1	1.1	8.0	9.3	13.2	21.0	3.2
Energy Charges	-	6.6	5.0	5.6	0.7	5.4	7.5	10.4	16.0	2.3
INCREMENTAL COSTS ($)										
Capital Cost	-	10,790	9,150	18,443	62,205	27,144	45,864	58,032	108,576	9,180
SIMPLE PAYBACK (YEARS)	-	2.5	2.8	5.0	136.7	7.7	9.3	8.5	10.4	6.1

Table 3.1: Individual Measure Analysis for Small Office Building - (cont'd)

MEASURE #	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19
DESCRIPTION	Condensing boiler (thermal efficiency = 95%)	Central air-to air heat recovery 60% annual effectiveness	Solar air preheating system	Install high efficiency motors on supply fans	Variable speed pump on heating loop	WLHP system with condens boiler and cooling tower	WLHP system (same as S15) plus thermal storage	WLHP system with ground source	Radiant panel heating and cooling with displacement ventilation	Low flow faucets
ENERGY USED (GJ)										
Space Heating	1,134	1,444	1,511	1,615	1,613	802	793	280	1,131	1,613
Space Cooling	235	235	235	234	235	306	306	192	227	235
Domestic Hot Water	158	158	158	158	158	158	158	158	158	130
Interior Lighting	784	784	784	784	784	784	784	784	784	784
Equipment/Appliances	422	422	422	422	422	422	422	422	422	422
Fans	311	300	311	304	311	292	292	293	33	311
Pumps	22	20	22	22	22	175	173	158	101	22
Elevators	151	151	151	151	151	151	151	151	151	151
Total	*3,215*	*3,513*	*3,592*	*3,689*	*3,695*	*3,089*	*3,078*	*2,437*	*3,006*	*3,666*
ELECTRICITY										
Metered Peak Demand (kW)	283	266	283	282	283	260	260	221	206	281
Metered Consumption (kWh)	597,076	592,070	597,076	595,055	597,076	717,202	716,622	676,881	540,216	589,257
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-
NATURAL GAS										
Metered Consumption (m^3)	28,448	36,865	38,588	41,302	41,246	13,526	13,285	-	28,320	41,246
ENERGY CHARGES ($)										
Electric (Consumption)	26,212	25,992	26,212	26,123	26,212	31,485	31,460	29,715	23,715	25,868
Electric (Demand)	19,233	19,173	19,233	19,179	19,233	21,148	21,149	19,048	16,443	19,011
Natural Gas	13,901	17,910	18,963	20,043	20,016	6,716	6,600	-	13,863	20,016
Total	*59,346*	*63,075*	*64,408*	*65,345*	*65,461*	*59,349*	*59,209*	*48,763*	*54,021*	*64,895*
ANNUAL SAVINGS ($)	6,115	2,386	1,053	116	0	6,112	6,252	16,698	11,440	566
SAVINGS (%)										
Energy Consumption	13.0	4.9	2.8	0.1	0.0	16.4	16.7	34.0	18.6	0.8
Energy Charges	9.3	3.6	1.6	0.2	0.0	9.3	9.6	25.5	17.5	0.9
INCREMENTAL COSTS ($)										
Capital Cost	34,500	15,039	30,096	952	35,000	(24,842)	(22,762)	237,585	0	0
SIMPLE PAYBACK (YEARS)	5.6	6.3	28.6	8.2	never	immediate	immediate	14.2	immediate	immediate

Table 3.1: Individual Measure Analysis for Small Office Building - (cont'd)

MEASURE #	S20	S21	S22	S23	S24	S25	S26
DESCRIPTION	Heat pump water heaters	Solar thermal domestic hot water system	Photovoltaic electric array	Microturbine with heat recovery	Low-energy office equipment	Elevator efficiency measures	Increase roof insulation by ΔRSI = 0.9
ENERGY USED (GJ)							
Space Heating	1,622	1,613	1,613	*	1,705	1,613	1,575
Space Cooling	235	235	235	*	222	235	235
Domestic Hot Water	73	82	158	*	158	158	158
Interior Lighting	784	784	784	*	784	784	784
Equipment/Appliances	422	422	422	*	276	422	421
Fans	311	311	311	*	310	311	310
Pumps	22	22	22	*	22	22	21
Elevators	151	151	151	*	151	90	151
Total	*3,618*	*3,619*	*3,695*	*	*3,628*	*3,634*	*3,656*
ELECTRICITY							
Metered Peak Demand (kW)	275	283	270	260	268	277	282
Metered Consumption (kWh)	573,771	576,116	574,466	492,076	554,122	580,353	596,430
Site Generated Energy (kWh)	-	-	22,610	101,556	-	-	-
NATURAL GAS							
Metered Consumption (m^3)	41,450	41,246	41,246	58,799	43,595	41,246	40,277
ENERGY CHARGES ($)							
Electric (Consumption)	25,189	25,293	25,219	21,602	24,326	25,477	26,183
Electric (Demand)	18,549	19,233	18,589	16,811	18,107	18,659	19,223
Natural Gas	20,114	20,016	20,016	28,221	21,132	20,016	19,552
Total	*63,852*	*64,542*	*63,824*	*66,634*	*63,565*	*64,152*	*64,958*
ANNUAL SAVINGS ($)	1,609	919	1,637	(1,173)	1,896	1,309	503
SAVINGS (%)							
Energy Consumption	2.1	2.0	2.2	-7.7	1.8	1.6	1.0
Energy Charges	2.5	1.4	2.5	-1.8	2.9	2.0	0.8
INCREMENTAL COSTS ($)							
Capital Cost	12,947	22,630	399,923	47,460	0	(70,000)	5,462
SIMPLE PAYBACK (YEARS)	8.0	24.6	244.3	never	immediate	immediate	10.9

* Detailed separately

Table 3.2: Individual Measure Analysis for Large Office Building

MEASURE #	L0	L1	L2	L3	L4	L5	L6	L7	L8	L9
DESCRIPTION	Base case	Lighting power density of 11.5 W/m^2	Perimeter daylighting with light dimming	Occupancy sensors for lighting	Active solar shading	Add low-E coating to windows	Add low-E coating and argon fill to windows	Add low-E coating, argon fill, and vinyl frames to windows	Triple-glazed low-e coated, argon filled, vinyl framed windows	Increase wall insulation by ΔRSI = 0.9
ENERGY USED (GJ)										
Space Heating	9,404	10,306	10,026	10,077	9,357	8,010	7,543	6,883	5,603	8,557
Space Cooling	1,029	878	952	908	949	1,038	1,046	1,048	1,069	1,026
Domestic Hot Water	898	898	898	898	898	898	898	898	898	898
Interior Lighting	4,518	2,927	3,641	3,269	4,518	4,518	4,518	4,518	4,518	4,518
Equipment/Appliances	2,419	2,419	2,419	2,419	2,419	2,419	2,419	2,419	2,419	2,419
Fans	1,528	1,379	1,440	1,403	1,552	1,517	1,519	1,509	1,505	1,527
Pumps	312	296	313	303	315	304	300	295	285	309
Elevators	602	602	602	602	602	602	602	602	602	602
Total	*20,710*	*19,705*	*20,292*	*19,880*	*20,610*	*19,306*	*18,846*	*18,172*	*16,899*	*19,856*
ELECTRICITY										
Metered Peak Demand (kW)	1,312	1,115	1,177	1,151	1,240	1,312	1,314	1,312	1,317	1,308
Metered Consumption (kWh)	3,257,278	2,736,366	2,975,356	2,846,157	3,242,766	3,237,683	3,233,734	3,221,861	3,207,721	3,245,389
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-
NATURAL GAS										
Metered Consumption (m^3)	239,823	263,070	255,759	257,178	238,553	204,217	192,302	175,463	142,809	218,178
ENERGY CHARGES ($)										
Electric (Consumption)	142,995	120,126	130,618	124,946	142,357	142,134	141,961	141,440	140,819	142,473
Electric (Demand)	101,050	84,536	90,572	87,154	99,407	100,868	100,870	100,664	100,746	100,673
Natural Gas	114,207	125,159	121,656	122,387	113,561	97,412	91,788	83,837	68,407	103,980
Total	*358,252*	*329,821*	*342,846*	*334,487*	*355,325*	*340,414*	*334,619*	*325,941*	*309,972*	*347,126*
ANNUAL SAVINGS ($)	-	28,431	15,406	23,765	2,927	17,838	23,633	32,311	48,280	11,126
SAVINGS (%)										
Energy Consumption	-	4.9	2.0	4.0	0.5	6.8	9.0	12.3	18.4	4.1
Energy Charges	-	7.9	4.3	6.6	0.8	5.0	6.6	9.0	13.5	3.1
INCREMENTAL COSTS ($)										
Capital Cost	-	85,782	38,244	106,563	293,436	111,766	188,846	238,948	447,064	37,753
SIMPLE PAYBACK (YEARS)	-	3.0	2.5	4.5	100.3	6.3	8.0	7.4	9.3	3.4

Table 3.2: Individual Measure Analysis for Large Office Building - (cont'd)

MEASURE #	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19
DESCRIPTION	Condensing boiler (thermal efficiency = 95%)	Central air-to air heat recovery 60% annual effectiveness	Solar air preheating system	Install high efficiency motors on supply fans	Variable speed pump on heating loop	WLHP system with condens boiler and cooling tower	WLHP system (same as L15) plus thermal storage	WLHP system with ground source	Radiant panel heating and cooling with displacement ventilation	Low flow faucets
ENERGY USED (GJ)										
Space Heating	6,496	8,837	9,059	9,408	9,404	8,183	8,200	2,621	9,682	9,404
Space Cooling	1,029	1,050	1,029	1,027	1,029	1,323	1,323	1,024	1,030	1,029
Domestic Hot Water	898	898	898	898	898	898	898	898	898	723
Interior Lighting	4,518	4,518	4,518	4,518	4,518	4,518	4,518	4,518	4,518	4,518
Equipment/Appliances	2,419	2,419	2,419	2,419	2,419	2,419	2,419	2,419	2,419	2,419
Fans	1,528	1,538	1,528	1,512	1,528	1,000	1,000	1,157	51	1,528
Pumps	312	307	312	312	312	910	909	756	258	312
Elevators	602	602	602	602	602	602	602	602	602	602
Total	*17,802*	*20,169*	*20,365*	*20,696*	*20,710*	*19,853*	*19,870*	*13,996*	*19,458*	*20,535*
ELECTRICITY										
Metered Peak Demand (kW)	1,312	1,266	1,312	1,309	1,312	1,434	1,434	1,360	1,085	1,297
Metered Consumption (kWh)	3,257,278	3,259,314	3,257,278	3,252,244	3,257,278	3,917,836	3,917,759	3,886,888	2,864,345	3,208,647
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-
NATURAL GAS										
Metered Consumption (m^3)	162,167	225,185	228,407	239,923	239,823	153,436	153,883	-	244,179	239,823
ENERGY CHARGES ($)										
Electric (Consumption)	142,995	143,084	142,995	142,774	142,995	171,993	171,990	170,634	125,745	140,860
Electric (Demand)	101,050	99,779	101,050	100,904	101,050	118,468	118,463	113,615	83,606	99,552
Natural Gas	77,456	107,211	109,044	114,254	114,207	73,580	73,801	-	116,435	114,207
Total	*321,501*	*350,074*	*353,089*	*357,932*	*358,252*	*364,041*	*364,254*	*284,249*	*325,786*	*354,619*
ANNUAL SAVINGS ($)	36,751	8,178	5,163	320	0	(5,789)	(6,002)	74,003	32,466	3,633
SAVINGS (%)										
Energy Consumption	14.0	2.6	1.7	0.1	0.0	4.1	4.1	32.4	6.0	0.8
Energy Charges	10.3	2.3	1.4	0.1	0.0	-1.6	-1.7	20.7	9.1	1.0
INCREMENTAL COSTS ($)										
Capital Cost	195,700	86,990	83,490	6,666	35,000	61,545	68,810	954,838	0	0
SIMPLE PAYBACK (YEARS)	5.3	10.6	16.2	20.8	never	never	never	12.9	immediate	immediate

Table 3.2: Individual Measure Analysis for Large Office Building - (cont'd)

MEASURE #	L20	L21	L22	L23	L24	L25	L26	L27	L28
DESCRIPTION	Heat pump water heaters	Solar thermal domestic hot water system	Photovoltaic electric array	Microturbine with heat recovery	Low-energy office equipment	Elevator efficiency measures	Increase roof insulation by ΔRSI = 0.9	High efficien. centrifugal heat recovery chiller (COP = 6.3)	Centrifugal chiller efficiency to COP = 6.3
ENERGY USED (GJ)									
Space Heating	9,433	9,404	9,404	*	9,863	9,404	8,998	8,957	9,404
Space Cooling	1,029	1,029	1,029	*	955	1,029	1,031	879	885
Domestic Hot Water	346	492	898	*	898	898	898	898	898
Interior Lighting	4,518	4,518	4,518	*	4,518	4,518	4,518	4,518	4,518
Equipment/Appliances	2,419	2,419	2,419	*	1,582	2,419	2,419	2,419	2,419
Fans	1,528	1,528	1,528	*	1,455	1,528	1,531	1,528	1,528
Pumps	312	312	312	*	305	312	314	312	312
Elevators	602	602	602	*	602	452	602	602	602
Total	*20,186*	*20,303*	*20,710*	*	*20,179*	*20,559*	*20,311*	*20,113*	*20,566*
ELECTRICITY									
Metered Peak Demand (kW)	1,252	1,312	1,262	1,218	1,222	1,297	1,304	1,249	1,249
Metered Consumption (kWh)	3,105,660	3,150,276	3,166,838	2,917,883	2,987,183	3,215,469	3,254,980	3,213,629	3,217,360
Site Generated Energy (kWh)	-	-	90,440	322,333	-	-	-	-	-
NATURAL GAS									
Metered Consumption (m^3)	242,569	239,823	239,823	292,936	251,626	239,823	229,381	233,051	239,823
ENERGY CHARGES ($)									
Electric (Consumption)	136,338	138,297	139,024	128,095	131,137	141,159	142,894	141,078	141,242
Electric (Demand)	95,427	101,050	98,559	91,459	94,150	99,655	100,803	97,823	98,164
Natural Gas	115,527	114,207	114,207	138,527	119,761	114,207	109,250	111,017	114,207
Total	*347,292*	*353,554*	*351,790*	*358,081*	*345,048*	*355,021*	*352,947*	*349,918*	*353,613*
ANNUAL SAVINGS ($)	10,960	4,698	6,462	171	13,204	3,231	5,305	8,334	4,639
SAVINGS (%)									
Energy Consumption	2.5	2.0	1.6	-3.8	2.6	0.7	1.9	2.9	0.7
Energy Charges	3.1	1.3	1.8	0.0	3.7	0.9	1.5	2.3	1.3
INCREMENTAL COSTS ($)									
Capital Cost	59,804	100,844	1,527,622	91,133	0	28,000	8,737	203,060	140,946
SIMPLE PAYBACK (YEARS)	5.5	21.5	236.4	532.9	immediate	8.7	1.6	24.4	30.4

4. MEASURE SET ANALYSIS

4.1 Introduction

This chapter presents the results of the energy performance and life cycle cost analysis of the measure sets. Thirteen measure sets were applied to the base case model small building and ten to the large building, and DOE 2.1E simulations were performed. As discussed in a previous chapter, the base case buildings were assumed to be constructed according to the Model National Energy Code for Buildings, and all initial simulations were performed using Ottawa weather data. Energy results were obtained for Halifax and Winnipeg to illustrate the sensitivity to weather changes. These results are presented in Tables 4.5 through 4.8 and Figures 4.4 through 4.7.

4.2 Measure Set Development

For both buildings, the measure sets consist of a mixture of measure sets developed in previous work, plus new measure sets. The measure sets are identified first by either an "S" or "L" to designate the "small" or "large" building, and followed by a letter (e.g. SA, SB, SC, LA, LB, LC, etc.) to designate a specific measure set.

The general methodology for developing the new measure sets was to rank order the individual measures for each building from shortest to longest payback period, based on the results of the individual measure analysis. (The results of the rank ordering process are shown in Tables 4.1 and 4.2.)

Individual measures were then added one at a time in order to achieve certain energy savings targets, starting at a minimum savings of approximately 25%. For the most part, all of the measures which had an immediate payback were included in each of the new measure sets.

The individual measures included in each measure set are also shown in Tables 4.1 and 4.2. A few comments should be made about the development of the measure sets:

- In several cases, the use of one individual measure precludes the use of another. For example, it is not possible to use both a radiant heating and cooling system and a water loop heat pump system in the same simulation. Another example is that only one window measure can be used.

- It is assumed that the water loop heat pump and the radiant heating and cooling system measure include the installation of a condensing boiler. Therefore, when these system types are used, an asterisk is not placed in the table beside the "condensing boiler" individual measure.

- The "high efficiency motors" measure is not implemented in any of the measure sets, despite having a reasonable payback period because the energy savings were minimal.

- The "central air-to-air heat recovery" and "solar air preheating" measures are not implemented together because it was reasoned that these would not be used together.
- Individual measures with payback periods of more than 20 years are not implemented.

The exceptions to this rule were that photovoltaics and solar thermal water heating were analyzed in one measure set.

4.3 Results

The results of the measure set energy analysis are provided in Tables 4.1, 4.2, 4.3, and 4.4 and in Figures 4.1, 4.2, and 4.3. Tables 4.1 and 4.2 present the "predicted" and "calculated" energy savings for each measure set, where the predicted savings are the sum of the individual measures savings, and the calculated savings are the actual results of the simulations. Tables 4.3 and 4.4 present detailed results, including component energy use (in GJ), electricity consumption and peak demand, natural gas consumption, and energy charges based on current Ottawa utility rates. These tables also present incremental capital and incremental annual maintenance costs[1], net annual savings (energy savings minus maintenance), and simple payback period. Figures 4.1 and 4.2 present the component energy use for the base cases and measure sets.

Figure 4.3(a) presents a plot of simple payback period versus calculated energy savings for the newly developed measure sets (i.e. SE to SM and LE to LJ). There appears to be a distinct trend of increasing payback period with increasing calculated energy savings. It is also apparent that little or no incremental cost is involved in reaching 20 to 25% energy savings compared to the base case building. Figure 4.3(b) presents the net present value of savings versus calculated energy savings for the same measure sets. The net present value is positive for all but two of the measure sets shown.

4.3.1 Small Office Building

In the small building, the calculated energy savings range from 27.9 to 59.8%, and the simple payback periods range from immediate to 14.9 years. Measure sets SE, SF, SH, and SI achieve immediate paybacks. Measure sets SE, SH, and SK have calculated savings that are greater than their predicted savings. In each of these cases, the measure sets consist of one measure that addresses the energy use of the space conditioning system, and five measures that reduce electrical loads.

4.3.2 Large Office Building

In the large building, the calculated energy savings range from 20.9 to 54.4%, and the simple payback periods range from 0.1 to 11.1 years. Measure sets LA, LC, LE, LF, and LG achieve paybacks (simple and actual) of less than 4 years. Measures set LC and LH have calculated energy savings that are slightly greater than their predicted savings.

4.3.3 Other Locations

Tables 4.5 and 4.6 present the measure set results for the small office in Halifax and Winnipeg. The results are shown graphically in Figures 4.4 and 4.5. Energy use and savings both generally increase in moving the building from Ottawa to Winnipeg and are reduced for Halifax. The

[1] In calculating the incremental costs, consideration is given to changes in equipment size that result from implementing the energy reducing measures. (Refer to section 5 of this report.)

warmer the climate, the lower the savings and energy use.

The large office building results are presented in Tables 4.7 and 4.8 and graphically in Figures 4.6 and 4.7. Again, energy use and energy savings are generally increased in Winnipeg and reduced in Halifax.

Note that the exceptions are the energy savings, associated with measure sets SE and SH and LC, LE, LF and LG. These measure sets involve internal load measures (i.e. impacts on equipment or plug loads and lighting). Any measure set which impacts on heating requirements shows increased savings in colder locations (e.g. SD, SJ through SM and LD, LH through LJ).

Table 4.1: Energy Measure Sets for Small Office Building

INDIVIDUAL MEASURES				MEASURE SETS												
#	Description	Energy Savings (%)	Payback Period (yrs.)	SA	SB	SC	SD	SE	SF	SG	SH	SI	SJ	SK	SL	SM
S18	Radiant panel heating and cooling with displacement ventilation	18.6	immediate					*	*	*						
S16	WLHP system with cond. boiler and cooling tower, plus storage	16.7	immediate								*	*	*			
S15	WLHP system with cond. boiler and cooling tower	16.4	immediate			*										
S24	Low-energy office equipment	1.8	immediate					*	*	*	*	*	*	*	*	*
S25	Elevator efficiency measures	1.6	immediate					*	*	*	*	*	*	*	*	*
S19	Low flow faucets	0.8	immediate			*	*	*	*	*	*	*	*	*	*	*
S1	Reduce overall lighting power density to 11.5 W/m^2	3.7	2.5	*	*	*	*	*	*	*	*	*	*	*	*	*
S2	Perimeter daylighting with light dimming	2.5	2.8			*		*	*		*	*		*	*	*
S3	Occupancy sensors for lighting	3.1	5.0							*			*			*
S10	Condensing boiler (thermal efficiency = 95%)	13.0	5.6	*	*											
S9	Increase wall insulation by ΔRSI = 0.9	3.2	6.1				*		*	*		*	*		*	*
S11	Central air-to-air heat recovery (60% annual effectiveness)	4.9	6.3		*	*			*	*		*	*		*	*
S5	Low-e coated windows	8.0	7.7						*			*			*	
S20	Heat pump water heaters	2.1	8.0							*			*			*
S13	High efficiency motors on supply fans	0.1	8.2													
S7	Low-e coated, argon filled, vinyl framed windows	13.2	8.5	*	*	*	*									
S6	Low-e coated, argon filled windows	9.3	9.3													
S8	Triple glazed, low-e coated, argon filled, vinyl framed windows	21.0	10.4							*			*			*
S26	Increase roof insulation by ΔRSI = 0.9	1.0	10.9							*			*			*
S17	WLHP system with ground source	34.0	14.2				*							*	*	*
S21	Solar thermal domestic hot water system	2.0	24.6													*
S12	Solar air preheating system	2.8	28.6													
S4	Active solar shading	1.1	136.7													
S22	Photovoltaic electric array	2.2	244.3													*
S14	Variable speed pump on heating loop	0.0	never													
S23	Microturbine with heat recovery	-7.7	never													
	Predicted Savings			29.9	34.8	41.5	54.9	29.0	45.1	61.8	27.1	43.2	59.9	44.4	60.5	83.9
	Calculated Savings			27.9	32.2	39.9	45.8	31.1	43.9	55.7	30.1	43.0	52.7	52.0	55.9	64.6

Table 4.2: Energy Measure Sets for Large Office Building

INDIVIDUAL MEASURES				MEASURE SETS									
#	Description	Energy Savings (%)	Payback Period (yrs.)	LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ
L18	Radiant panel heating and cooling with displacement ventilation	6.0	immediate					*	*	*			
L24	Low-energy office equipment	2.6	immediate					*	*	*	*	*	*
L19	Low flow faucets	0.8	immediate	*	*	*	*	*	*	*	*	*	*
L26	Increase roof insulation by ΔRSI = 0.9	1.9	1.6			*		*	*	*	*	*	*
L2	Perimeter daylighting with light dimming	2.0	2.5					*	*	*	*	*	*
L1	Reduce overall lighting power density to 11.5 W/m^2	4.9	3.0	*	*	*	*	*	*	*	*	*	*
L9	Increase wall insulation by ΔRSI = 0.9	4.1	3.4		*	*	*	*	*	*	*	*	*
L3	Occupancy sensors for lighting	4.0	4.5										
L10	Condensing boiler (thermal efficiency = 95%)	14.0	5.3	*	*		*						
L20	Heat pump water heaters	2.5	5.5						*	*		*	*
L5	Low-e coated windows	6.8	6.3						*			*	
L7	Low-e coated, argon filled, vinyl framed windows	12.3	7.4	*	*	*							
L6	Low-e coated, argon filled windows	9.0	8.0										
L25	Elevator efficiency measures	0.7	8.7							*			*
L8	Triple glazed, low-e coated, argon filled, vinyl framed windows	18.4	9.3				*			*			*
L11	Central air-to-air heat recovery (60% annual effectiveness)	2.6	10.6	*			*			*			*
L17	WLHP system with ground source	32.4	12.9								*	*	*
L12	Solar air preheating system	1.7	16.2										
L13	High efficiency motors on supply fans	0.1	20.8										
L21	Solar thermal domestic hot water system	2.0	21.5										
L27	High efficiency centrifugal heat recovery chiller (COP = 6.3)	2.9	24.4		*		*						
L28	Centrifugal chiller efficiency to COP = 6.3	0.7	30.4			*							
L4	Active solar shading	0.5	100.3										
L22	Photovoltaic electric array	1.6	236.4										
L23	Microturbine with heat recovery	-3.8	532.9										
L14	Variable speed pump on heating loop	0.0	never										
L16	WLHP system with cond. boiler and cooling tower, plus storage	4.1	never										
L15	WLHP system with cond. boiler and cooling tower	4.1	never										
	Predicted Savings			34.6	39.0	24.7	47.8	22.4	31.7	46.6	48.7	58.1	73.0
	Calculated Savings			32.6	34.3	25.1	43.0	20.9	27.4	42.0	49.1	52.4	54.4

Table 4.3: Measure Set Results for Small Office Building - Ottawa

MEASURE SET	S0*	SA	SB	SC	SD	SE	SF	SG	SH	SI	SJ	SK	SL	SM
ENERGY USED (GJ)														
Space Heating	1,613	935	791	503	227	1,392	922	541	1,055	623	318	344	230	148
Space Cooling	235	192	190	244	152	162	149	168	199	208	240	125	131	140
Domestic Hot Water	158	158	158	130	130	130	130	65	130	130	65	130	130	44
Interior Lighting	784	508	508	370	508	371	370	368	371	370	368	371	370	299
Equipment	422	422	422	422	422	276	276	276	276	276	276	276	276	276
Fans	311	280	269	262	265	32	41	40	284	264	257	285	265	256
Pumps	22	19	17	141	148	90	93	88	178	144	133	153	136	135
Elevators	151	151	151	151	151	91	91	91	91	91	91	91	91	91
Total	*3,695*	*2,664*	*2,505*	*2,221*	*2,002*	*2,544*	*2,072*	*1,636*	*2,583*	*2,105*	*1,747*	*1,773*	*1,628*	*1,388*
ELECTRICITY														
Metered Peak Demand (kW)	283	238	220	186	187	137	123	122	193	170	161	177	159	138
Metered Consumption (kWh)	597,076	495,747	489,714	535,149	556,038	343,062	335,381	313,744	525,351	478,993	438,844	492,522	452,068	362,952
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-	-	-	-	22,610
NATURAL GAS														
Metered Consumption (m^3)	41,246	23,472	19,798	7,862	-	34,945	23,087	13,539	18,452	10,163	4,649	-	-	-
ENERGY CHARGES ($)														
Electric (Consumption)	26,212	21,763	21,498	23,493	24,410	15,060	14,723	13,773	23,063	21,028	19,265	21,622	19,846	15,934
Electric (Demand)	19,233	15,837	15,687	15,456	15,833	10,432	10,017	9,448	15,656	14,115	13,144	13,865	12,666	10,991
Natural Gas	20,016	11,512	9,716	3,930	-	17,021	11,328	6,698	9,110	5,062	2,333	-	-	-
Total	*65,461*	*49,112*	*46,901*	*42,879*	*40,243*	*42,513*	*36,068*	*29,919*	*47,829*	*40,205*	*34,742*	*35,487*	*32,512*	*26,925*
Annual Savings	-	*16,349*	*18,560*	*22,582*	*25,218*	*22,948*	*29,393*	*35,542*	*17,632*	*25,256*	*30,719*	*29,974*	*32,949*	*38,536*
SAVINGS (%)														
Energy Consumption	-	27.9	32.2	39.9	45.8	31.1	43.9	55.7	30.1	43.0	52.7	52.0	55.9	64.6
Energy Charges	-	25.0	28.4	34.5	38.5	35.1	44.9	54.3	26.9	38.6	46.9	45.8	50.3	58.9
INCREMENTAL COSTS ($)														
Capital Cost	-	83,856	60,690	5,628	241,200	-61,595	-37,432	73,271	-37,761	-31,427	91,001	128,439	137,599	656,238
Annual Maintenance	-	9,593	9,076	10,403	8,916	7,482	6,206	6,222	13,922	12,910	12,992	9,143	8,916	9,285
NET ANNUAL SAVINGS ($)	-	6,756	9,484	12,179	16,302	15,466	23,187	29,320	3,710	12,346	17,727	20,831	24,033	29,251
SIMPLE PAYBACK (YEARS)	-	12.4	6.4	0.5	14.8	immediate	immediate	2.5	immediate	immediate	5.1	6.2	5.7	22.4

Ottawa

* **S0** = Base Case

Table 4.4: Measure Set Results for Large Office Building - Ottawa

MEASURE SET	L0*	LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ
ENERGY USED (GJ)											
Space Heating	9,404	4,735	4,533	6,432	2,713	9,994	9,069	5,842	2,743	2,509	2,030
Space Cooling	1,029	901	761	771	786	727	738	845	691	713	799
Domestic Hot Water	898	723	723	723	723	723	302	303	723	301	301
Interior Lighting	4,518	2,927	2,927	2,927	2,927	2,359	2,360	2,360	2,359	2,360	2,360
Equipment	2,419	2,419	2,419	2,419	2,419	1,582	1,582	1,582	1,582	1,582	1,582
Fans	1,528	1,368	1,358	1,359	1,363	184	179	252	1,110	1,082	1,246
Pumps	312	277	276	277	261	211	206	370	724	715	663
Elevators	602	602	602	602	602	602	602	452	602	602	452
Total	*20,710*	*13,951*	*13,599*	*15,511*	*11,795*	*16,384*	*15,039*	*12,006*	*10,534*	*9,864*	*9,433*
ELECTRICITY											
Metered Peak Demand (kW)	1,312	1,061	1,041	1,031	1,009	752	704	651	1,100	1,051	975
Metered Consumption (kWh)	3,257,278	2,647,035	2,602,143	2,601,581	2,578,764	1,923,735	1,797,556	1,816,294	2,925,688	2,739,550	2,619,890
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-	-
NATURAL GAS											
Metered Consumption (m^3)	239,823	118,008	116,165	164,025	74,182	252,517	229,346	146,552	-	-	-
ENERGY CHARGES ($)											
Electric (Consumption)	142,995	116,205	114,234	114,209	113,208	84,452	78,913	79,735	128,438	120,266	115,013
Electric (Demand)	101,050	81,651	79,271	79,430	78,849	56,282	52,914	52,772	85,299	81,871	78,037
Natural Gas	114,207	56,516	55,707	78,394	35,700	120,248	109,320	70,159	-	-	-
Total	*358,252*	*254,372*	*249,212*	*272,033*	*227,757*	*260,982*	*241,147*	*202,666*	*213,737*	*202,137*	*193,050*
Annual Savings	-	*103,880*	*109,040*	*86,219*	*130,495*	*97,270*	*117,105*	*155,586*	*144,515*	*156,115*	*165,202*
SAVINGS (%)											
Energy Consumption	-	32.6	34.3	25.1	43.0	20.9	27.4	42.0	49.1	52.4	54.4
Energy Charges	-	29.0	30.4	24.1	36.4	27.2	32.7	43.4	40.3	43.6	46.1
INCREMENTAL COSTS ($)											
Capital Cost	-	240,473	492,900	285,373	607,691	8,110	171,673	492,167	1,386,804	1,531,903	1,986,655
Annual Maintenance	-	13,668	15,355	5,037	11,000	5,448	6,031	2,937	-4,511	-3,742	-3,742
NET ANNUAL SAVINGS ($)	-	90,212	93,685	81,182	119,495	91,822	111,074	152,649	149,026	159,857	168,944
SIMPLE PAYBACK (YEARS)	-	2.7	5.3	3.5	5.1	0.1	1.5	3.2	9.3	9.6	11.8

Ottawa

* **L0** = Base Case

Figure 4.1: Measure Set Results for Small Office Building - Ottawa

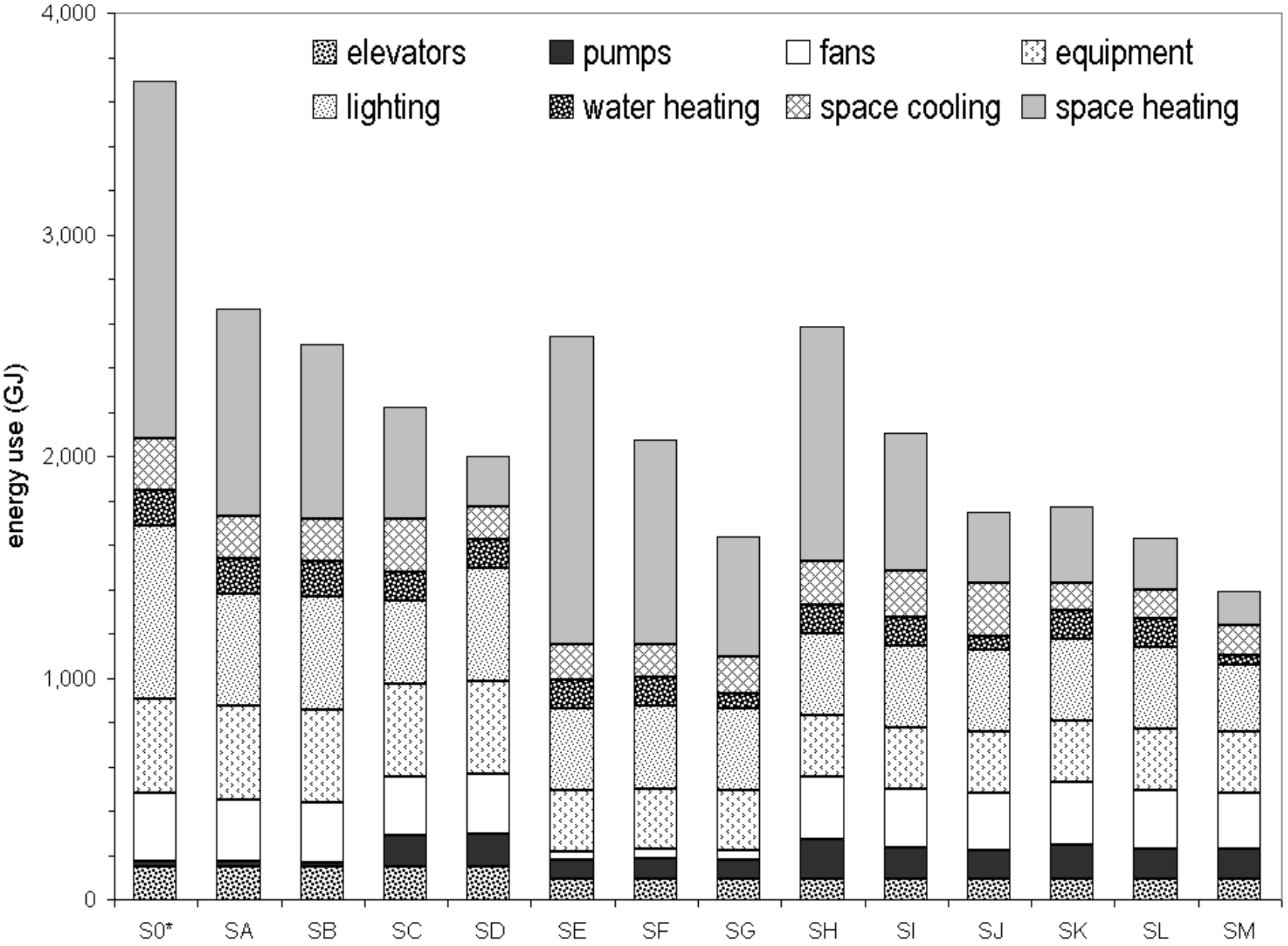


Figure 4.2: Measure Set Results for Large Office Building - Ottawa

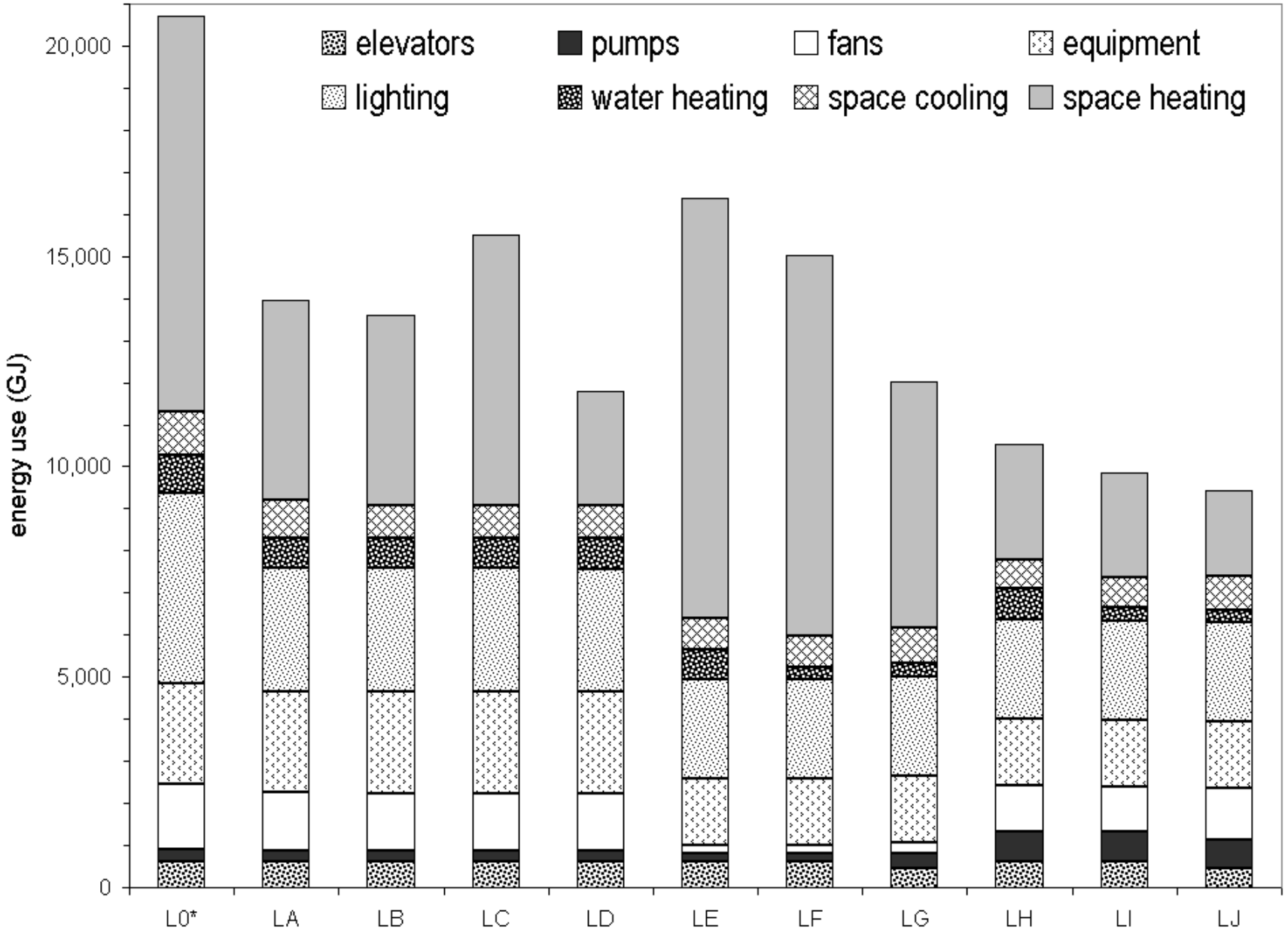


Figure 4.3(a): Simple Payback Period versus Calculated Energy Savings - Ottawa
(Measure Sets SE to SM and LE to LJ only)

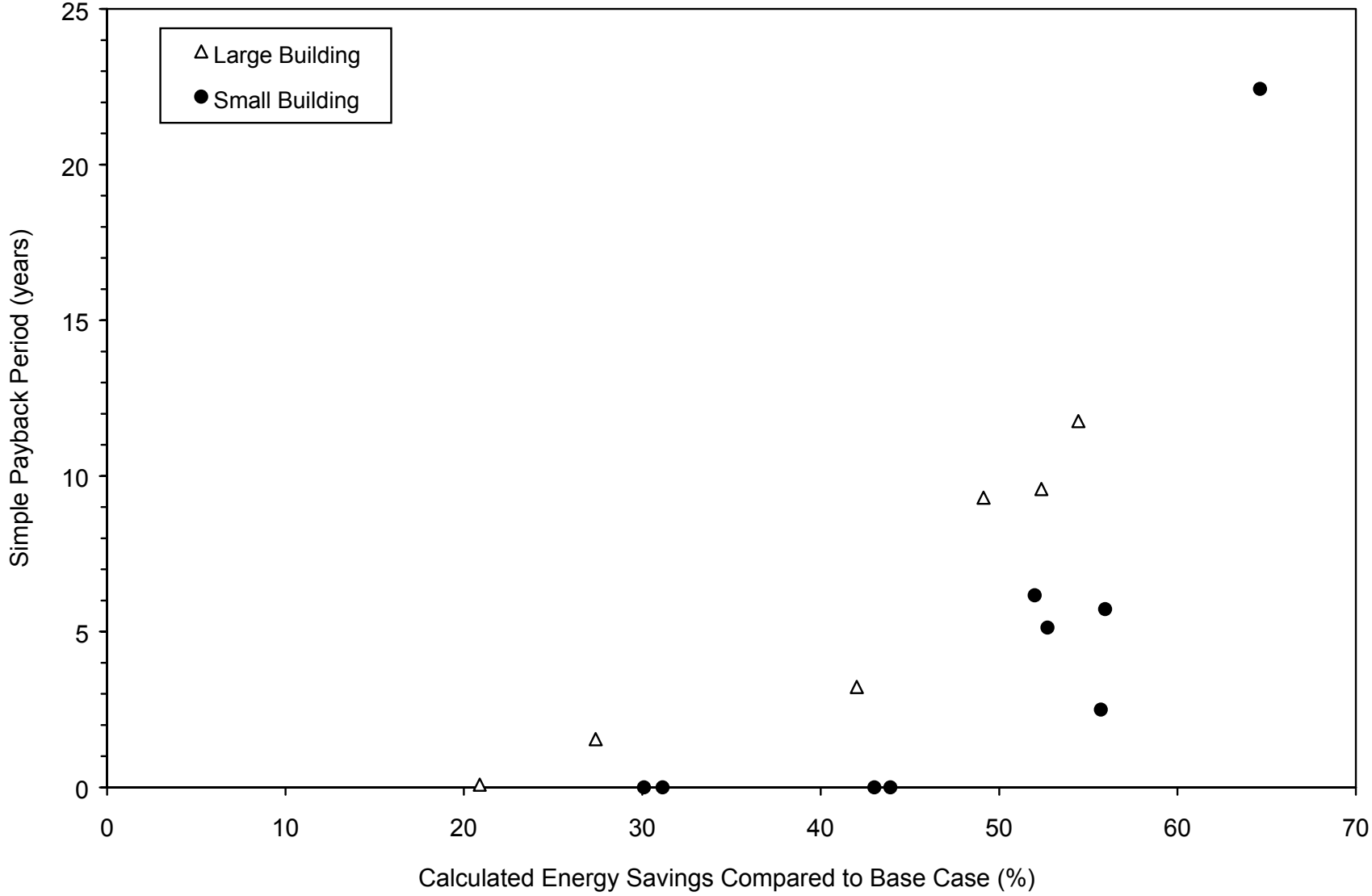


Figure 4.3(b): Net Present Value of Savings versus Calculated Energy Savings - Ottawa
(Measure Sets SE to SM and LE to LJ only)

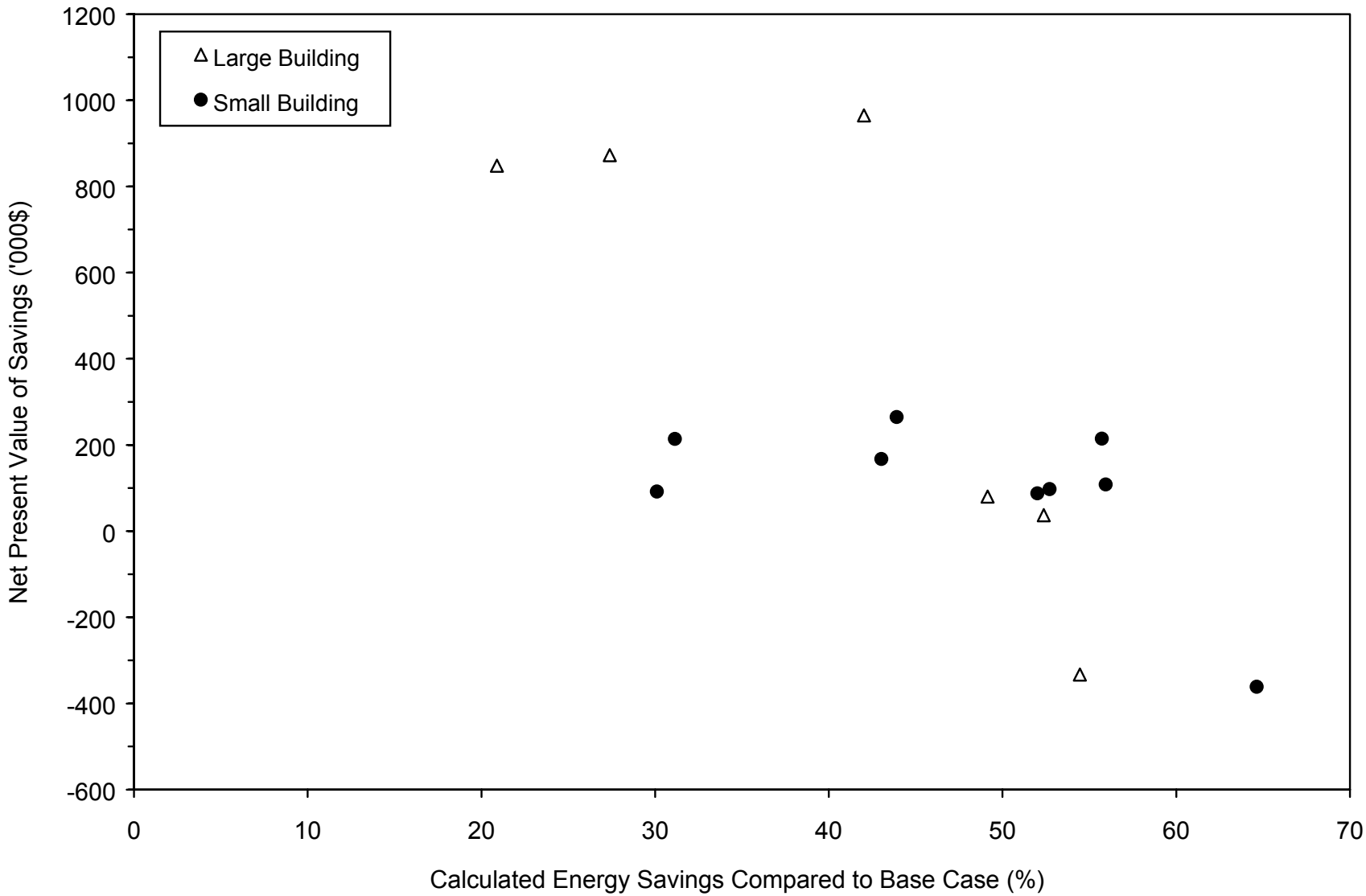


Table 4.5: Measure Set Results for Small Office Building - Halifax

MEASURE SET	S0*	SA	SB	SC	SD	SE	SF	SG	SH	SI	SJ	SK	SL	SM
ENERGY USED (GJ)														
Space Heating	1,223	682	601	308	165	1,110	722	383	759	406	171	277	183	110
Space Cooling	175	141	142	220	135	126	127	149	163	183	220	105	118	128
Domestic Hot Water	155	155	155	127	127	127	127	62	127	127	62	127	127	43
Interior Lighting	784	508	508	369	508	369	369	368	369	369	368	369	369	298
Equipment	422	422	422	422	422	276	276	276	276	276	276	276	276	276
Fans	306	275	265	261	264	32	41	40	286	263	254	288	265	253
Pumps	21	19	17	126	137	93	99	92	150	127	121	143	132	132
Elevators	151	151	151	151	151	91	91	91	91	91	91	91	91	91
Total	*3,237*	*2,353*	*2,259*	*1,983*	*1,909*	*2,225*	*1,852*	*1,459*	*2,221*	*1,843*	*1,562*	*1,676*	*1,560*	*1,331*
ELECTRICITY														
Metered Peak Demand (kW)	250	209	200	172	180	121	114	114	186	163	150	171	155	133
Metered Consumption (kWh)	574,505	476,031	471,562	509,958	530,193	329,841	327,185	305,996	487,909	452,681	416,842	465,380	433,368	350,013
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-	-	-	-	19,617
NATURAL GAS														
Metered Consumption (m^3)	31,196	17,050	14,992	3,915	-	27,701	17,792	9,536	12,407	5,682	1,742	-	-	-
SAVINGS (%)														
Energy Consumption	-	27.3	30.2	38.7	41.0	31.3	42.8	54.9	31.4	43.1	51.7	48.2	51.8	61.1

Halifax

* **S0** = Base Case

Table 4.6: Measure Set Results for Small Office Building - Winnipeg

MEASURE SET	S0*	SA	SB	SC	SD	SE	SF	SG	SH	SI	SJ	SK	SL	SM
ENERGY USED (GJ)														
Space Heating	2,191	1,294	1,078	749	295	1,802	1,216	753	1,406	888	513	431	294	196
Space Cooling	230	184	190	238	150	154	144	166	202	204	236	127	128	138
Domestic Hot Water	166	166	166	137	137	137	137	67	137	137	66	137	137	44
Interior Lighting	784	508	508	369	508	369	369	368	369	369	368	369	369	298
Equipment	422	422	422	422	422	276	276	276	276	276	276	276	276	276
Fans	334	296	286	274	278	34	43	42	301	277	268	304	278	266
Pumps	26	23	20	148	139	91	91	87	182	152	137	145	133	131
Elevators	151	151	151	151	151	91	91	91	91	91	91	91	91	91
Total	*4,304*	*3,044*	*2,820*	*2,486*	*2,078*	*2,953*	*2,367*	*1,849*	*2,964*	*2,393*	*1,954*	*1,881*	*1,705*	*1,440*
ELECTRICITY														
Metered Peak Demand (kW)	283	235	221	191	197	134	123	122	201	180	162	183	166	146
Metered Consumption (kWh)	611,563	506,787	502,350	556,929	577,186	348,110	340,352	317,584	557,008	503,235	456,280	522,323	473,500	375,003
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-	-	-	-	25,056
NATURAL GAS														
Metered Consumption (m^3)	56,121	32,561	27,008	12,829	-	45,385	30,484	19,013	22,582	15,514	8,952	-	-	-
SAVINGS (%)														
Energy Consumption	-	29.3	34.5	42.2	51.7	31.4	45.0	57.0	31.1	44.4	54.6	56.3	60.4	68.6

Winnipeg

* **S0** = Base Case

Table 4.7: Measure Set Results for Large Office Building - Halifax

MEASURE SET	L0*	LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ
ENERGY USED (GJ)											
Space Heating	7,420	3,683	3,434	4,843	2,234	8,112	7,269	4,435	2,277	2,055	1,651
Space Cooling	721	636	541	544	575	511	531	764	514	537	689
Domestic Hot Water	883	711	711	711	711	711	294	294	711	294	294
Interior Lighting	4,518	2,927	2,927	2,927	2,927	2,355	2,354	2,354	2,355	2,354	2,354
Equipment	2,419	2,419	2,419	2,419	2,419	1,582	1,582	1,582	1,582	1,582	1,582
Fans	1,516	1,366	1,358	1,361	1,365	183	178	257	1,112	1,082	1,244
Pumps	277	240	243	243	223	209	205	395	656	648	635
Elevators	602	602	602	602	602	602	602	452	602	602	452
Total	*18,355*	*12,584*	*12,234*	*13,649*	*11,056*	*14,264*	*13,015*	*10,532*	*9,808*	*9,154*	*8,900*
ELECTRICITY											
Metered Peak Demand (kW)	1,196	1,004	962	958	970	662	629	627	1,040	1,005	944
Metered Consumption (kWh)	3,134,338	2,543,455	2,510,422	2,508,809	2,495,375	1,845,236	1,721,971	1,778,077	2,723,912	2,542,206	2,462,956
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-	-
NATURAL GAS											
Metered Consumption (m^3)	188,763	91,472	86,873	123,243	57,966	203,482	182,090	110,400	-	-	-
SAVINGS (%)											
Energy Consumption	-	31.4	33.3	25.6	39.8	22.3	29.1	42.6	46.6	50.1	51.5

Halifax

* **L0** = Base Case

Table 4.8: Measure Set Results for Large Office Building - Winnipeg

MEASURE SET	L0*	LA	LB	LC	LD	LE	LF	LG	LH	LI	LJ
ENERGY USED (GJ)											
Space Heating	12,442	6,275	6,023	8,743	3,312	12,927	11,769	7,706	3,483	3,186	2,615
Space Cooling	1,016	960	742	761	840	688	699	834	679	699	784
Domestic Hot Water	947	763	763	763	763	763	306	307	763	303	303
Interior Lighting	4,518	2,927	2,927	2,927	2,927	2,354	2,355	2,354	2,354	2,355	2,355
Equipment	2,419	2,419	2,419	2,419	2,419	1,582	1,582	1,582	1,582	1,582	1,582
Fans	1,611	1,434	1,422	1,423	1,417	204	196	264	1,243	1,196	1,371
Pumps	354	319	308	309	305	237	230	386	763	745	703
Elevators	602	602	602	602	602	602	602	452	602	602	452
Total	*23,910*	*15,698*	*15,206*	*17,947*	*12,585*	*19,357*	*17,738*	*13,884*	*11,469*	*10,667*	*10,164*
ELECTRICITY											
Metered Peak Demand (kW)	1,256	1,038	1,003	1,000	997	734	689	656	1,184	1,123	1,032
Metered Consumption (kWh)	3,335,166	2,729,351	2,660,880	2,662,197	2,646,931	1,965,099	1,826,936	1,847,744	3,185,134	2,962,612	2,822,846
Site Generated Energy (kWh)	-	-	-	-	-	-	-	-	-	-	-
NATURAL GAS											
Metered Consumption (m^3)	317,772	156,757	156,820	223,252	96,149	327,919	300,053	195,131	-	-	-
SAVINGS (%)											
Energy Consumption	-	34.3	36.4	24.9	47.4	19.0	25.8	41.9	52.0	55.4	57.5

Winnipeg

* **L0** = Base Case

Figure 4.4: Comparison of Small Building Energy Use by Location

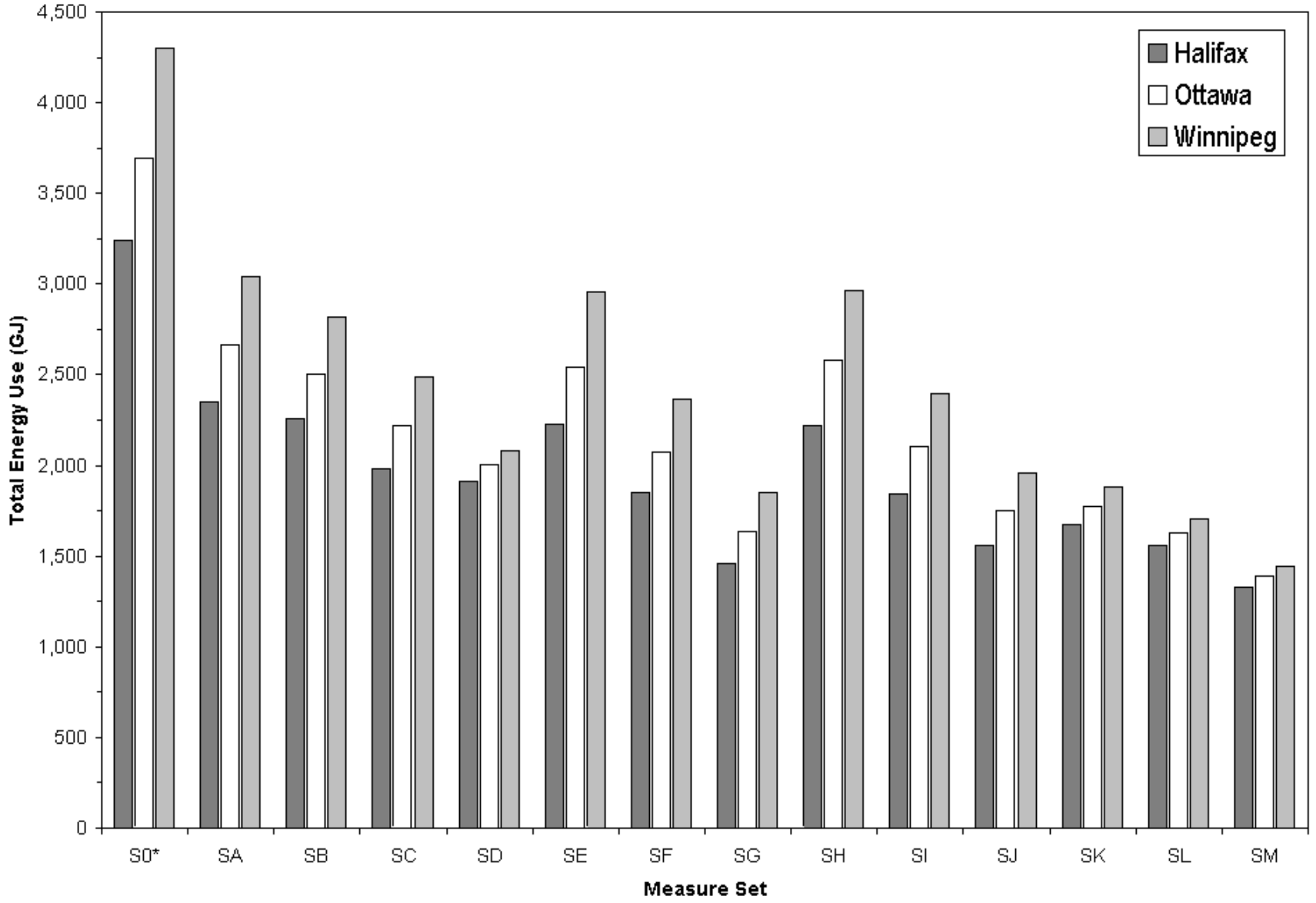


Figure 4.5: Comparison of Small Building Energy Savings by Location

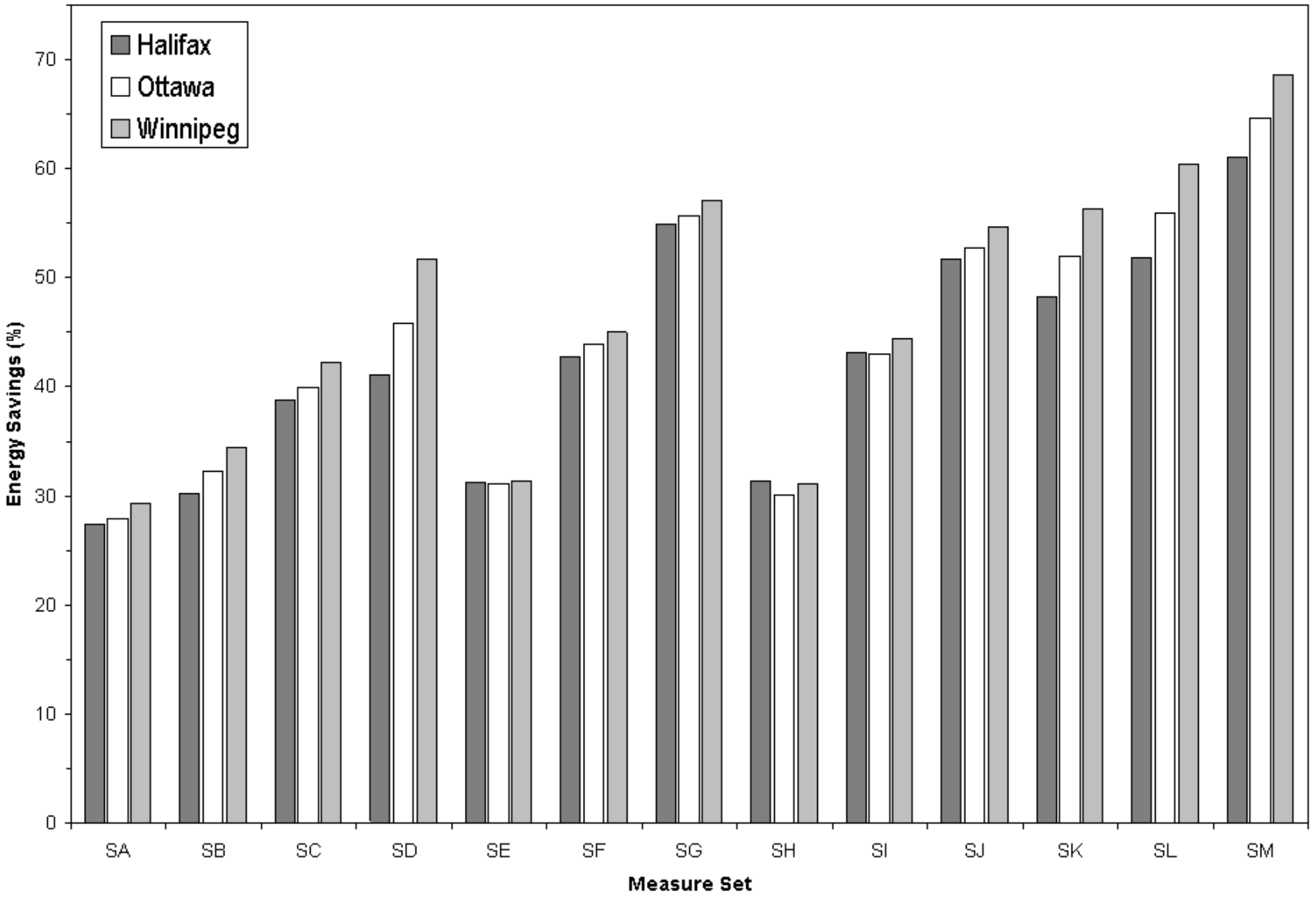


Figure 4.6: Comparison of Large Building Energy Use by Location

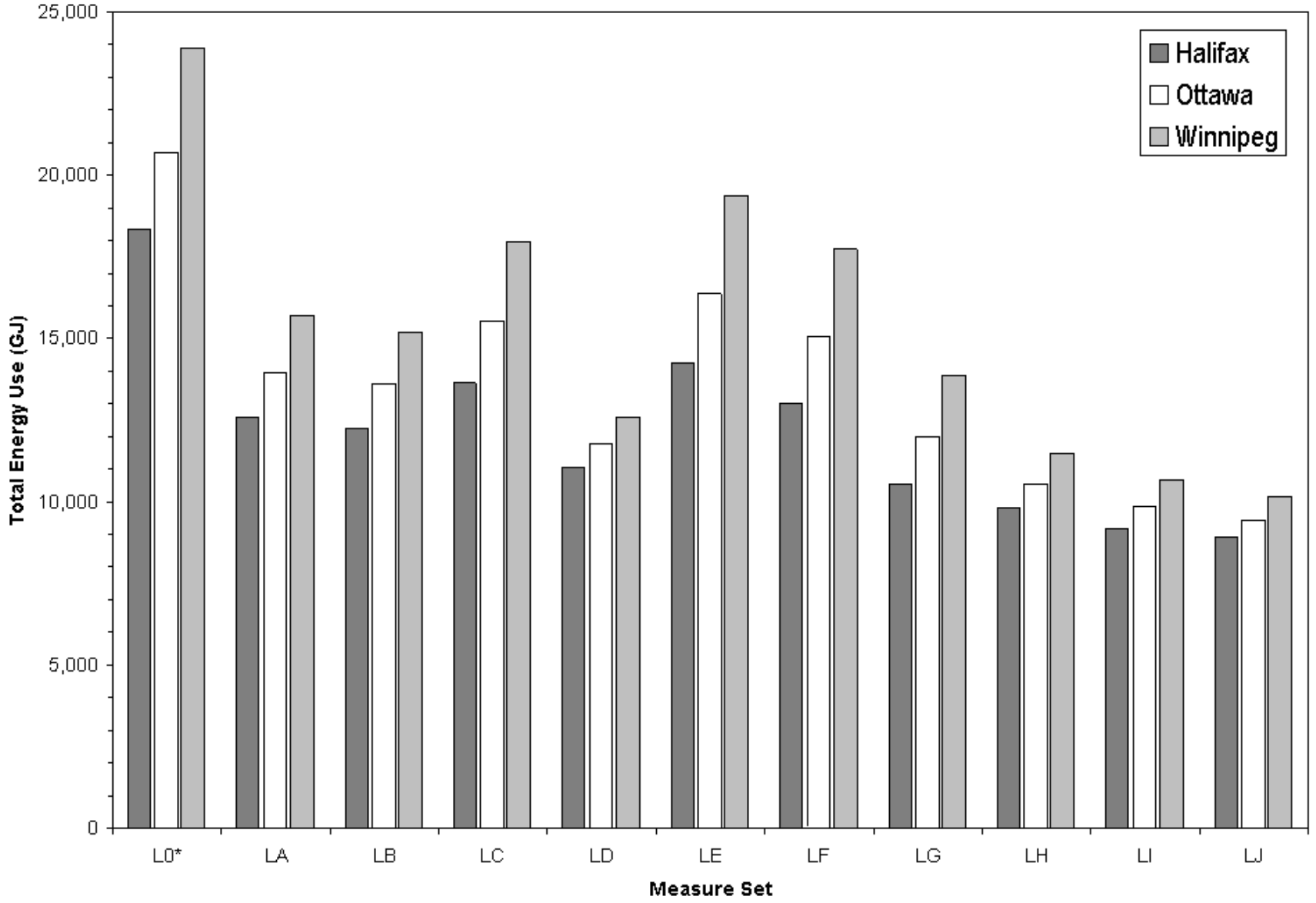
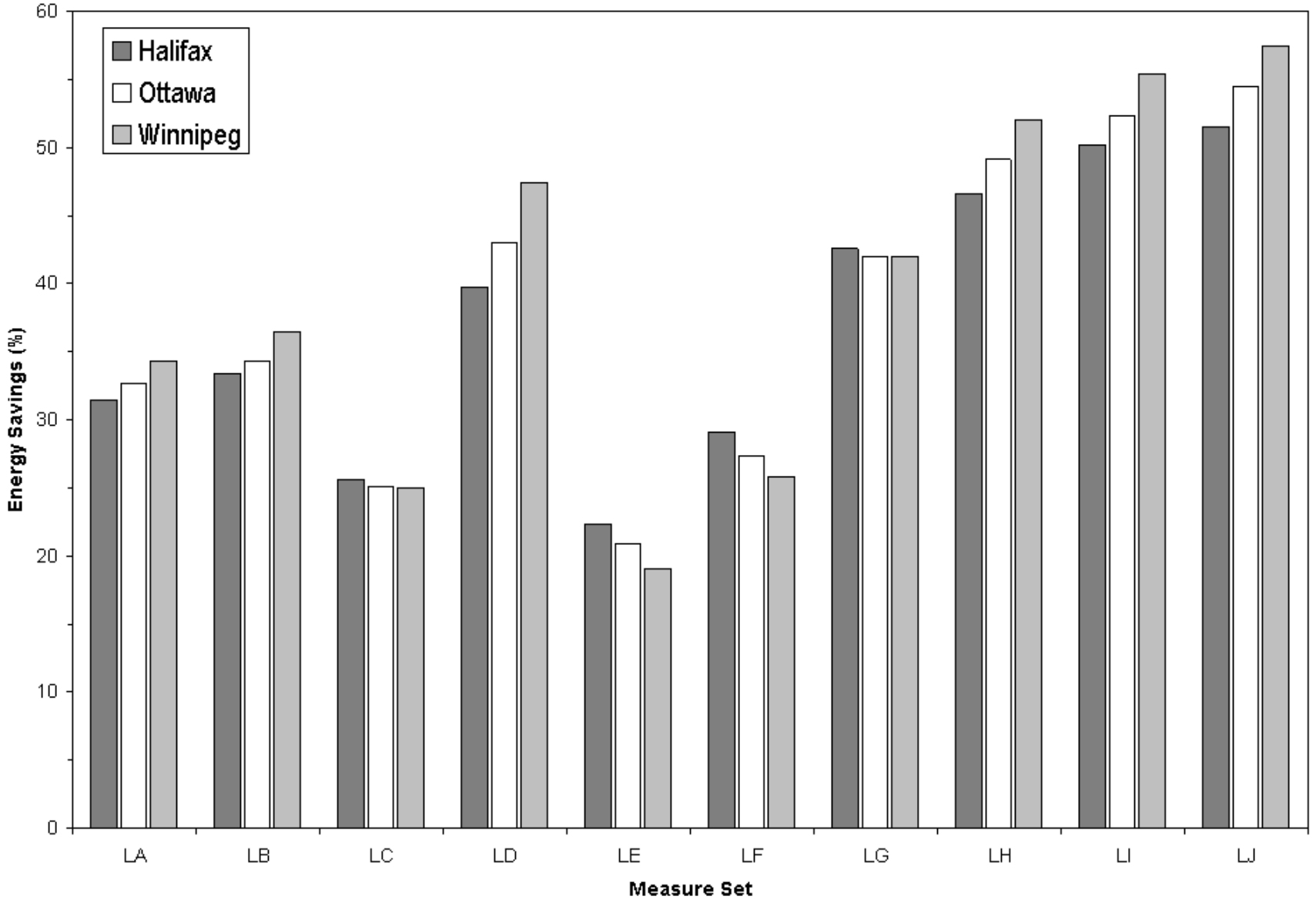


Figure 4.7: Comparison of Large Building Energy Savings by Location



5. MEASURE SET LIFE CYCLE COST ANALYSIS

5.1 Approach

A life cycle cost analysis was undertaken to evaluate the economic attractiveness of the various measure sets for each office building [1]. The inputs and results of the life cycle costing are shown in Tables 5.1 and 5.2 for the small and large office buildings respectively.

Savings and costs used in the life cycle analysis include the impact on equipment sizing. The sizing changes, shown in Tables 5.3 and 5.4, can result in a significant cost reduction for the measure sets. In order to realize the payback periods shown, equipment must be sized in accordance with load reductions. The predicted cost reductions gained by resizing the equipment are shown in Table 5.5.

A radiant panel system has a capital cost within 5% of the base case system (with no other measures implemented) [2]. It is therefore useful to set up a separate base case, for radiant panel systems, whose cost is approximately equivalent to the standard base case. This allows for a direct comparison of equipment sizing and energy savings for the measure sets which include radiant panel systems (SE, SF, SG, and LE, LF, LG).

The energy costs were calculated for each year of the analysis period using projected average annual escalation rates of commercial sector electricity and fuel input prices supplied by Natural Resources Canada [3]. A real discount rate of 10% was used to convert all future expenses and savings into current (2001) dollars. This allowed calculation of the net present value of the savings and costs. Also calculated were the actual (discounted) payback period and the simple payback period. These measures are calculated as follows.

Simple Payback was calculated as the period required for the incremental capital cost to be offset or paid-back by the resulting net savings in operating costs (ignoring any change in energy costs). If the incremental cost is negative, the simple payback period was considered to be 0.0 years, or immediate.

Actual Payback or discounted payback is that time required for the incremental capital cost to be just offset by the discounted net savings in operating costs. Here future energy costs are also corrected for predicted future cost escalation [1]. A negative incremental cost here also results in an instantaneous actual payback period.

Net Present Value of Savings was the sum, over the analysis period of each year's energy cost savings minus maintenance costs, discounted to the present, minus the original incremental capital cost. (Note: capital cost savings are added to Net Present Value of Savings).

Each of these quantities were calculated over a life-cycle analysis period of 20 years, the assumed life of the mechanical system. It was assumed that 100% of the incremental installed capital cost was incurred in the first year rather than some portion being borrowed. Maintenance costs were considered to remain constant in real terms. Real energy escalation rates are shown in Table B1 (i.e. net of inflation).

5.2 Results

The actual or discounted payback period of the energy efficiency measures is larger than the simple payback. The measure sets with smaller incremental costs saw a smaller increase from simple to actual payback. Generally, it can be stated that measure sets that save electricity are more attractive than those that save natural gas.

5.2.1 Small Office

There are several measure sets in the small building with immediate payback; SE, SF, SH, SI. Measures SE and SF are radiant panel systems with displacement ventilation. These systems have a similar cost to the base case, but they offer energy savings. Furthermore, significant sizing reductions, mainly in the cooling tower and chiller sizes, offset the incremental cost of the envelope and heat recovery measures. Because the elevator efficiency measures offer a net savings in capital cost, the capital cost of the other measures is further offset.

Measures SH and SI are hydronic water loop systems with water to air heat pumps. These systems also offer energy savings over the base case, but have an incremental cost over the base case. Other than the system type, these measures are the same as SE and SF, so either payback period is immediate for similar reasons. The impact of the added cost of the water loop heat pump system can be seen in the decreased net present value of the savings.

5.2.2 Large Office

In the large office, the radiant panel systems with displacement ventilation again show favorable results (LE, LF, LG). The payback period is not immediate in larger buildings due to the increased cost of implementing the envelope improvement measures.

Table 5.1: Life Cycle Cost Summary for the Small Office

City	Building	Measure Set	Incremental Installed Capital Cost	Incremental Maintenance Cost	Electricity Savings	Fuel Savings	Discount Rate	Simple Payback (yrs.)	Actual Payback (yrs)	Internal Rate of Return	Net Present Value Savings
Ottawa	Small Office	SA	$83,856	$9,593	$7,845	$8,504	10%	12.4	>20	8.9%	($7,035)
Ottawa	Small Office	SB	$60,690	$9,076	$8,260	$10,300	10%	6.4	8.8	18.1%	$42,430
Ottawa	Small Office	SC	$5,628	$10,403	$6,496	$16,086	10%	0.5	0.5	225.6%	$127,805
Ottawa	Small Office	SD	$241,200	$8,916	$5,202	$20,016	10%	14.8	>20	6.0%	($67,742)
Ottawa	Small Office	SE	($61,595)	$7,482	$19,953	$2,995	10%	immediate	immediate	infinite	$214,021
Ottawa	Small Office	SF	($37,432)	$6,206	$20,705	$8,688	10%	immediate	immediate	infinite	$264,863
Ottawa	Small Office	SG	$73,271	$6,222	$22,224	$13,318	10%	2.5	2.9	42.1%	$214,646
Ottawa	Small Office	SH	($37,761)	$13,922	$6,726	$10,906	10%	immediate	immediate	infinite	$91,398
Ottawa	Small Office	SI	($31,427)	$12,910	$10,302	$14,954	10%	immediate	immediate	infinite	$167,643
Ottawa	Small Office	SJ	$91,001	$12,992	$13,036	$17,683	10%	5.1	6.7	22.1%	$97,399
Ottawa	Small Office	SK	$128,439	$9,143	$9,958	$20,016	10%	6.2	8.6	18.1%	$87,442
Ottawa	Small Office	SL	$137,599	$8,916	$12,933	$20,016	10%	5.7	7.9	19.3%	$107,953
Ottawa	Small Office	SM	$656,238	$9,285	$18,520	$20,016	10%	22.4	>20	1.1%	($361,727)

Table 5.2: Life Cycle Cost Summary for the Large Office

City	Building	Measure Set	Incremental Installed Capital Cost	Incremental Maintenance Cost	Electricity Savings	Fuel Savings	Discount Rate	Simple Payback (yrs.)	Actual Payback (yrs)	Internal Rate of Return	Net Present Value Savings
Ottawa	Large Office	LA	$240,473	$13,668	$46,189	$57,691	10%	2.7	3.1	39.8%	$652,808
Ottawa	Large Office	LB	$492,900	$15,355	$50,540	$58,500	10%	5.3	7.2	20.6%	$434,709
Ottawa	Large Office	LC	$285,373	$5,037	$50,406	$35,813	10%	3.5	4.4	30.2%	$501,175
Ottawa	Large Office	LD	$607,691	$11,000	$51,988	$78,507	10%	5.1	6.9	21.3%	$571,265
Ottawa	Large Office	LE	$8,110	$5,448	$103,311	($6,041)	10%	0.1	0.1	1137.3%	$848,297
Ottawa	Large Office	LF	$171,673	$6,031	$112,218	$4,887	10%	1.5	1.8	65.8%	$872,486
Ottawa	Large Office	LG	$492,167	$2,937	$111,538	$44,048	10%	3.2	4.0	32.5%	$964,966
Ottawa	Large Office	LH	$1,386,804	($4,511)	$30,308	$114,207	10%	9.3	17.6	10.8%	$80,270
Ottawa	Large Office	LI	$1,531,903	($3,742)	$41,908	$114,207	10%	9.6	18.9	10.3%	$36,799
Ottawa	Large Office	LJ	$1,986,655	($3,742)	$50,995	$114,207	10%	11.8	>20	7.6%	($333,214)

Table 5.3: Small Office Building- Impact of Measure Sets on Equipment Sizing

HVAC And SHW Components		MNECB		Equipment Size as a Percent of Base Load												
		Base Case	Base Case (RP)	SA	SB	SC	SD	SE (RP)	SF (RP)	SG (RP)	SH	SI	SJ	SK	SL	SM
Gas Hot Water Boiler	(1,000 Btu/hr)	1177	1358	88%	75%	128%	-	104%	80%	68%	143%	128%	128%	-	-	-
Cooling Tower	(1000 Btu/hr)	-	1236	-	-	N/A	-	83%	65%	71%	N/A	N/A	N/A	-	-	-
Cooling Tower Pump	(HP)	-	-	-	-	N/A	-	-	-	-	N/A	N/A	N/A	-	-	-
Chiller	(1000 Btu/hr)	-	996	-	-	-	-	83%	65%	71%	-	-		-	-	-
Service HW boiler	-total storage vol. (gal)	75	75	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
	-total electric (kW)	21	21	100%	100%	100%	100%	100%	100%	136%	100%	100%	136%	100%	100%	136%
Circulation Pumps	-hot water (HP)	1.4	3.2	88%	80%	429%	738%	97%	87%	88%	480%	428%	430%	761%	678%	681%
	-cold water (HP)	-	9.2	-	-	-	-	97%	89%	90%	-	-	-	-	-	-
Packaged rooftop unit	-no. of units	5	-	100%	100%	-	-	-	-	-	-	-	-	-	-	-
	-hydron. htg (1,000 But/hr)	1150	-	86%	86%	-	-	-	-	-	-	-	-	-	-	-
	-cooling (tons)	156	-	94%	87%	-	-	-	-	-	-	-	-	-	-	-
	-max. air flow (cfm)	56343	-	93%	93%	-	-	-	-	-	-	-	-	-	-	-
Make Up Air Unit	-max. air flow (cfm)	-	3657	-	-	N/A	N/A	97%	97%	97%	N/A	N/A	N/A	N/A	N/A	N/A
Zone conditioning	-type	-	RP	-	-	WLHP	GSHP	RP	RP	RP	WLHP	WLHP	WLHP	GSHP	GSHP	GSHP
	-hydronic htg (1,000 Btu/hr)	-	2927	-	-	N/A	N/A	97%	87%	88%	N/A	N/A	N/A	N/A	N/A	N/A
	-hydronic cooling (tons)	-	175	-	-	N/A	N/A	97%	90%	90%	N/A	N/A	N/A	N/A	N/A	N/A
	-max. air flow (cfm)	-	56343	-	-	N/A	N/A	97%	92%	93%	N/A	N/A	N/A	N/A	N/A	N/A
Air to air heat recovery	-central (cfm)	-	-	-	N/A	N/A	-	-	N/A	N/A	-	N/A	N/A	-	N/A	N/A

RP denotes radiant panel heating. This system type has a separate base case for equipment sizing.

WLHP - Water Loop Heat Pump

GSHP - Ground Source Heat Pump

N/A - no base case cost for comparison

Table 5.4: Large Office Building- Impact of Measure Sets on Equipment Sizing

HVAC And SHW Components		MNECB		Equipment Size as a Percent of Base Load									
		Base Case	Base Case (RP)	LA	LB	LC	LD	LE (RP)	LF (RP)	LG (RP)	LH	LI	LJ
Gas Hot Water Boiler	(1,000 Btu/hr)	6676	8680	83%	88%	84%	74%	92%	91%	76%	-	-	-
Cooling Tower	(1000 Btu/hr)	7596	6816	81%	88%	87%	78%	83%	82%	70%	-	-	-
Cooling Tower Pump	(HP)	-	-	-	-	-	-	-	-	-	-	-	-
Chiller	(1000 Btu/hr)	6313	5664	81%	90%	89%	81%	83%	82%	70%	-	-	-
Service HW boiler	-total storage vol. (gal)	350	350	86%	86%	86%	86%	86%	86%	86%	86%	86%	86%
	-total electric (kW)	97	97	86%	86%	86%	86%	86%	102%	102%	86%	102%	102%
Circulation Pumps	-hot water (HP)	11.5	10.6	95%	100%	100%	95%	86%	85%	175%	442%	437%	437%
	-cold water (HP)	32.5	29.2	85%	91%	91%	84%	85%	84%	79%	-	-	-
Packaged VAV system	-no. of units	18	-	100%	100%	100%	100%	-	-	-	-	-	-
	-hydron. htg (1,000 But/hr)	10664	-	101%	101%	101%	101%	-	-	-	-	-	-
	-cooling (tons)	620	-	85%	91%	91%	84%	-	-	-	-	-	-
	-max. air flow (cfm)	172617	-	90%	90%	90%	89%	-	-	-	-	-	-
Make Up Air Unit	-max. air flow (cfm)	20826	20826	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Zone conditioning	-type	-	RP	-	-	-	-	RP	RP	RP	GSHP	GSHP	GSHP
	-hydronic htg (1,000 Btu/hr)	-	9694	-	-	-	-	86%	85%	74%	N/A	N/A	N/A
	-hydronic cooling (tons)	-	557	-	-	-	-	85%	84%	79%	N/A	N/A	N/A
	-max. air flow (cfm)	-	172617	-	-	-	-	84%	83%	81%	N/A	N/A	N/A
Air to air heat recovery	-central (cfm)	-	-	N/A	-	-	N/A	-	-	N/A	-	-	N/A

RP denotes radiant panel heating. This system type has a separate base case for equipment sizing.

WLHP - Water Loop Heat Pump

GSHP - Ground Source Heat Pump

N/A - no base case cost for comparison

Table 5.5: Impact of Measure Sets on HVAC Cost

HVAC - Sizing Effects							
Small Office				Large Office			
Base Case System Cost	Measure	Cost Savings Due to Sizing	Percent Savings Due to Sizing	Base Case System Cost	Measure	Cost Savings Due to Sizing	Percent Savings Due to Sizing
$345,882	SA	($19,466)	6%	**$1,432,177**	LA	($366,947)	26%
	SB	($57,671)	17%		LB	($268,343)	19%
	SC	($62,541)	18%		LC	($226,793)	16%
	SD	($74,387)	22%		LD	($448,658)	31%
	SE	($11,535)	3%		LE	($162,406)	11%
	SF	($38,735)	11%		LF	($170,413)	12%
	SG	($37,166)	11%		LG	($300,207)	21%
	SH	$35,061	-10%		LH	$261,450	-18%
	SI	($9,968)	3%		LI	$234,979	-16%
	SJ	$3,326	-1%		LJ	$239,443	-17%
	SK	($59,086)	17%				
	SL	($101,289)	29%				
	SM	($121,803)	35%				

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Performance and Economics

The performance and economics of the measure sets applied to the model office buildings have demonstrated that significant energy savings (upwards of 60% compared to the base case buildings) with attractive economic returns, are possible through careful selection and application of individual measures. Energy savings over 50% were achieved in four cases in the small office building with discounted payback periods between 2.5 and 6 years. The 50% savings relative to the MNECB is considered by many (i.e. NRCan's C 2000 Program) as the high performance threshold. Thus, the small office guidelines can contain a variety of measure sets to choose from to achieve this high performance level.

The large office building results were also encouraging. Five measure sets yielded energy savings between 42 and 55%. One of these, measure set LG had predicted a discounted payback period of 4 years.

6.2 CBIP Levels for New Buildings

Figure 4.3(a) illustrated that it is possible to achieve CBIP performance levels (i.e. 25%) at little or no incremental cost compared to the MNECB base case building. This may suggest that the MNECB is not that stringent for use as a standard for Public Works new buildings; that the CBIP performance level would seem economically justified. In fact, with careful consideration to measure selection and application, at the early stages of design, and adjusting equipment capacities to account for measure impacts, many designs result in energy savings in the 30 to 40% range with no incremental cost (i.e. immediate payback period).

6.3 Integrated Design Process

To successfully implement such a Program in Public Works, it would probably require that a more integrated design process involving energy simulation specialists to facilitate and support the architect and the mechanical/electrical engineers be encouraged. The energy specialist would work as an integral part of the design team to ensure that measures are properly planned and implemented and that their impacts are accounted for in HVAC equipment sizing.

6.4 Retrofit of Existing Buildings

The purpose of this investigation was to develop cost justified guidelines for reducing energy use in new small and large office buildings by as much as 60 to 70% compared to the Model National Energy Code, 1997. The existing stock of buildings operated and maintained by Public Works represent a much larger opportunity than new buildings for energy savings. While progress has been made in the area of no or low cost energy measures through the FBI program, significant opportunities remain. Many of the measures and results presented here (i.e. those with little or no incremental cost) would be applicable to existing buildings particularly where major system upgrades, replacements or building renewals/renovations are planned. There may even be cases where pre-mature replacement/retrofits could be justified on a life cycle cost basis (i.e. full cost economics).

Similar modelling and analysis should be undertaken to develop retrofit guidelines for existing

PWGSC building stock. New measure costing would need to be developed to reflect retrofit versus new construction situations. PWGSC would need to provide information on prototypical buildings to provide a basis or benchmark for the existing building stock. These buildings would be retrofited employing much the same approaches used here - analyze individual measures, one by one followed by sets of measures, using economics as the guiding criterion.

5. REFERENCES

1. Cost - Benefit Analysis, Chapter 6, “Guide to energy Efficiency in Masonry and Concrete Buildings” Masonry Council Canada, April 1982.

2. Appendix A, “Technical Guide Office Buildings” Commercial Building Incentive Program, Natural Resources Canada, 1999.

3. “Canada’s Emissions Outlook: 1997-2020" National Climate Change Process Analysis and Modelling Group, Natural Resources Canada, December 1998.

APPENDIX A

DESCRIPTIONS OF ENERGY REDUCING MEASURES

DESCRIPTIONS OF ENERGY REDUCING MEASURES

S1/ L1: Lighting Power Density of 11.5 W/m^2

The overall building lighting power density is limited to 11.5 W/m^2. Savings can be achieved by limiting the installed lighting load through the use of efficient fixtures, lamps and ballasts. Lighter coloured interior surfaces and furniture will allow suitable lighting levels to be maintained. The use of compact fluorescent rather than incandescent lamps, T8 lamps with electronic ballast rather than T12 with electromagnetic ballast, and surface rather than recessed lighting fixtures can all provide energy efficiency improvements.

S2/ L2: Perimeter Daylighting with Light Dimming

Daylight sensors and automatic controls are used to vary the output of the lighting systems according to the available daylight and the visual requirements of the spaces. This measure is applied to spaces within 12 feet of the building perimeter.

S3/ L3: Occupancy Sensors for Lighting

Occupancy sensors are installed throughout the building to switch off lighting in unoccupied areas. It is assumed that this provides a 30% reduction in lighting power consumption during occupied hours.

S4/ L4: Active Solar Shading

Motorized blinds, sensors, and automatic controls are installed on the South, East, and West sides of the building to control glare and heat gain through the windows.

S5/ L5: Add Low-E Coating to Windows

Radiative heat transfer through windows is reduced by adding a Low-Emissivity ("Low-E") coating to one of the panes. (A Low-E value of e = 0.1 is used.)

S6/ L6: Add Low-E Coating and Argon Fill to Windows

Radiative and convective heat transfer through windows is reduced by adding a Low-Emissivity coating (as above) plus an argon fill (rather than air) between the window panes.

S7/ L7: Add Low-E Coating, Argon Fill, and Vinyl Frames to Windows

Radiative, convective, and conductive heat transfer through windows is reduced by adding a Low-Emissivity coating and argon fill (as above) plus using vinyl frames (rather than aluminum).

S8/ L8: Triple Glazed, Low-E Coated, Argon Filled, Vinyl Framed Windows

Radiative, convective, and conductive heat transfer through windows is reduced by using triple glazing (rather than double), applying Low-Emissivity coatings to two of the panes, using argon fills between the panes, and using vinyl frames.

S9/ L9: Increase Wall Insulation by ΔRSI = 0.9

Heat transfer through the exterior walls is reduced by increasing the insulation level in the walls by ΔRSI = 0.9 (approximately R5).

S10/ L10: Condensing Boiler (Thermal Efficiency = 95%)

The energy consumption of the boiler is reduced by upgrading its thermal efficiency (i.e. full-load, steady-state efficiency) from 80% (i.e. MNECB level) to 95%.

S11/ L11: Central Air-to-Air Heat Recovery (60% Annual Effectiveness)

Heat recovery is implemented to reduce energy use for conditioning ventilation air. It is assumed that the sensible effectiveness of the heat recovery unit is 60%.

S12/ L12: Solar Air Pre-heating

- Small Office - 55 m^2 solar collector
- Large Office - 200 m^2 solar collector

This measure involves installing a perforated-plate solar ventilation air pre-heating system, such as the SolarWall™ (Conserval Engineering Inc). The solar collector is installed on the south-facing side of the building and is used to warm ventilation air before it is drawn into the air handling unit. A bypass-damper is installed so that the solar collector may be bypassed when solar heating is not desired (i.e. during the summer). The modeled collectors were sized to the maximum areas that could be reasonably installed on the buildings without significant changes to the architecture. This resulted in collectors that were approximately 10 feet in width, and of height equal to that of the respective buildings (60 feet for the small, and 216 feet for the large). One potential installation is depicted in Figure A.1.

S13/ L13: Install High Efficiency Motors on Supply Fans

This measure involves selecting motors with the highest available efficiencies (rather than minimum efficiencies) for the supply fans.

S14/ L14: Variable Speed Pump on Heating Loop

This measure involves using a variable speed drive (rather than constant speed) on the main heating circulation pump plus implementing controls to modulate the flow rate of the heating fluid with the heating load. This measure reduces the electrical energy used for pumping to

the minimum required to meet the load.

S15/ L15: Water-Loop Heat Pump System with Condensing Boiler and Cooling Tower

This measure involves using a Water-loop Heat Pump System (heat pumps must meet MNECB efficiency levels: EER = 10.0, COP = 3.8) with a Condensing Boiler (thermal efficiency = 95%) and Cooling Tower.

S16/ L16: Water-Loop Heat Pump System plus Thermal Storage

This measure is identical to S15/L15, except that the fluid capacity of the water-loop is increased in order to store thermal energy between periods of net heating and net cooling. (These periods would normally be on the order of hours.) The additional fluid capacity can be implemented by installing fluid storage tanks or by increasing the size of the piping in the water-loop. In this study, it is assumed that the fluid capacity of the water-loop system is increased by one third above its normal value.

S17/ L17: Water-Loop Heat Pump System with Ground Source

This measure is identical to S14/L14, except that a ground heat exchanger is used as the heat source and sink, rather than a boiler and cooling tower. The boiler used in a water loop heat pump system is replaced by a ground heat exchanger which extracts solar heat stored in the upper layers of the earth. In cooling, heat is rejected to the ground eliminating the need for a closed-circuit cooler or cooling tower, with lower operating costs because ground is cooler than outdoor air.

S18/ L18: Radiant Panel Heating and Cooling with Displacement Ventilation

This measure involves the implementation of a radiant panel heating and cooling system with displacement ventilation. The boiler is a high efficiency condensing boiler (thermal efficiency = 95%), and the chiller has a COP of 4.4. Ventilation air is 100% outdoor air. The temperature of the space is maintained by either radiant heating or cooling panels within the space. This measure reduces the fan electrical energy consumption as air recirculation is not needed. Fan energy is reduced to the amount required to just meet outdoor air requirements.

S19/ L19: Low Flow Faucets

This measure reduces the energy required for domestic water heating by reducing the water flow rates. It is assumed that this measure reduces the water flow by 20% compared to faucets that meet the requirements of the MNECB.

S20/ L20:Heat Pump Water Heaters

This measure involves the use of add-on heat pump water heaters (COP = 3.2) rather than

electric resistance heaters to provide domestic water heating. The heat pumps extract heat from the air of the zone in which they are located, and transfer this heat to the water. (A consequence of this process is that the air in the zone is cooled.) The heat pump water heaters should be installed in interior zones where the air must constantly be cooled.

S21/ L21:Solar Domestic Hot Water System

- Small Office - 36 m^2 of solar collectors, 200 gallons of thermal storage
- Large Office - 180 m^2 of solar collectors, 1000 gallons of thermal storage

This measure involves installing a solar domestic water heating system to preheat supply water before it is delivered to the distributed electric storage water heaters. This measure requires the installation of the solar heating system (including solar collectors and a storage tank), plus a separate piping system to deliver the preheated water to the electric storage heaters. The basic elements of the system are shown in Figure A.2.

The modeled system consisted of the following:
- flat plate solar collectors (total area as specified above)
- as manufactured by Thermo Dynamics Inc. (model S32), 3 m^2 each
- south facing, with tilt angle equal to the latitude (45°)
- a collector piping loop containing 50% propylene glycol solution (by volume)
- a heat exchanger (effectiveness = 0.8) to separate the potable water from the collector fluid
- two circulator pumps
- a temperature differential controller (not shown in the figure)
- a thermally stratified storage tank (volume as specified above)
- a tempering valve (to limit the water delivery temperature to 60°C)

Note: These systems were sized to displace approximately 50% of the annual base case domestic hot water electric loads.

S22/ L22: Photovoltaic Electricity Generation

- Small Office - 30 kWp[2] of photovoltaic panels
- Large Office - 120 kWp of photovoltaic panels

This measure involves installing a grid-connected photovoltaic electricity generation system. The system includes an array of photovoltaic panels, an array controller and DC-to-AC inverter, and grid interface equipment. The basic elements of the system are shown in Figure A.3. It is assumed that a net-metering arrangement can be established with the electricity provider, so that any power produced in excess of the building demand is sold to the grid at par value.

The modeled system consisted of the following:
- photovoltaic modules (with total rated capacity as specified above)
  - consisting of Kyocera Solar Inc. 120 kWp modules (model KC120-1)

[2]kWp = kilowatt peak = the rated power output of the array when exposed to 1000 W/m^2 of incoming solar radiation

- modeled as multiple 15 kWp arrays, each with 9 sets of 14 modules in series
- each module is 0.93 m^2
- rated power conversion efficiency of the modules is approximately 14%
- it is assumed that the modules are south-facing and tilted to the latitude (45°)
- 18.5 kW inverters (one for each array)
- based on Abacus Controls (model 7173-4-200)

S23/ L23: Microturbine with Heat Recovery (Cogeneration)

- Small Office - 25 kW Electrical Generation Capacity
- Large Office - 100 kW Electrical Generation Capacity

This measure involves installing a natural gas microturbine to produce electricity and waste heat. A heat recovery system is used to capture some of the waste heat and supply it to the building heating loads. It is assumed that the microturbine has an electrical generation efficiency of 35%, and a combined efficiency of 80%. It is assumed that the microturbine operates from 7 am to 7 pm on weekdays.

S24/ L24: Low Energy Office Equipment

This measure involves using only "Energy-Star" rated office equipment and activating all of the available energy saving features on this equipment. For example, computer monitors and hard drives turn themselves off if they are unused for a certain amount of time. (A computer could shut itself off completely if left long enough.) A photocopier could revert to a low power mode if unused for a certain amount of time.

S25/ L25: Elevator Energy Efficiency Measures

- Small Office - Install a hydraulic elevator rather than an overhead-geared elevator.
- Large Office - Install advanced elevator controls rather than using a silcon controlled rectifier.

S26/ L26: Increase Roof Insulation by ΔRSI = 0.9

Heat transfer through the roof is reduced by increasing the insulation level by ΔRSI = 0.9 (approximately R5).

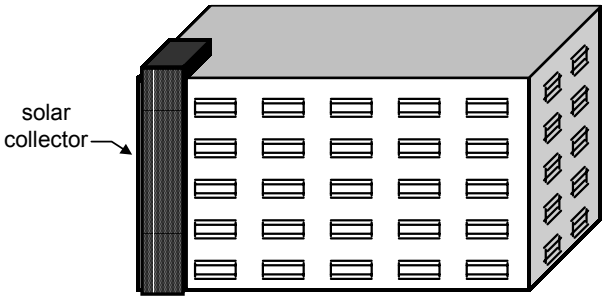
L27: High Efficiency Centrifugal Heat Recovery Chiller (COP = 6.3)

This measure involves the installation of a heat recovery ("Double Bundle") chiller with a COP of 6.3 at standard rating conditions. Recovered heat is used to meet the space heating load.

L28: Centrifugal Chiller Efficiency to COP = 6.3

This measure involves installing chillers with full load COP at standard rating conditions of not less than 6.3.

Figure A.1- Solar Air Pre-heating



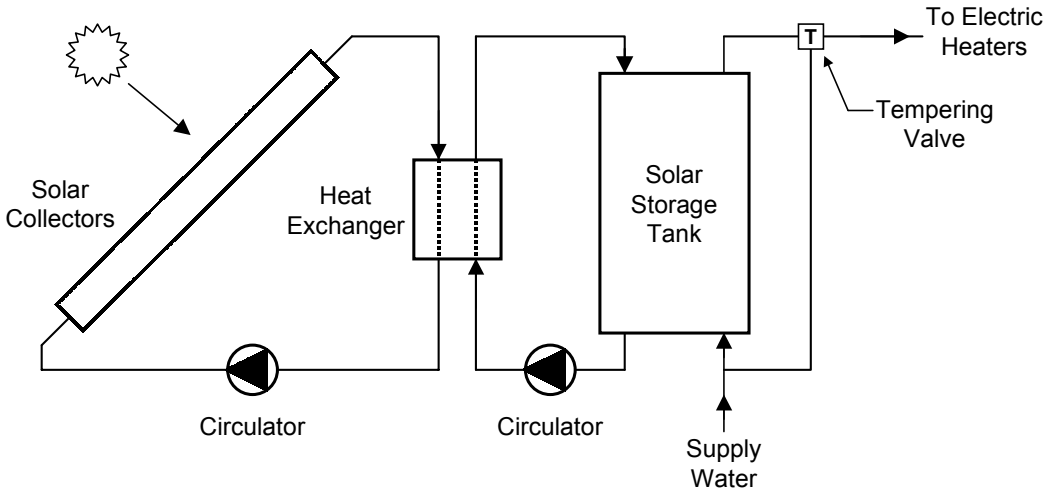


Figure A.2 - Solar Domestic Hot Water System

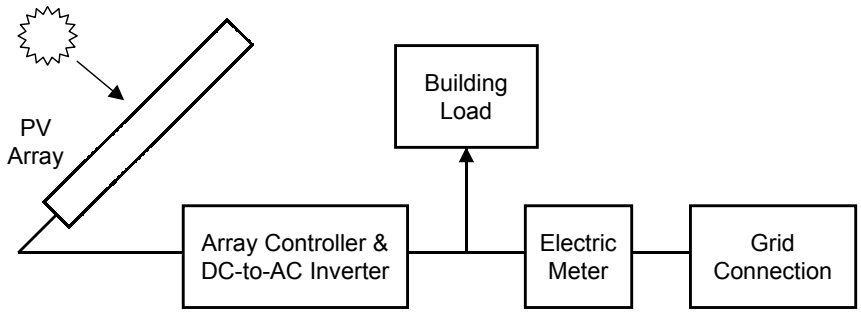


Figure A.3 - Photovoltaic Electricity Generation

APPENDIX B

ENERGY ESCALATION RATES

Table B1: Energy Escalation Rates

Fuel Escalation Rates Calculated from NRCan Fuel Cost Projections										Interpolated:		
	Ontario			Alberta			Quebec			Manitoba		
Year	Elec.	N.G.	L.F.O.	Elec.	N.G.	L.F.O.	Elec.	N.G.	L.F.O.	Elec.	N.G.	L.F.O.
1990	-	-	-	-	-	-	-	-	-	-	-	-
1991	8.49%	1.18%	0.14%	8.04%	0.97%	0.53%	0.76%	-0.47%	-2.85%	3.20%	2.11%	1.24%
1992	7.82%	1.17%	0.14%	7.44%	0.96%	0.53%	0.76%	-0.48%	-2.94%	3.10%	2.07%	1.22%
1993	7.26%	1.15%	0.14%	6.93%	0.95%	0.53%	0.75%	-0.48%	-3.03%	3.01%	2.02%	1.21%
1994	6.76%	1.14%	0.14%	6.48%	0.94%	0.52%	0.75%	-0.48%	-3.12%	2.92%	1.98%	1.19%
1995	6.34%	1.13%	0.14%	6.08%	0.93%	0.52%	0.74%	-0.48%	-3.22%	2.84%	1.95%	1.18%
1996	0.00%	4.44%	6.95%	1.84%	14.97%	3.42%	1.84%	7.84%	-0.05%	1.83%	6.39%	3.81%
1997	0.00%	4.25%	6.50%	1.80%	13.02%	3.31%	1.80%	7.27%	-0.05%	1.80%	6.01%	3.67%
1998	0.00%	2.61%	-2.59%	1.90%	3.25%	1.96%	2.97%	2.46%	-0.03%	1.90%	2.82%	0.55%
1999	0.00%	2.55%	-2.66%	1.86%	3.14%	1.92%	2.89%	2.40%	-0.03%	1.87%	2.74%	0.55%
2000	0.00%	2.48%	-2.73%	1.83%	3.05%	1.89%	2.81%	2.35%	-0.03%	1.83%	2.67%	0.55%
2001	0.49%	2.02%	1.75%	2.30%	2.34%	1.29%	1.64%	1.99%	1.83%	2.29%	2.18%	1.69%
2002	0.48%	1.98%	1.72%	2.25%	2.28%	1.28%	1.61%	1.95%	1.80%	2.24%	2.14%	1.66%
2003	0.48%	1.94%	1.69%	2.20%	2.23%	1.26%	1.59%	1.92%	1.77%	2.19%	2.09%	1.63%
2004	0.48%	1.90%	1.67%	2.15%	2.18%	1.24%	1.56%	1.88%	1.74%	2.14%	2.05%	1.61%
2005	0.48%	1.87%	1.64%	2.11%	2.14%	1.23%	1.54%	1.84%	1.71%	2.10%	2.01%	1.58%
2006	1.70%	2.16%	1.67%	1.70%	2.52%	1.72%	1.70%	2.13%	1.83%	1.71%	2.28%	1.76%
2007	1.67%	2.11%	1.65%	1.67%	2.46%	1.69%	1.67%	2.08%	1.79%	1.68%	2.23%	1.73%
2008	1.65%	2.07%	1.62%	1.64%	2.40%	1.66%	1.64%	2.04%	1.76%	1.65%	2.18%	1.70%
2009	1.62%	2.03%	1.59%	1.61%	2.34%	1.64%	1.62%	2.00%	1.73%	1.63%	2.13%	1.67%
2010	1.59%	1.99%	1.57%	1.59%	2.29%	1.61%	1.59%	1.96%	1.70%	1.60%	2.09%	1.65%
2011	8.19%	8.88%	9.51%	8.27%	9.64%	9.83%	8.47%	9.11%	8.37%	8.23%	9.47%	9.79%
2012	8.08%	9.16%	9.67%	8.05%	10.05%	9.66%	7.81%	9.59%	9.46%	8.04%	9.80%	9.83%
2013	-2.49%	-2.80%	-2.94%	-2.48%	-3.04%	-2.94%	0.00%	-2.92%	-2.88%	-2.48%	-2.98%	-2.98%
2014	-2.56%	-2.88%	-3.03%	-2.55%	-3.14%	-3.02%	0.00%	-3.00%	-2.97%	-2.54%	-3.07%	-3.08%
2015	-2.62%	-2.96%	-3.12%	-2.61%	-3.24%	-3.12%	0.00%	-3.10%	-3.06%	-2.61%	-3.16%	-3.17%
2016	1.62%	1.83%	1.93%	1.61%	2.01%	1.93%	0.00%	1.92%	1.89%	1.61%	1.96%	1.97%
2017	1.59%	1.80%	1.90%	1.58%	1.97%	1.90%	0.00%	1.88%	1.86%	1.58%	1.92%	1.93%
2018	1.57%	1.77%	1.86%	1.56%	1.93%	1.86%	0.00%	1.85%	1.82%	1.56%	1.89%	1.89%
2019	1.54%	1.74%	1.83%	1.54%	1.90%	1.83%	0.00%	1.81%	1.79%	1.53%	1.85%	1.86%
2020	1.52%	1.71%	1.79%	1.51%	1.86%	1.79%	0.00%	1.78%	1.76%	1.51%	1.82%	1.82%

APPENDIX C

SUMMARY OF COST ESTIMATION PROCEDURES

The Means City Cost Index [1] provides city-specific multipliers which are applied to Means' average U.S. costs and, for Canada, result in a conversion to Canadian dollars. The multipliers are given for material, labour, and a weighted total for each of the building divisions. The average location factor for Canada is used to adjust Means cost data.

Where available cost data is several years old, no inflation value has been added.

Most components have been modeled using a linear approximation of the cost as a function of another variable. This allowed interpolation between available data points (equipment sizes). The quality of the linear fit was evaluated subjectively and can be considered valid for all variables. Since capital costs are determined using a linear model, the actual availability of particular equipment sizes has not been investigated. It is assumed that this error is negligible.

MECHANICAL SYSTEM AND BUILDING COMPONENTS

Packaged Rooftop Units

Means Mechanical Cost data [1] was used to estimate the cost of rooftop air-conditioning units. The rooftop air-conditioner for the large office was VAV, single-zone, gas-fired, with electric cooling, standard controls, curb and economizer. A linear regression analysis allowed the costs of the units to be determined as a function of cooling capacity [1].

The small office is served by an individual zone packaged rooftop unit, with DX cooling and an economizer. The cost of the small office unit was determined using linear regression on the cooling capacity [1].

Water-Source Heat Pump (WSHP) System

The cost of the WSHP system was determined using the water source heat pump system cost estimator [3]. The costs given include: circulation pumps, the heat pumps, closed circuit cooler, mechanical room piping, controls, chemical treatment, ducting and piping for each heat pump, loop piping, condensate drains and installation. Although, this estimation method includes some ducting to each heat pump, an additional makeup air unit and ducting for fresh air to each heat pump is required (further discussion is contained below in the ductwork section). In the calculation, it was assumed that the heat pump units had an average capacity of 4 tons. The costs for the heat pumps were modified slightly using more recent data [1].

Ground Source Heat Pump (GSHP) System

Capital costs for WSHP systems [3] can be used to estimate costs for GSHP systems by adding factors which account for differences in system components [14]. Examples of differences between GSHP systems and WSHP systems are: a GSHP system requires a ground heat exchanger, larger circulation pumps, larger pipe, pipe insulation and larger, extended range heat pumps. A recent survey of twenty-three GSHP sites [15] was also used for data on borehole lengths for the ground heat exchanger. As with the WSHP system above, heat pumps were sized at a nominal four tons each. A makeup air unit and fresh-air ductwork was needed to complete the system (see ductwork section). The costs given are for all the system components except the fresh-air ductwork, and the make-up air unit.

Storage

In order to increase the efficiency of a hydronic loop, extra water storage is added. This is accomplished by increasing the pipe sizes in the loop. From Means [1] it can be seen that the cost of pipe per linear foot is approximately equal to 5.4*exp(diameter/2). The storage capacity of the system is increased to 21.25 gal/ton from 15 gal/ton. This corresponds to a change in pipe diameter of approximately 19%. An initial average pipe diameter of 3" is assumed. The calculated cost increase is therefore 33%. This increases the piping costs for the buildings from $42/ton to $55/ton for an incremental cost of $13/ton.

Heat Recovery

A linear regression analysis was performed to determine costs as a function of air-flow capacity for heat recovery wheels. Pricing was obtained from Means [1]. The heat recovery wheel must be used in conjunction with a Make-up Air Unit.

Make-up Air Unit

The make-up air unit was priced as a function of capacity [1] in cfm.

Radiant Ceiling

A Canadian manufacturer of radiant ceiling panels [20] was contacted to obtain pricing for the radiant ceiling. Pricing is based on the square footage of the panels; panels are 2 ft. wide and run the length of the outside wall. Costs for the hydronic piping, to serve the radiant panels, are assumed to be similar to that for the WSHP system [3]. The cost of displacement ventilation includes the cost of the makeup air unit, and the required ducting, which is significantly reduced from the base case (see ductwork section below).

Cooling Tower

Cost data for packaged cooling towers is available in Means [1]. Costs were not explicitly given for water-side economizers and have been assumed to add 5% to the overall cost of the cooling tower.

Chiller

Costs were estimated by performing a linear regression analysis on water chiller data [1] with respect to cooling capacity. For increased efficiency chillers, a relative cost multiplier [2] was used. A water-cooled, reciprocating, multi-compressor, semi-hermetic chiller was specified for the small office, where required. For the large office, a water-cooled centrifugal chiller was chosen. The incremental cost for a heat recovery chiller was determined on a per ton basis [21].

Condensing Boiler

Costs for high efficiency condensing boilers were obtained from manufacturers [17]. However, since there were discrepancies between the manufacturer's data and an industry survey [16], the two estimates were averaged and a linear regression was used to give cost as a function of heating capacity. Installation and labour costs for the condensing boiler was estimated at 40% of the material cost [18].

Service Hot Water

Costs for water heater storage tanks were obtained from Means [1].

Circulating Pumps

Circulating pumps were priced as a linear function of horsepower [1]. Circulating pumps are included in the cost of the WSHP and GSHP systems and are not itemized separately.

Ductwork

The amount of ductwork is given as a cost per ton of cooling [1] to reflect the heat-carrying capacity of the delivered air. Therefore, it is apparent that as cooling requirements decrease, so will the amount and cost of ductwork. For most of the systems specified, the ductwork requirements follows the requirement of $1275 per ton of cooling.

For distributed systems such as the water-source and ground-source heat pump systems, the ducting requirement is less. Each heat pump has a certain amount of ducting associated with it for serving the zone [3]. A makeup air unit supplies fresh air to the heat pumps and exhausts to the ambient. Since the makeup air requirement is low, the ductwork required is not as large as the central system. It is assumed that the cost of ductwork is associated with the mass of material, which is proportional to the outside perimeter of the ductwork. Therefore, the cost of the ductwork has been scaled proportionally to the size of ductwork, assuming similar air flow velocities. The result is that ductwork costs per ton can be scaled by the ratio of the volumetric flow rates to the power of 0.5.

For the case of displacement ventilation with radiant heating, the heat-carrying capacity of the fresh air is inconsequential. Thus, the fresh air delivery can be accomplished using smaller ductwork, scaled according to the methodology described above.

Hydronic Piping

For most systems, hydronic piping costs are a function of the cooling capacity and are based on the costs given for WSHP systems. Comparisons with piping costs for assemblies given in Means [1], affirms that this is a reasonable estimate. For the WLHP and GSHP systems the hydronic piping is included in the incremental cost.

Windows

Cost information was available for windows [10] with various features such as tinting, low emissivity coating, argon fill, and triple glazing. Cost information was available for aluminum, and vinyl window frames.

Walls

A linear regression analysis of wall construction cost information [11] was used to estimate the increased cost of higher insulation levels (RSI). Metal stud wall constructions were used for estimating costs.

Roof

Linear regression analysis of cost information [11] provided the basis for estimating roof costs as a function of the RSI value.

Fluorescent Lighting

Lighting cost models [4], [7] were used to determine typical, and upgraded lighting costs. To meet the lighting load requirement of 10.8W/m^2, a 60W fixture can be selected and the standard spacing of 5.95m^2 (64ft^2) per fixture (for offices) [5] can be retained. Similarly, a 70W fixture can be used to meet the 11.5W/m^2 requirement. The 60 Watt fixture contains two T8 lamps with an electronic ballast and the 70 Watt fixture contains two T8 lamps with an energy-efficient magnetic ballast [19].

Daylighting Controls

It is assumed that daylighting controls, with dimmable ballasts cost approximately \$0.54/ft^2 [9] which includes the cost of an upgraded dimmable ballast, a photosensor, and a powerpack. It is assumed that one photosensor is required for every six work areas of approximately 8x8 feet (and a hallway) and is installed on the outer 20 ft of the building.

Occupancy Controls

A ceiling mounted occupancy control unit costs approximately \$170 and is assumed to operate lighting for six work areas (8x8 feet with a hallway).

Active Solar Shading

Costs were obtained directly from distributors and manufacturers [12],[13] for shading systems with photo-sensors and motors. Incremental costs were comparable between the two manufacturers, averaging \$858 per window (5'x6'). Since the costs were given on a per window basis, they yield unreasonable results when applied to an entire building. Some assumptions were made which better approximate a large system: i) the motor represented 50% of the incremental cost, the sensor and labour equally dividing the rest; ii) one motor would be suitable for 10 ft of window; iii) only one sensor was needed per floor per side; iv) the labour can be attributed to the motor; iv) active solar shading is needed only on one side of the building.

Low-Flow Shower and Bath Fixtures

There is no incremental cost for these fixtures over conventional ones.

Low Energy Office Equipment

The energy consumption of CPU's monitors, laser printers, copiers, and faxes. The vast majority of office equipment in use today comply with US Environmental Protection Agency's ENERGY STAR office equipment program [26]. It is assumed that only laser printers, copiers and fax machines are left on during off hours, and all equipment is running during occupied hours. The current average ENERGY STAR implementation rates were compared to full implementation. This resulted in a total reduction in energy consumption of 35.4% from office equipment [26]. Since most office equipment is ENERGY STAR compliant (the features are disabled) there is no capital cost for this measure.

Elevator Efficiency Measures

For the small office, a conventional overhead geared elevator is replaced with a hydraulic elevator. This results in a cost savings of $70,000 [27]. A control system was added to the elevators in the large office to improve efficiency by 30% over a silicon controlled rectifier. The incremental capital cost of this system is $7,000 per elevator, or $28,000 [28].

Heat Pump Water Heaters

Heat pump water heaters were costed based on kilowatts of hot water output [29]. This resulted in an incremental cost of $12,947 and $59,804 for the small and large offices respectively. A conventional hot water heater must be added to this cost.

High Efficiency Motors on Supply Fans

Except for very large motors, performance improvements of premium efficiency motors over new Canadian standards is negligible. Therefore no costing information is provided for premium efficiency motors.

Solar Thermal Domestic Hot Water System

Means cost data was used to determine the cost of a domestic hot water solar preheat system [1]. A standard costing package was used, with modifications to the collector panel area, racking, storage tank and heat transfer fluid, copper tubing and pipe covering to suit the building sizes. The resulting incremental cost was $22,632 $100,844 for the small and large offices respecitvely.

Solar Air Preheating System

Costs for solar air preheating systems were determined using RETScreen cost analysis software. This resulted in an incremental cost of $83,490 for the large office, and $30,096 for the small office [30].

Photovoltaic Electric Array

Also using RETScreen cost analysis software, a cost for a photovoltaic generation array was generated [30]. The cost of such a system for the large office was $1,527,622, and $399,923 for the small office.

Maintenance

A number of general assumptions were made in the process of deriving the incremental maintenance costs used in the life cycle costing analysis, as follows:

- building envelope maintenance costs do not change from the base case;
- many of the maintenance costs for chillers, cooling towers, boilers and rooftop equipment were based on an EPRI report [22];
- costs for lighting maintenance in offices include only the cost of lamp and ballast replacement; labour was assumed to be the same for both conventional and high efficiency units;
- ventilation system maintenance costs were the same for central systems and HRV systems, based on a conversation with an experienced practitioner [7];

Specific details and assumptions used in the development of maintenance cost estimates are presented below:

- water-cooled reciprocating chiller maintenance costs were interpolated between $2500 US for 10 tons and $9000 US for 185 tons [22]; chiller maintenance costs do not vary with efficiency;
- cooling tower maintenance costs were determined by combining the costs for repairs and the costs for yearly preventative procedures [25]. For a 50 ton unit, the resulting maintenance cost is $700 per year. Costs for smaller-sized units were interpolated on a per ton basis;
- rooftop air conditioner costs were interpolated between $40 US/ton for 3 tons and $80 US/ton for 60 tons [22];
- water source heat pump maintenance costs were interpolated between $20 US/ton for 0.5 tons, $40 US/ton for 75 tons [22];
- ground source heat pump system maintenance costs are $0.065 US per square foot [23];
- maintenance for space and SHW boilers costs $1.67 US/kBtu for standard efficiency, $3.33 US/kBtu for high efficiency [22];
- heat recovery chiller costs were interpolated between $11,000 US for 500 tons and $15,000 US for 1,000 tons;
- circulating pump maintenance costs were assumed to be $200 per year (i.e. one 4 hour visit at $50 per hour per year), and are insensitive to size. Therefore pump maintenance costs do not contribute to incremental maintenance costs;
- lighting maintenance costs for fluorescent tubes - for the base case: the two F40 tubes cost $3 and the conventional ballast costs $8.50 to replace; for 10.8 W/m^2, the two T8's cost $10 and the ballast costs $24 to replace; for 11.5 W/m^2, the ballast costs $15. For the office buildings, lighting schedules [24] dictate 3000 hours per year of operation. Lamp life is 20,000 hours and ballast life is 50,000 hours [6]. Therefore 15% of lamps and 6% of ballasts are replaced annually. Labour costs are the same and provided at the same frequency for both types of light ;
- incandescent lamps must be replaced every 2,500 hours and compact fluorescent lamps (CFLs) every 10,000 hours and their ballasts every 50,000 hours [8]. Lighting schedules[24] were used to determine the hours of operation for lights in various locations in the hotel: corridors (8800 hrs/yr., suites 3000 hrs/yr., and the lobby 8000 hrs/yr.). Labour costs for lamp replacement must be considered because replacement frequency is higher for incandescent bulbs than CFLs. Labour costs are $4.20 per lamp assuming this is done by in-house staff [25] and $37.50 to replace the CFL ballast (it is assumed that the incandescent fixture does not require replacement.
- A maintenance cost of $50-$100 is estimated for heat pump water heaters [29]. A value of $75 dollars per year was used. This cost does not depend on size.

- Photovoltaic panels require little or no maintenance. Components like the inverter are more susceptible to failure. An annual maintenance cost of $100 is used for the PV systems [30].

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APPENDIX D

DETAILED MEASURE COSTS

BUILDING ENVELOPE AND LIGHTING INCREMENTAL COSTS
Ottawa - Small office

Measure Set SA		**Measure Set SB**		**Measure Set SC**	
Lighting	$10,790	Lighting	$10,790	Lighting	$10,790
Window	$58,032	Window	$58,032	Window	$58,032
Wall	$0	Wall	$0	Wall	$0
Roof	$0	Roof	$0	Roof	$0
Inc. Cost	$68,822	Inc. Cost	$68,822	Inc. Cost	$68,822

Measure Set SD		**Measure Set SE**		**Measure Set SF**	
Lighting	$10,790	Lighting	$10,790	Lighting	$10,790
Window	$58,032	Window	$0	Window	$27,144
Wall	$9,180	Wall	$0	Wall	$9,180
Roof	$0	Roof	$0	Roof	$0
Inc. Cost	$78,002	Inc. Cost	$10,790	Inc. Cost	$47,114

Measure Set SG		**Measure Set SH**		**Measure Set SI**	
Lighting	$10,790	Lighting	$10,790	Lighting	$10,790
Window	$108,576	Window	$0	Window	$27,144
Wall	$9,180	Wall	$0	Wall	$9,180
Roof	$5,462	Roof	$0	Roof	$0
Inc. Cost	$134,008	Inc. Cost	$10,790	Inc. Cost	$47,114

Measure Set SJ		**Measure Set SK**		**Measure Set SL**	
Lighting	$10,790	Lighting	$10,790	Lighting	$10,790
Window	$108,576	Window	$0	Window	$27,144
Wall	$9,180	Wall	$0	Wall	$9,180
Roof	$5,462	Roof	$0	Roof	$0
Inc. Cost	$134,008	Inc. Cost	$10,790	Inc. Cost	$47,114

Measure Set SM	
Lighting	$10,790
Window	$108,576
Wall	$9,180
Roof	$5,462
Inc. Cost	$134,008

HVAC INCREMENTAL COSTS
Ottawa - Small office

Measure Set SA		**Measure Set SB**		**Measure Set SC**	
Rooftop	($11,825)	Rooftop	($25,809)	Rooftop	($184,329)
Ductwork	($9,095)	Ductwork	($19,851)	Ductwork	($120,173)
Heat Recovery	$0	Heat Recovery	$6,117	Heat Recovery	$6,117
Make-Up Air Unit	$0	Make-Up Air Unit	$0	Make-Up Air Unit	$5,624
Hydronic Piping	$0	Hydronic Piping	$0	Hydronic Piping	$0
Circulating Pump	($32)	Circulating Pump	($51)	Circulating Pump	$1,419
Hot Water Boiler	$35,986	Hot Water Boiler	$31,462	Hot Water Boiler	$2,152
Chiller	$0	Chiller	$0	Chiller	$0
Cooling Tower	$0	Cooling Tower	$0	Cooling Tower	$12,239
	$0		$0	WLHP	$204,607
	$0		$0		$0
Inc. Cost	$15,034	Inc. Cost	($8,132)	Inc. Cost	($72,344)

Measure Set SD		**Measure Set SE**[1]		**Measure Set SF**[1]	
Rooftop	($184,329)	Rooftop	$0	Rooftop	$0
Ductwork	($117,629)	Ductwork	($1,747)	Ductwork	($4,326)
Heat Recovery	$0	Heat Recovery	$0	Heat Recovery	$6,117
Make-Up Air Unit	$5,631	Make-Up Air Unit	($76)	Make-Up Air Unit	($79)
Hydronic Piping	$0	Hydronic Piping	($2,576)	Hydronic Piping	($8,003)
Circulating Pump	$1,662	Circulating Pump	($73)	Circulating Pump	($260)
Hot Water Boiler	($11,464)	Hot Water Boiler	$344	Hot Water Boiler	($1,753)
Chiller	$0	Chiller	($6,263)	Chiller	($12,862)
Cooling Tower	$0	Cooling Tower	($1,144)	Cooling Tower	($2,530)
GSHP	$469,327	Radiant Panels	$0	Radiant Panels	$0
	$0		$0		$0
Inc. Cost	$163,198	Inc. Cost	($11,535)	Inc. Cost	($23,696)

[1] Radiant panel base case

HVAC INCREMENTAL COSTS
Ottawa - Small office

Measure SG[1]	Base case: Radiant Panel
Rooftop	$0
Ductwork	($4,355)
Heat Recovery	$6,117
Make-Up Air Unit	($80)
Hydronic Piping	($8,053)
Circulating Pump	($243)
Hot Water Boiler	($2,844)
Chiller	($10,625)
Cooling Tower	($2,044)
Radiant Panels	$0
HP Water Heater	$12,947
Inc. Cost	($9,180)

Measure Set SH	
Rooftop	($184,329)
Ductwork	($116,664)
Heat Recovery	$0
Make-Up Air Unit	$5,634
Hydronic Piping	$0
Circulating Pump	$1,621
Hot Water Boiler	$55,271
Chiller	$0
Cooling Tower	$19,497
WLHP (plus storage)	$231,269
	$0
Inc. Cost	$12,299

Measure Set SI	
Rooftop	($184,329)
Ductwork	($120,189)
Heat Recovery	$6,117
Make-Up Air Unit	$5,628
Hydronic Piping	$0
Circulating Pump	$1,414
Hot Water Boiler	$49,803
Chiller	$0
Cooling Tower	$17,589
WLHP (plus storage)	$206,276
	$0
Inc. Cost	($17,691)

Measure Set SJ	
Rooftop	($184,329)
Ductwork	($118,607)
Heat Recovery	$6,117
Make-Up Air Unit	$5,627
Hydronic Piping	$0
Circulating Pump	$1,424
Hot Water Boiler	$50,041
Chiller	$0
Cooling Tower	$17,679
WLHP (plus storage)	$217,651
HP Water Heater	$12,947
Inc. Cost	$8,550

Measure Set SK	
Rooftop	($184,329)
Ductwork	($116,664)
Heat Recovery	$0
Make-Up Air Unit	$5,634
Hydronic Piping	$0
Circulating Pump	$1,721
Hot Water Boiler	($11,464)
Chiller	$0
Cooling Tower	$0
GSHP	$483,601
	$0
Inc. Cost	$178,499

Measure Set SL	
Rooftop	($184,329)
Ductwork	($120,189)
Heat Recovery	$6,117
Make-Up Air Unit	$5,628
Hydronic Piping	$0
Circulating Pump	$1,504
Hot Water Boiler	$11,464
Chiller	$0
Cooling Tower	$0
GSHP	$431,140
	$0
Inc. Cost	$151,335

Measure Set SM	
Rooftop	($184,329)
Ductwork	($120,044)
Heat Recovery	$6,117
Make-Up Air Unit	$5,627
Hydronic Piping	$0
Circulating Pump	$1,514
Hot Water Boiler	($11,464)
Chiller	$0
Cooling Tower	$0
GSHP	$433,400
HP Water Heater	$12,947
Inc. Cost	$143,768

[1] Radiant panel base case

OTHER INCREMENTAL COSTS
Ottawa - Small office

Measure Set SA	
Daylighting Controls	$0
Occupancy Sensors	$0
Other	$0
Inc. Cost	$0

Measure Set SB	
Daylighting Controls	$0
Occupancy Sensors	$0
Other	$0
Inc. Cost	$0

Measure Set SC	
Daylighting Controls	$9,150
Occupancy Sensors	$0
Other	$0
Inc. Cost	$9,150

Measure Set SD	
Daylighting Controls	$0
Occupancy Sensors	$0
Other	$0
Inc. Cost	$0

Measure Set SE	
Daylighting Controls	$9,150
Occupancy Sensors	$0
Efficient Elevator	($70,000)
Inc. Cost	($60,850)

Measure Set SF	
Daylighting Controls	$9,150
Occupancy Sensors	$0
Efficient Elevator	($70,000)
Inc. Cost	($60,850)

Measure Set SG	
Daylighting Controls	$0
Occupancy Sensors	$18,443
Efficient Elevator	($70,000)
Inc. Cost	($51,557)

Measure Set SH	
Daylighting Controls	$9,150
Occupancy Sensors	$0
Efficient Elevator	($70,000)
Inc. Cost	($60,850)

Measure Set SI	
Daylighting Controls	$9,150
Occupancy Sensors	$0
Efficient Elevator	($70,000)
Inc. Cost	($60,850)

Measure Set SJ	
Daylighting Controls	$0
Occupancy Sensors	$18,443
Efficient Elevator	($70,000)
Inc. Cost	($51,557)

Measure Set SK	
Daylighting Controls	$9,150
Occupancy Sensors	$0
Efficient Elevator	($70,000)
Inc. Cost	($60,850)

Measure Set SL	
Daylighting Controls	$9,150
Occupancy Sensors	$0
Efficient Elevator	($70,000)
Inc. Cost	($60,850)

Measure Set SM	
Daylighting Controls	$9,150
Occupancy Sensors[1]	$9,293
Solar Water Heating	$30,096
Photovoltaics	$399,923
Efficient Elevator	($70,000)
Inc. Cost	$378,462

[1] Core only

INCREMENTAL INSTALLED CAPITAL COSTS
Ottawa - Small office

Measure Set SA		**Measure Set SB**		**Measure Set SC**	
Envelope & Lighting	$68,822	Envelope & Lighting	$68,822	Envelope & Lighting	$68,822
HVAC System	$15,034	HVAC System	($8,132)	HVAC System	($72,344)
Other	$0	Other	$0	Other	$9,150
Inc. Cost	$83,856	Inc. Cost	$60,690	Inc. Cost	$5,628

Measure Set SD		**Measure Set SE**		**Measure Set SF**	
Envelope & Lighting	$78,002	Envelope & Lighting	$10,790	Envelope & Lighting	$47,114
HVAC System	$163,198	HVAC System	($11,535)	HVAC System	($23,696)
Other	$0	Other	($60,850)	Other	($60,850)
Inc. Cost	$241,200	Inc. Cost	($61,595)	Inc. Cost	($37,432)

Measure Set SG		**Measure Set SH**		**Measure Set SI**	
Envelope & Lighting	$134,008	Envelope & Lighting	$10,790	Envelope & Lighting	$47,114
HVAC System	($9,180)	HVAC System	$12,299	HVAC System	($17,691)
Other	($51,557)	Other	($60,850)	Other	($60,850)
Inc. Cost	$73,271	Inc. Cost	($37,761)	Inc. Cost	($31,427)

Measure Set SJ		**Measure Set SK**		**Measure Set SL**	
Envelope & Lighting	$134,008	Envelope & Lighting	$10,790	Envelope & Lighting	$47,114
HVAC System	$8,550	HVAC System	$178,499	HVAC System	$151,335
Other	($51,557)	Other	($60,850)	Other	($60,850)
Inc. Cost	$91,001	Inc. Cost	$128,439	Inc. Cost	$137,599

Measure Set SM	
Envelope & Lighting	$134,008
HVAC System	$143,768
Other	$378,462
Inc. Cost	$656,238

BUILDING ENVELOPE AND LIGHTING INCREMENTAL COSTS
Ottawa - Large office

Measure Set LA	
Lighting	$85,782
Window	$238,948
Wall	$0
Roof	$0
Inc. Cost	$324,730

Measure Set LB	
Lighting	$85,782
Window	$238,948
Wall	$37,753
Roof	$0
Inc. Cost	$362,483

Measure Set LC	
Lighting	$85,782
Window	$238,948
Wall	$37,753
Roof	$8,737
Inc. Cost	$371,220

Measure Set LD	
Lighting	$85,782
Window	$447,064
Wall	$37,753
Roof	$0
Inc. Cost	$570,599

Measure Set LE	
Lighting	$85,782
Window	$0
Wall	$37,753
Roof	$8,737
Inc. Cost	$132,272

Measure Set LF	
Lighting	$85,782
Window	$111,766
Wall	$37,753
Roof	$8,737
Inc. Cost	$244,038

Measure LG	
Lighting	$85,782
Window	$447,064
Wall	$37,753
Roof	$8,737
Inc. Cost	$579,336

Measure Set LH	
Lighting	$85,782
Window	$0
Wall	$37,753
Roof	$8,737
Inc. Cost	$132,272

Measure Set LI	
Lighting	$85,782
Window	$111,766
Wall	$37,753
Roof	$8,737
Inc. Cost	$244,038

Measure Set LJ	
Lighting	$85,782
Window	$447,064
Wall	$37,753
Roof	$8,737
Inc. Cost	$579,336

HVAC INCREMENTAL COSTS
Ottawa - Large office

Measure Set LA		**Measure Set LB**		**Measure Set LC**	
Rooftop	($15,519)	Rooftop	($15,531)	Rooftop	($15,531)
Ductwork	($89,606)	Ductwork	($54,901)	Ductwork	($54,918)
Heat Recovery	$19,400	Heat Recovery	$0	Heat Recovery	$0
Make-Up Air Unit	$47	Make-Up Air Unit	$0	Make-Up Air Unit	$0
Hydronic Piping	($41,438)	Hydronic Piping	($25,389)	Hydronic Piping	($25,397)
Circulating Pump	($995)	Circulating Pump	($550)	Circulating Pump	($550)
Hot Water Boiler	$134,450	Hot Water Boiler	$144,094	Hot Water Boiler	($6,958)
Chiller	($85,312)	Chiller	$85,819	Chiller	$21,022
Cooling Tower	($5,284)	Cooling Tower	($3,125)	Cooling Tower	($3,515)
	$0		$0		$0
	$0		$0		$0
Inc. Cost	($84,257)	Inc. Cost	$130,417	Inc. Cost	($85,847)

Measure Set LD		**Measure Set LE**[1]		**Measure Set LF**[1]	
Rooftop	($16,790)	Rooftop	$0	Rooftop	$0
Ductwork	($93,819)	Ductwork	($41,582)	Ductwork	($44,391)
Heat Recovery	$19,400	Heat Recovery	$0	Heat Recovery	$0
Make-Up Air Unit	$47	Make-Up Air Unit	$0	Make-Up Air Unit	$0
Hydronic Piping	($43,386)	Hydronic Piping	($36,439)	Hydronic Piping	($38,900)
Circulating Pump	$1,039	Circulating Pump	($1,049)	Circulating Pump	($1,122)
Hot Water Boiler	$115,043	Hot Water Boiler	($4,683)	Hot Water Boiler	($5,080)
Chiller	$49,459	Chiller	($73,882)	Chiller	($75,807)
Cooling Tower	$6,099	Cooling Tower	($4,771)	Cooling Tower	($5,113)
	$0	Radiant Panels	$0	Radiant Panels	$0
	$0		$0	HP Water Heaters	$59,804
Inc. Cost	$37,092	Inc. Cost	($162,406)	Inc. Cost	($110,609)

[1] Radiant panel base case

HVAC INCREMENTAL COSTS
Ottawa - Large office

Measure LG[1]	Base case: Radiant Panel
Rooftop	$0
Ductwork	($58,084)
Heat Recovery	$19,400
Make-Up Air Unit	$64
Hydronic Piping	($51,150)
Circulating Pump	$329
Hot Water Boiler	($17,278)
Chiller	($97,360)
Cooling Tower	($9,138)
Radiant Panels	$0
HP Water Heater	$59,804
Inc. Cost	($153,413)

Measure Set LH	
Rooftop	($184,708)
Ductwork	($227,862)
Heat Recovery	$0
Make-Up Air Unit	$7,540
Hydronic Piping	($272,776)
Circulating Pump	$1,249
Hot Water Boiler	($47,837)
Chiller	($261,630)
Cooling Tower	($46,293)
GSHP	$2,248,605
	$0
Inc. Cost	$1,216,288

Measure Set LI	
Rooftop	($184,708)
Ductwork	($231,522)
Heat Recovery	$0
Make-Up Air Unit	$7,540
Hydronic Piping	($272,776)
Circulating Pump	$1,154
Hot Water Boiler	($47,837)
Chiller	($261,630)
Cooling Tower	($46,293)
GSHP	$2,225,889
HP Water Heater	$59,804
Inc. Cost	$1,249,621

Measure Set LJ	
Rooftop	($184,708)
Ductwork	($231,522)
Heat Recovery	$91,400
Make-Up Air Unit	$7,540
Hydronic Piping	($272,776)
Circulating Pump	$1,154
Hot Water Boiler	($47,837)
Chiller	($261,630)
Cooling Tower	($46,239)
GSHP	$2,225,889
HP Water Heater	$59,804
Inc. Cost	$1,341,075

[1] Radiant panel base case

OTHER INCREMENTAL COSTS
Ottawa - Large office

Measure Set LA		**Measure Set LB**		**Measure Set LC**	
Daylighting Controls	$0	Daylighting Controls	$0	Daylighting Controls	$0
Occupancy Sensors	$0	Occupancy Sensors	$0	Occupancy Sensors	$0
Other	$0	Other	$0	Other	$0
Inc. Cost	$0	Inc. Cost	$0	Inc. Cost	$0

Measure Set LD		**Measure Set LE**		**Measure Set LF**	
Daylighting Controls	$0	Daylighting Controls	$38,244	Daylighting Controls	$38,244
Occupancy Sensors	$0	Occupancy Sensors	$0	Occupancy Sensors	$0
Other	$0	Other	$0	Other	$0
Inc. Cost	$0	Inc. Cost	$38,244	Inc. Cost	$38,244

Measure LG		**Measure Set LH**		**Measure Set LI**	
Daylighting Controls	$38,244	Daylighting Controls	$38,244	Daylighting Controls	$38,244
Occupancy Sensors	$0	Occupancy Sensors	$0	Occupancy Sensors	$0
Efficient Elevator	$28,000	Other	$0	Other	$0
Inc. Cost	$66,244	Inc. Cost	$38,244	Inc. Cost	$38,244

Measure Set LJ	
Daylighting Controls	$38,244
Occupancy Sensors	$0
Efficient Elevator	$28,000
Inc. Cost	$66,244

INCREMENTAL INSTALLED CAPITAL COSTS
Ottawa - Large office

Measure Set LA		**Measure Set LB**		**Measure Set LC**	
Envelope & Lighting	$324,730	Envelope & Lighting	$362,483	Envelope & Lighting	$371,220
HVAC System	($84,257)	HVAC System	$130,417	HVAC System	($85,847)
Other	$0	Other	$0	Other	$0
Inc. Cost	$240,473	Inc. Cost	$492,900	Inc. Cost	$285,373

Measure Set LD		**Measure Set LE**		**Measure Set LF**	
Envelope & Lighting	$570,599	Envelope & Lighting	$132,272	Envelope & Lighting	$244,038
HVAC System	$37,092	HVAC System	($162,406)	HVAC System	($110,609)
Other	$0	Other	$38,244	Other	$38,244
Inc. Cost	$607,691	Inc. Cost	$8,110	Inc. Cost	$171,673

Measure LG		**Measure Set LH**		**Measure Set LI**	
Envelope & Lighting	$579,336	Envelope & Lighting	$132,272	Envelope & Lighting	$244,038
HVAC System	($153,413)	HVAC System	$1,216,288	HVAC System	$1,249,621
Other	$66,244	Other	$38,244	Other	$38,244
Inc. Cost	$492,167	Inc. Cost	$1,386,804	Inc. Cost	$1,531,903

Measure Set LJ	
Envelope & Lighting	$579,336
HVAC System	$1,341,075
Other	$66,244
Inc. Cost	$1,986,655

APPENDIX E

LIFE CYCLE ANALYSIS RESULTS

Life Cycle Costs

Ottawa - Small Office - SA

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	12.41 year(s)
Actual Payback	> 20 year(s)
Internal Rate of Return	8.9%
Net Present Value Savings	($7,035)
Discount Rate	10%
Incremental Installed Capital Cost	$83,856
Incremental Maintenance Cost	$9,593
Electricity Savings	$7,845
Fuel Savings	$8,504

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$83,856	$83,856	($83,856)	($83,856)
1	$9,593	($16,559)	($6,966)	$76,890	$6,332	($77,524)
2	$9,593	($16,768)	($7,175)	$69,715	$5,930	($71,594)
3	$9,593	($16,978)	($7,385)	$62,330	$5,548	($66,045)
4	$9,593	($17,188)	($7,595)	$54,736	$5,187	($60,858)
5	$9,593	($17,397)	($7,804)	$46,931	$4,846	($56,012)
6	$9,593	($17,736)	($8,143)	$38,788	$4,596	($51,416)
7	$9,593	($18,075)	($8,482)	$30,307	$4,352	($47,063)
8	$9,593	($18,413)	($8,820)	$21,487	$4,115	($42,949)
9	$9,593	($18,752)	($9,159)	$12,328	$3,884	($39,064)
10	$9,593	($19,091)	($9,498)	$2,830	$3,662	($35,403)
11	$9,593	($20,726)	($11,133)	($8,303)	$3,902	($31,501)
12	$9,593	($22,523)	($12,930)	($21,233)	$4,120	($27,381)
13	$9,593	($21,924)	($12,331)	($33,563)	$3,572	($23,809)
14	$9,593	($21,325)	($11,732)	($45,295)	$3,089	($20,720)
15	$9,593	($20,726)	($11,133)	($56,428)	$2,665	($18,055)
16	$9,593	($21,085)	($11,492)	($67,920)	$2,501	($15,553)
17	$9,593	($21,445)	($11,852)	($79,772)	$2,345	($13,209)
18	$9,593	($21,804)	($12,211)	($91,983)	$2,196	($11,012)
19	$9,593	($22,163)	($12,570)	($104,553)	$2,055	($8,957)
20	$9,593	($22,523)	($12,930)	($117,483)	$1,922	($7,035)
Total	**$143,897**	**($393,202)**	**($117,483)**		**($7,035)**	

Life Cycle Costs

Ottawa - Small Office - SB

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	6.40 year(s)
Actual Payback	8.84 year(s)
Internal Rate of Return	18.1%
Net Present Value Savings	$42,430
Discount Rate	10%
Incremental Installed Capital Cost	$60,690
Incremental Maintenance Cost	$9,076
Electricity Savings	$8,260
Fuel Savings	$10,300

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$60,690	$60,690	($60,690)	($60,690)
1	$9,076	($18,808)	($9,732)	$50,958	$8,848	($51,842)
2	$9,076	($19,056)	($9,980)	$40,977	$8,248	($43,594)
3	$9,076	($19,304)	($10,228)	$30,749	$7,685	($35,909)
4	$9,076	($19,552)	($10,476)	$20,273	$7,155	($28,754)
5	$9,076	($19,800)	($10,724)	$9,548	$6,659	($22,095)
6	$9,076	($20,188)	($11,113)	($1,564)	$6,273	($15,822)
7	$9,076	($20,577)	($11,501)	($13,066)	$5,902	($9,920)
8	$9,076	($20,965)	($11,890)	($24,955)	$5,547	($4,374)
9	$9,076	($21,354)	($12,278)	($37,233)	$5,207	$833
10	$9,076	($21,742)	($12,667)	($49,900)	$4,884	$5,717
11	$9,076	($23,610)	($14,535)	($64,435)	$5,094	$10,811
12	$9,076	($25,666)	($16,590)	($81,025)	$5,286	$16,097
13	$9,076	($24,980)	($15,905)	($96,930)	$4,607	$20,704
14	$9,076	($24,295)	($15,220)	($112,149)	$4,008	$24,712
15	$9,076	($23,610)	($14,535)	($126,684)	$3,479	$28,192
16	$9,076	($24,021)	($14,946)	($141,629)	$3,253	$31,444
17	$9,076	($24,432)	($15,357)	($156,986)	$3,038	$34,483
18	$9,076	($24,843)	($15,768)	($172,754)	$2,836	$37,319
19	$9,076	($25,254)	($16,179)	($188,933)	$2,645	$39,964
20	$9,076	($25,666)	($16,590)	($205,523)	$2,466	$42,430
Total	**$136,133**	**($447,724)**	**($205,523)**		**$42,430**	

Life Cycle Costs

Ottawa - Small Office - SC

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	0.46 year(s)
Actual Payback	0.49 year(s)
Internal Rate of Return	225.6%
Net Present Value Savings	$127,805
Discount Rate	10%
Incremental Installed Capital Cost	$5,628
Incremental Maintenance Cost	$10,403
Electricity Savings	$6,496
Fuel Savings	$16,086

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$5,628	$5,628	($5,628)	($5,628)
1	$10,403	($22,938)	($12,536)	($6,908)	$11,396	$5,768
2	$10,403	($23,294)	($12,892)	($19,799)	$10,654	$16,422
3	$10,403	($23,650)	($13,248)	($33,047)	$9,953	$26,375
4	$10,403	($24,007)	($13,604)	($46,651)	$9,292	$35,667
5	$10,403	($24,363)	($13,960)	($60,611)	$8,668	$44,335
6	$10,403	($24,858)	($14,455)	($75,066)	$8,160	$52,495
7	$10,403	($25,353)	($14,950)	($90,016)	$7,672	$60,167
8	$10,403	($25,848)	($15,445)	($105,462)	$7,205	$67,372
9	$10,403	($26,343)	($15,940)	($121,402)	$6,760	$74,132
10	$10,403	($26,838)	($16,436)	($137,838)	$6,337	$80,469
11	$10,403	($29,172)	($18,769)	($156,607)	$6,579	$87,048
12	$10,403	($31,760)	($21,357)	($177,965)	$6,805	$93,853
13	$10,403	($30,897)	($20,495)	($198,460)	$5,937	$99,789
14	$10,403	($30,035)	($19,632)	($218,092)	$5,170	$104,959
15	$10,403	($29,172)	($18,769)	($236,861)	$4,493	$109,452
16	$10,403	($29,690)	($19,287)	($256,148)	$4,197	$113,650
17	$10,403	($30,207)	($19,805)	($275,953)	$3,918	$117,568
18	$10,403	($30,725)	($20,322)	($296,275)	$3,655	$121,223
19	$10,403	($31,242)	($20,840)	($317,115)	$3,407	$124,631
20	$10,403	($31,760)	($21,357)	($338,472)	$3,175	$127,805
Total	**$156,039**	**($552,153)**	**($338,472)**		**$127,805**	

Life Cycle Costs

Ottawa - Small Office - SD

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	14.80 year(s)
Actual Payback	> 20 year(s)
Internal Rate of Return	6.0%
Net Present Value Savings	($67,742)
Discount Rate	10%
Incremental Installed Capital Cost	$241,200
Incremental Maintenance Cost	$8,916
Electricity Savings	$5,202
Fuel Savings	$20,016

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$241,200	$241,200	($241,200)	($241,200)
1	$8,916	($25,647)	($16,731)	$224,469	$15,210	($225,990)
2	$8,916	($26,076)	($17,160)	$207,309	$14,182	($211,808)
3	$8,916	($26,505)	($17,589)	$189,720	$13,215	($198,593)
4	$8,916	($26,935)	($18,018)	$171,701	$12,307	($186,286)
5	$8,916	($27,364)	($18,448)	$153,253	$11,455	($174,832)
6	$8,916	($27,930)	($19,013)	$134,240	$10,733	($164,099)
7	$8,916	($28,495)	($19,579)	$114,661	$10,047	($154,052)
8	$8,916	($29,061)	($20,145)	$94,516	$9,398	($144,654)
9	$8,916	($29,627)	($20,711)	$73,805	$8,783	($135,870)
10	$8,916	($30,193)	($21,277)	$52,528	$8,203	($127,667)
11	$8,916	($32,835)	($23,918)	$28,609	$8,383	($119,284)
12	$8,916	($35,775)	($26,859)	$1,750	$8,558	($110,726)
13	$8,916	($34,795)	($25,879)	($24,128)	$7,496	($103,230)
14	$8,916	($33,815)	($24,899)	($49,027)	$6,557	($96,673)
15	$8,916	($32,835)	($23,918)	($72,945)	$5,726	($90,947)
16	$8,916	($33,423)	($24,507)	($97,452)	$5,333	($85,614)
17	$8,916	($34,011)	($25,095)	($122,547)	$4,965	($80,649)
18	$8,916	($34,599)	($25,683)	($148,229)	$4,619	($76,030)
19	$8,916	($35,187)	($26,271)	($174,500)	$4,295	($71,734)
20	$8,916	($35,775)	($26,859)	($201,359)	$3,992	($67,742)
Total	**$133,742**	**($620,882)**	**($201,359)**		**($67,742)**	

Life Cycle Costs

Ottawa - Small Office - SE

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	immediate year(s)
Actual Payback	immediate year(s)
Internal Rate of Return	infinite
Net Present Value Savings	$214,021
Discount Rate	10%
Incremental Installed Capital Cost	($61,595)
Incremental Maintenance Cost	$7,482
Electricity Savings	$19,953
Fuel Savings	$2,995

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	($61,595)	($61,595)	$61,595	$61,595
1	$7,482	($23,105)	($15,624)	($77,219)	$14,203	$75,798
2	$7,482	($23,263)	($15,781)	($93,000)	$13,042	$88,841
3	$7,482	($23,420)	($15,938)	($108,938)	$11,975	$100,815
4	$7,482	($23,577)	($16,096)	($125,034)	$10,994	$111,809
5	$7,482	($23,735)	($16,253)	($141,287)	$10,092	$121,901
6	$7,482	($24,154)	($16,672)	($157,959)	$9,411	$131,312
7	$7,482	($24,573)	($17,091)	($175,050)	$8,770	$140,082
8	$7,482	($24,992)	($17,510)	($192,560)	$8,168	$148,250
9	$7,482	($25,410)	($17,929)	($210,488)	$7,604	$155,854
10	$7,482	($25,829)	($18,348)	($228,836)	$7,074	$162,928
11	$7,482	($27,971)	($20,489)	($249,325)	$7,181	$170,109
12	$7,482	($30,273)	($22,792)	($272,117)	$7,262	$177,371
13	$7,482	($29,506)	($22,024)	($294,141)	$6,380	$183,751
14	$7,482	($28,738)	($21,257)	($315,398)	$5,598	$189,348
15	$7,482	($27,971)	($20,489)	($335,887)	$4,905	$194,253
16	$7,482	($28,431)	($20,950)	($356,837)	$4,559	$198,813
17	$7,482	($28,892)	($21,410)	($378,247)	$4,236	$203,049
18	$7,482	($29,352)	($21,871)	($400,118)	$3,934	$206,982
19	$7,482	($29,813)	($22,331)	($422,449)	$3,651	$210,634
20	$7,482	($30,273)	($22,792)	($445,241)	$3,388	$214,021
Total	**$112,225**	**($533,279)**	**($445,241)**		**$214,021**	

Life Cycle Costs

Ottawa - Small Office - SF

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	immediate year(s)
Actual Payback	immediate year(s)
Internal Rate of Return	infinite
Net Present Value Savings	$264,863
Discount Rate	10%
Incremental Installed Capital Cost	($37,432)
Incremental Maintenance Cost	$6,206
Electricity Savings	$20,705
Fuel Savings	$8,688

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	($37,432)	($37,432)	$37,432	$37,432
1	$6,206	($29,669)	($23,463)	($60,895)	$21,330	$58,762
2	$6,206	($29,945)	($23,739)	($84,634)	$19,619	$78,381
3	$6,206	($30,221)	($24,015)	($108,649)	$18,043	$96,424
4	$6,206	($30,496)	($24,291)	($132,940)	$16,591	$113,015
5	$6,206	($30,772)	($24,567)	($157,507)	$15,254	$128,269
6	$6,206	($31,340)	($25,134)	($182,641)	$14,187	$142,457
7	$6,206	($31,907)	($25,701)	($208,342)	$13,189	$155,645
8	$6,206	($32,474)	($26,268)	($234,610)	$12,254	$167,900
9	$6,206	($33,041)	($26,835)	($261,446)	$11,381	$179,280
10	$6,206	($33,608)	($27,403)	($288,848)	$10,565	$189,845
11	$6,206	($36,435)	($30,229)	($319,077)	$10,595	$200,441
12	$6,206	($39,503)	($33,297)	($352,375)	$10,610	$211,050
13	$6,206	($38,480)	($32,275)	($384,650)	$9,349	$220,399
14	$6,206	($37,458)	($31,252)	($415,901)	$8,230	$228,629
15	$6,206	($36,435)	($30,229)	($446,131)	$7,237	$235,865
16	$6,206	($37,048)	($30,843)	($476,974)	$6,712	$242,577
17	$6,206	($37,662)	($31,456)	($508,430)	$6,223	$248,801
18	$6,206	($38,276)	($32,070)	($540,500)	$5,768	$254,569
19	$6,206	($38,889)	($32,684)	($573,184)	$5,344	$259,913
20	$6,206	($39,503)	($33,297)	($606,481)	$4,949	$264,863
Total	**$93,084**	**($693,162)**	**($606,481)**		**$264,863**	

Life Cycle Costs

Ottawa - Small Office - SG

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	2.50 year(s)
Actual Payback	2.94 year(s)
Internal Rate of Return	42.1%
Net Present Value Savings	$214,646
Discount Rate	10%
Incremental Installed Capital Cost	$73,271
Incremental Maintenance Cost	$6,222
Electricity Savings	$22,224
Fuel Savings	$13,318

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$73,271	$73,271	($73,271)	($73,271)
1	$6,222	($35,919)	($29,697)	$43,574	$26,997	($46,274)
2	$6,222	($36,295)	($30,073)	$13,501	$24,854	($21,420)
3	$6,222	($36,672)	($30,450)	($16,949)	$22,877	$1,457
4	$6,222	($37,049)	($30,827)	($47,775)	$21,055	$22,512
5	$6,222	($37,425)	($31,203)	($78,979)	$19,375	$41,887
6	$6,222	($38,129)	($31,907)	($110,886)	$18,011	$59,898
7	$6,222	($38,833)	($32,610)	($143,496)	$16,734	$76,632
8	$6,222	($39,536)	($33,314)	($176,810)	$15,541	$92,173
9	$6,222	($40,240)	($34,018)	($210,828)	$14,427	$106,600
10	$6,222	($40,943)	($34,721)	($245,549)	$13,387	$119,987
11	$6,222	($44,410)	($38,188)	($283,736)	$13,384	$133,371
12	$6,222	($48,189)	($41,967)	($325,703)	$13,372	$146,743
13	$6,222	($46,929)	($40,707)	($366,410)	$11,791	$158,534
14	$6,222	($45,669)	($39,447)	($405,857)	$10,388	$168,922
15	$6,222	($44,410)	($38,188)	($444,044)	$9,142	$178,064
16	$6,222	($45,165)	($38,943)	($482,988)	$8,475	$186,539
17	$6,222	($45,921)	($39,699)	($522,687)	$7,854	$194,393
18	$6,222	($46,677)	($40,455)	($563,142)	$7,276	$201,669
19	$6,222	($47,433)	($41,211)	($604,353)	$6,738	$208,408
20	$6,222	($48,189)	($41,967)	($646,319)	$6,238	$214,646
Total	**$93,331**	**($844,032)**	**($646,319)**		**$214,646**	

Life Cycle Costs

Ottawa - Small Office - SH

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	immediate year(s)
Actual Payback	immediate year(s)
Internal Rate of Return	infinite
Net Present Value Savings	$91,398
Discount Rate	10%
Incremental Installed Capital Cost	($37,761)
Incremental Maintenance Cost	$13,922
Electricity Savings	$6,726
Fuel Savings	$10,906

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	($37,761)	($37,761)	$37,761	$37,761
1	$13,922	($17,885)	($3,963)	($41,724)	$3,603	$41,364
2	$13,922	($18,137)	($4,216)	($45,940)	$3,484	$44,848
3	$13,922	($18,390)	($4,468)	($50,408)	$3,357	$48,205
4	$13,922	($18,643)	($4,721)	($55,129)	$3,225	$51,430
5	$13,922	($18,896)	($4,974)	($60,103)	$3,088	$54,518
6	$13,922	($19,272)	($5,350)	($65,453)	$3,020	$57,538
7	$13,922	($19,648)	($5,726)	($71,179)	$2,938	$60,476
8	$13,922	($20,024)	($6,102)	($77,282)	$2,847	$63,323
9	$13,922	($20,400)	($6,478)	($83,760)	$2,748	$66,071
10	$13,922	($20,776)	($6,855)	($90,615)	$2,643	$68,713
11	$13,922	($22,570)	($8,648)	($99,263)	$3,031	$71,745
12	$13,922	($24,550)	($10,629)	($109,892)	$3,387	$75,131
13	$13,922	($23,890)	($9,968)	($119,860)	$2,888	$78,019
14	$13,922	($23,230)	($9,308)	($129,169)	$2,451	$80,470
15	$13,922	($22,570)	($8,648)	($137,817)	$2,070	$82,540
16	$13,922	($22,966)	($9,044)	($146,861)	$1,968	$84,509
17	$13,922	($23,362)	($9,440)	($156,302)	$1,868	$86,376
18	$13,922	($23,758)	($9,836)	($166,138)	$1,769	$88,145
19	$13,922	($24,154)	($10,233)	($176,371)	$1,673	$89,819
20	$13,922	($24,550)	($10,629)	($186,999)	$1,580	$91,398
Total	**$208,826**	**($427,674)**	**($186,999)**		**$91,398**	

Life Cycle Costs

Ottawa - Small Office - SI

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	immediate year(s)
Actual Payback	immediate year(s)
Internal Rate of Return	infinite
Net Present Value Savings	$167,643
Discount Rate	10%
Incremental Installed Capital Cost	($31,427)
Incremental Maintenance Cost	$12,910
Electricity Savings	$10,302
Fuel Savings	$14,954

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	($31,427)	($31,427)	$31,427	$31,427
1	$12,910	($25,608)	($12,697)	($44,124)	$11,543	$42,970
2	$12,910	($25,960)	($13,049)	($57,174)	$10,784	$53,755
3	$12,910	($26,311)	($13,401)	($70,575)	$10,068	$63,823
4	$12,910	($26,663)	($13,753)	($84,328)	$9,393	$73,216
5	$12,910	($27,015)	($14,105)	($98,432)	$8,758	$81,974
6	$12,910	($27,549)	($14,639)	($113,071)	$8,263	$90,238
7	$12,910	($28,084)	($15,174)	($128,245)	$7,787	$98,024
8	$12,910	($28,619)	($15,708)	($143,953)	$7,328	$105,352
9	$12,910	($29,153)	($16,243)	($160,196)	$6,889	$112,241
10	$12,910	($29,688)	($16,777)	($176,974)	$6,468	$118,709
11	$12,910	($32,246)	($19,335)	($196,309)	$6,777	$125,486
12	$12,910	($35,066)	($22,155)	($218,464)	$7,059	$132,546
13	$12,910	($34,126)	($21,215)	($239,680)	$6,145	$138,691
14	$12,910	($33,186)	($20,275)	($259,955)	$5,339	$144,030
15	$12,910	($32,246)	($19,335)	($279,290)	$4,629	$148,659
16	$12,910	($32,810)	($19,899)	($299,190)	$4,331	$152,989
17	$12,910	($33,374)	($20,463)	($319,653)	$4,049	$157,038
18	$12,910	($33,938)	($21,027)	($340,680)	$3,782	$160,820
19	$12,910	($34,502)	($21,591)	($362,272)	$3,530	$164,350
20	$12,910	($35,066)	($22,155)	($384,427)	$3,293	$167,643
Total	**$193,655**	**($611,206)**	**($384,427)**		**$167,643**	

Life Cycle Costs

Ottawa - Small Office - SJ

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	5.13 year(s)
Actual Payback	6.72 year(s)
Internal Rate of Return	22.1%
Net Present Value Savings	$97,399
Discount Rate	10%
Incremental Installed Capital Cost	$91,001
Incremental Maintenance Cost	$12,992
Electricity Savings	$13,036
Fuel Savings	$17,683

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$91,001	$91,001	($91,001)	($91,001)
1	$12,992	($31,139)	($18,147)	$72,854	$16,497	($74,504)
2	$12,992	($31,559)	($18,567)	$54,287	$15,345	($59,159)
3	$12,992	($31,979)	($18,987)	$35,300	$14,265	($44,894)
4	$12,992	($32,399)	($19,407)	$15,892	$13,255	($31,638)
5	$12,992	($32,820)	($19,827)	($3,935)	$12,311	($19,327)
6	$12,992	($33,467)	($20,474)	($24,410)	$11,557	($7,770)
7	$12,992	($34,114)	($21,122)	($45,531)	$10,839	$3,069
8	$12,992	($34,761)	($21,769)	($67,300)	$10,155	$13,224
9	$12,992	($35,408)	($22,416)	($89,715)	$9,506	$22,731
10	$12,992	($36,055)	($23,063)	($112,778)	$8,892	$31,622
11	$12,992	($39,157)	($26,165)	($138,943)	$9,171	$40,793
12	$12,992	($42,575)	($29,583)	($168,525)	$9,426	$50,219
13	$12,992	($41,436)	($28,443)	($196,969)	$8,239	$58,458
14	$12,992	($40,296)	($27,304)	($224,273)	$7,190	$65,648
15	$12,992	($39,157)	($26,165)	($250,438)	$6,264	$71,912
16	$12,992	($39,841)	($26,848)	($277,286)	$5,843	$77,755
17	$12,992	($40,524)	($27,532)	($304,818)	$5,447	$83,202
18	$12,992	($41,208)	($28,216)	($333,034)	$5,075	$88,276
19	$12,992	($41,891)	($28,899)	($361,933)	$4,725	$93,002
20	$12,992	($42,575)	($29,583)	($391,516)	$4,397	$97,399
Total	**$194,882**	**($742,360)**	**($391,516)**		**$97,399**	

Life Cycle Costs

Ottawa - Small Office - SK

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	6.17 year(s)
Actual Payback	8.65 year(s)
Internal Rate of Return	18.1%
Net Present Value Savings	$87,442
Discount Rate	10%
Incremental Installed Capital Cost	$128,439
Incremental Maintenance Cost	$9,143
Electricity Savings	$9,958
Fuel Savings	$20,016

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$128,439	$128,439	($128,439)	($128,439)
1	$9,143	($30,426)	($21,284)	$107,155	$19,349	($109,090)
2	$9,143	($30,878)	($21,736)	$85,420	$17,963	($91,127)
3	$9,143	($31,331)	($22,188)	$63,232	$16,670	($74,457)
4	$9,143	($31,783)	($22,640)	$40,591	$15,464	($58,993)
5	$9,143	($32,235)	($23,093)	$17,499	$14,339	($44,654)
6	$9,143	($32,884)	($23,741)	($6,243)	$13,401	($31,253)
7	$9,143	($33,533)	($24,390)	($30,633)	$12,516	($18,737)
8	$9,143	($34,182)	($25,039)	($55,672)	$11,681	($7,056)
9	$9,143	($34,830)	($25,688)	($81,359)	$10,894	$3,838
10	$9,143	($35,479)	($26,336)	($107,695)	$10,154	$13,992
11	$9,143	($38,554)	($29,411)	($137,107)	$10,308	$24,300
12	$9,143	($41,956)	($32,814)	($169,920)	$10,455	$34,755
13	$9,143	($40,822)	($31,679)	($201,600)	$9,176	$43,932
14	$9,143	($39,688)	($30,545)	($232,145)	$8,044	$51,975
15	$9,143	($38,554)	($29,411)	($261,556)	$7,041	$59,016
16	$9,143	($39,234)	($30,092)	($291,647)	$6,549	$65,565
17	$9,143	($39,915)	($30,772)	($322,419)	$6,088	$71,653
18	$9,143	($40,595)	($31,453)	($353,872)	$5,657	$77,310
19	$9,143	($41,276)	($32,133)	($386,005)	$5,254	$82,564
20	$9,143	($41,956)	($32,814)	($418,819)	$4,878	$87,442
Total	**$137,140**	**($730,111)**	**($418,819)**		**$87,442**	

Life Cycle Costs

Ottawa - Small Office - SL

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	5.73 year(s)
Actual Payback	7.90 year(s)
Internal Rate of Return	19.3%
Net Present Value Savings	$107,953
Discount Rate	10%
Incremental Installed Capital Cost	$137,599
Incremental Maintenance Cost	$8,916
Electricity Savings	$12,933
Fuel Savings	$20,016

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$137,599	$137,599	($137,599)	($137,599)
1	$8,916	($33,416)	($24,500)	$113,099	$22,272	($115,327)
2	$8,916	($33,882)	($24,966)	$88,133	$20,633	($94,693)
3	$8,916	($34,349)	($25,433)	$62,700	$19,108	($75,585)
4	$8,916	($34,816)	($25,900)	$36,801	$17,690	($57,895)
5	$8,916	($35,282)	($26,366)	$10,434	$16,371	($41,524)
6	$8,916	($35,983)	($27,067)	($16,633)	$15,279	($26,245)
7	$8,916	($36,684)	($27,768)	($44,400)	$14,249	($11,996)
8	$8,916	($37,384)	($28,468)	($72,869)	$13,281	$1,284
9	$8,916	($38,085)	($29,169)	($102,037)	$12,370	$13,655
10	$8,916	($38,786)	($29,869)	($131,907)	$11,516	$25,171
11	$8,916	($42,131)	($33,215)	($165,122)	$11,642	$36,812
12	$8,916	($45,823)	($36,907)	($202,028)	$11,760	$48,572
13	$8,916	($44,592)	($35,676)	($237,705)	$10,334	$58,906
14	$8,916	($43,362)	($34,446)	($272,150)	$9,071	$67,977
15	$8,916	($42,131)	($33,215)	($305,365)	$7,951	$75,928
16	$8,916	($42,870)	($33,953)	($339,319)	$7,389	$83,317
17	$8,916	($43,608)	($34,692)	($374,010)	$6,864	$90,181
18	$8,916	($44,346)	($35,430)	($409,440)	$6,372	$96,553
19	$8,916	($45,084)	($36,168)	($445,609)	$5,914	$102,467
20	$8,916	($45,823)	($36,907)	($482,515)	$5,486	$107,953
Total	**$133,742**	**($798,437)**	**($482,515)**		**$107,953**	

Life Cycle Costs

Ottawa - Small Office - SM

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	22.43 year(s)
Actual Payback	> 20 year(s)
Internal Rate of Return	1.1%
Net Present Value Savings	($361,727)
Discount Rate	10%
Incremental Installed Capital Cost	$656,238
Incremental Maintenance Cost	$9,285
Electricity Savings	$18,520
Fuel Savings	$20,016

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$656,238	$656,238	($656,238)	($656,238)
1	$9,285	($39,030)	($29,745)	$626,493	$27,041	($629,197)
2	$9,285	($39,524)	($30,238)	$596,255	$24,990	($604,207)
3	$9,285	($40,018)	($30,732)	$565,523	$23,090	($581,117)
4	$9,285	($40,511)	($31,226)	$534,296	$21,328	($559,789)
5	$9,285	($41,005)	($31,720)	$502,576	$19,696	($540,094)
6	$9,285	($41,803)	($32,518)	$470,058	$18,356	($521,738)
7	$9,285	($42,601)	($33,316)	$436,742	$17,096	($504,642)
8	$9,285	($43,399)	($34,114)	$402,628	$15,914	($488,727)
9	$9,285	($44,197)	($34,912)	$367,716	$14,806	($473,921)
10	$9,285	($44,995)	($35,710)	$332,006	$13,768	($460,154)
11	$9,285	($48,850)	($39,565)	$292,442	$13,867	($446,286)
12	$9,285	($53,084)	($43,799)	$248,643	$13,956	($432,331)
13	$9,285	($51,672)	($42,387)	$206,256	$12,278	($420,053)
14	$9,285	($50,261)	($40,976)	$165,280	$10,790	($409,262)
15	$9,285	($48,850)	($39,565)	$125,715	$9,471	($399,791)
16	$9,285	($49,697)	($40,411)	$85,304	$8,795	($390,996)
17	$9,285	($50,543)	($41,258)	$44,046	$8,163	($382,834)
18	$9,285	($51,390)	($42,105)	$1,941	$7,573	($375,261)
19	$9,285	($52,237)	($42,952)	($41,011)	$7,023	($368,238)
20	$9,285	($53,084)	($43,799)	($84,810)	$6,510	($361,727)
Total	**$139,278**	**($926,751)**	**($84,810)**		**($361,727)**	

Life Cycle Costs

Ottawa - Large Office - LA

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	2.67 year(s)
Actual Payback	3.14 year(s)
Internal Rate of Return	39.8%
Net Present Value Savings	$652,808
Discount Rate	10%
Incremental Installed Capital Cost	$240,473
Incremental Maintenance Cost	$13,668
Electricity Savings	$46,189
Fuel Savings	$57,691

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$240,473	$240,473	($240,473)	($240,473)
1	$13,668	($105,268)	($91,601)	$148,872	$83,273	($157,200)
2	$13,668	($106,657)	($92,989)	$55,883	$76,850	($80,349)
3	$13,668	($108,045)	($94,378)	($38,494)	$70,907	($9,442)
4	$13,668	($109,434)	($95,766)	($134,260)	$65,409	$55,968
5	$13,668	($110,822)	($97,154)	($231,415)	$60,325	$116,293
6	$13,668	($112,997)	($99,329)	($330,744)	$56,069	$172,361
7	$13,668	($115,172)	($101,504)	($432,248)	$52,088	$224,449
8	$13,668	($117,346)	($103,679)	($535,926)	$48,367	$272,816
9	$13,668	($119,521)	($105,853)	($641,779)	$44,892	$317,708
10	$13,668	($121,696)	($108,028)	($749,807)	$41,649	$359,357
11	$13,668	($132,150)	($118,483)	($868,290)	$41,527	$400,885
12	$13,668	($143,656)	($129,988)	($998,278)	$41,418	$442,303
13	$13,668	($139,821)	($126,153)	($1,124,431)	$36,542	$478,845
14	$13,668	($135,986)	($122,318)	($1,246,749)	$32,210	$511,055
15	$13,668	($132,150)	($118,483)	($1,365,232)	$28,364	$539,419
16	$13,668	($134,452)	($120,784)	($1,486,016)	$26,286	$565,705
17	$13,668	($136,753)	($123,085)	($1,609,101)	$24,352	$590,057
18	$13,668	($139,054)	($125,386)	($1,734,487)	$22,552	$612,609
19	$13,668	($141,355)	($127,687)	($1,862,174)	$20,878	$633,486
20	$13,668	($143,656)	($129,988)	($1,992,162)	$19,322	$652,808
Total	**$205,016**	**($2,505,990)**	**($1,992,162)**		**$652,808**	

Life Cycle Costs

Ottawa - Large Office - LB

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	5.26 year(s)
Actual Payback	7.21 year(s)
Internal Rate of Return	20.6%
Net Present Value Savings	$434,709
Discount Rate	10%
Incremental Installed Capital Cost	$492,900
Incremental Maintenance Cost	$15,355
Electricity Savings	$50,540
Fuel Savings	$58,500

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$492,900	$492,900	($492,900)	($492,900)
1	$15,355	($110,466)	($95,111)	$397,789	$86,464	($406,436)
2	$15,355	($111,892)	($96,537)	$301,252	$79,782	($326,653)
3	$15,355	($113,318)	($97,963)	$203,290	$73,601	($253,052)
4	$15,355	($114,744)	($99,388)	$103,901	$67,884	($185,169)
5	$15,355	($116,169)	($100,814)	$3,087	$62,598	($122,571)
6	$15,355	($118,439)	($103,084)	($99,997)	$58,188	($64,383)
7	$15,355	($120,709)	($105,354)	($205,351)	$54,063	($10,319)
8	$15,355	($122,979)	($107,624)	($312,975)	$50,207	$39,888
9	$15,355	($125,249)	($109,893)	($422,868)	$46,606	$86,493
10	$15,355	($127,518)	($112,163)	($535,031)	$43,244	$129,737
11	$15,355	($138,457)	($123,102)	($658,133)	$43,146	$172,884
12	$15,355	($150,483)	($135,128)	($793,262)	$43,056	$215,940
13	$15,355	($146,475)	($131,120)	($924,381)	$37,981	$253,920
14	$15,355	($142,466)	($127,111)	($1,051,492)	$33,472	$287,393
15	$15,355	($138,457)	($123,102)	($1,174,594)	$29,470	$316,862
16	$15,355	($140,862)	($125,507)	($1,300,101)	$27,314	$344,176
17	$15,355	($143,267)	($127,912)	($1,428,013)	$25,307	$369,483
18	$15,355	($145,673)	($130,318)	($1,558,331)	$23,439	$392,922
19	$15,355	($148,078)	($132,723)	($1,691,054)	$21,701	$414,623
20	$15,355	($150,483)	($135,128)	($1,826,183)	$20,086	$434,709
Total	**$230,326**	**($2,626,183)**	**($1,826,183)**		**$434,709**	

Life Cycle Costs

Ottawa - Large Office - LC

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	3.52 year(s)
Actual Payback	4.39 year(s)
Internal Rate of Return	30.2%
Net Present Value Savings	$501,175
Discount Rate	10%
Incremental Installed Capital Cost	$285,373
Incremental Maintenance Cost	$5,037
Electricity Savings	$50,406
Fuel Savings	$35,813

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$285,373	$285,373	($285,373)	($285,373)
1	$5,037	($87,186)	($82,150)	$203,223	$74,682	($210,691)
2	$5,037	($88,154)	($83,117)	$120,106	$68,692	($141,999)
3	$5,037	($89,121)	($84,085)	$36,021	$63,174	($78,825)
4	$5,037	($90,089)	($85,052)	($49,031)	$58,092	($20,733)
5	$5,037	($91,056)	($86,020)	($135,051)	$53,411	$32,678
6	$5,037	($92,785)	($87,749)	($222,800)	$49,532	$82,210
7	$5,037	($94,514)	($89,477)	($312,277)	$45,916	$128,126
8	$5,037	($96,243)	($91,206)	($403,484)	$42,548	$170,675
9	$5,037	($97,972)	($92,935)	($496,419)	$39,414	$210,088
10	$5,037	($99,701)	($94,664)	($591,083)	$36,497	$246,585
11	$5,037	($108,170)	($103,133)	($694,216)	$36,148	$282,733
12	$5,037	($117,423)	($112,387)	($806,603)	$35,810	$318,543
13	$5,037	($114,339)	($109,302)	($915,905)	$31,661	$350,204
14	$5,037	($111,254)	($106,218)	($1,022,123)	$27,970	$378,174
15	$5,037	($108,170)	($103,133)	($1,125,256)	$24,689	$402,864
16	$5,037	($110,020)	($104,984)	($1,230,240)	$22,848	$425,711
17	$5,037	($111,871)	($106,835)	($1,337,075)	$21,137	$446,848
18	$5,037	($113,722)	($108,685)	($1,445,760)	$19,548	$466,396
19	$5,037	($115,573)	($110,536)	($1,556,296)	$18,074	$484,469
20	$5,037	($117,423)	($112,387)	($1,668,683)	$16,706	$501,175
Total	**$75,548**	**($2,054,786)**	**($1,668,683)**		**$501,175**	

Life Cycle Costs

Ottawa - Large Office - LD

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	5.09 year(s)
Actual Payback	6.88 year(s)
Internal Rate of Return	21.3%
Net Present Value Savings	$571,265
Discount Rate	10%
Incremental Installed Capital Cost	$607,691
Incremental Maintenance Cost	$11,000
Electricity Savings	$51,988
Fuel Savings	$78,507

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$607,691	$607,691	($607,691)	($607,691)
1	$11,000	($132,332)	($121,332)	$486,359	$110,302	($497,389)
2	$11,000	($134,168)	($123,168)	$363,191	$101,792	($395,597)
3	$11,000	($136,005)	($125,005)	$238,186	$93,918	($301,679)
4	$11,000	($137,841)	($126,842)	$111,344	$86,635	($215,045)
5	$11,000	($139,678)	($128,678)	($17,334)	$79,899	($135,146)
6	$11,000	($142,448)	($131,448)	($148,782)	$74,199	($60,947)
7	$11,000	($145,218)	($134,218)	($283,000)	$68,875	$7,929
8	$11,000	($147,988)	($136,988)	($419,989)	$63,906	$71,835
9	$11,000	($150,758)	($139,758)	($559,747)	$59,271	$131,106
10	$11,000	($153,528)	($142,528)	($702,275)	$54,951	$186,056
11	$11,000	($166,765)	($155,765)	($858,040)	$54,595	$240,651
12	$11,000	($181,367)	($170,367)	($1,028,407)	$54,284	$294,935
13	$11,000	($176,499)	($165,500)	($1,193,907)	$47,939	$342,875
14	$11,000	($171,632)	($160,633)	($1,354,539)	$42,300	$385,174
15	$11,000	($166,765)	($155,765)	($1,510,305)	$37,289	$422,463
16	$11,000	($169,686)	($158,686)	($1,668,990)	$34,535	$456,998
17	$11,000	($172,606)	($161,606)	($1,830,596)	$31,973	$488,971
18	$11,000	($175,526)	($164,526)	($1,995,122)	$29,591	$518,562
19	$11,000	($178,446)	($167,446)	($2,162,569)	$27,379	$545,941
20	$11,000	($181,367)	($170,367)	($2,332,936)	$25,324	$571,265
Total	**$164,998**	**($3,160,623)**	**($2,332,936)**		**$571,265**	

Life Cycle Costs

Ottawa - Large Office - LE

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	0.09 year(s)
Actual Payback	0.10 year(s)
Internal Rate of Return	1137.3%
Net Present Value Savings	$848,297
Discount Rate	10%
Incremental Installed Capital Cost	$8,110
Incremental Maintenance Cost	$5,448
Electricity Savings	$103,311
Fuel Savings	($6,041)

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$8,110	$8,110	($8,110)	($8,110)
1	$5,448	($97,650)	($92,202)	($84,092)	$83,820	$75,710
2	$5,448	($98,030)	($92,582)	($176,674)	$76,514	$152,224
3	$5,448	($98,410)	($92,962)	($269,636)	$69,844	$222,068
4	$5,448	($98,790)	($93,342)	($362,978)	$63,754	$285,821
5	$5,448	($99,169)	($93,722)	($456,699)	$58,194	$344,015
6	$5,448	($100,827)	($95,379)	($552,078)	$53,839	$397,854
7	$5,448	($102,485)	($97,037)	($649,115)	$49,795	$447,649
8	$5,448	($104,142)	($98,694)	($747,810)	$46,042	$493,691
9	$5,448	($105,800)	($100,352)	($848,162)	$42,559	$536,250
10	$5,448	($107,457)	($102,010)	($950,171)	$39,329	$575,579
11	$5,448	($116,211)	($110,763)	($1,060,935)	$38,822	$614,401
12	$5,448	($125,512)	($120,064)	($1,180,999)	$38,256	$652,657
13	$5,448	($122,412)	($116,964)	($1,297,962)	$33,880	$686,537
14	$5,448	($119,311)	($113,864)	($1,411,826)	$29,984	$716,521
15	$5,448	($116,211)	($110,763)	($1,522,589)	$26,516	$743,037
16	$5,448	($118,071)	($112,624)	($1,635,213)	$24,510	$767,547
17	$5,448	($119,931)	($114,484)	($1,749,697)	$22,650	$790,197
18	$5,448	($121,792)	($116,344)	($1,866,040)	$20,925	$811,123
19	$5,448	($123,652)	($118,204)	($1,984,244)	$19,327	$830,450
20	$5,448	($125,512)	($120,064)	($2,104,308)	$17,847	$848,297
Total	**$81,717**	**($2,221,374)**	**($2,104,308)**		**$848,297**	

Life Cycle Costs

Ottawa - Large Office - LF

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	1.55 year(s)
Actual Payback	1.76 year(s)
Internal Rate of Return	65.8%
Net Present Value Savings	$872,486
Discount Rate	10%
Incremental Installed Capital Cost	$171,673
Incremental Maintenance Cost	$6,031
Electricity Savings	$112,218
Fuel Savings	$4,887

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$171,673	$171,673	($171,673)	($171,673)
1	$6,031	($117,749)	($111,717)	$59,956	$101,561	($70,112)
2	$6,031	($118,392)	($112,361)	($52,405)	$92,860	$22,749
3	$6,031	($119,036)	($113,005)	($165,410)	$84,902	$107,651
4	$6,031	($119,680)	($113,648)	($279,058)	$77,623	$185,274
5	$6,031	($120,323)	($114,292)	($393,350)	$70,966	$256,240
6	$6,031	($122,395)	($116,364)	($509,714)	$65,685	$321,925
7	$6,031	($124,468)	($118,436)	($628,151)	$60,777	$382,701
8	$6,031	($126,540)	($120,509)	($748,659)	$56,218	$438,920
9	$6,031	($128,612)	($122,581)	($871,241)	$51,986	$490,906
10	$6,031	($130,685)	($124,653)	($995,894)	$48,059	$538,965
11	$6,031	($141,433)	($135,402)	($1,131,296)	$47,458	$586,423
12	$6,031	($152,928)	($146,897)	($1,278,193)	$46,806	$633,229
13	$6,031	($149,097)	($143,065)	($1,421,258)	$41,441	$674,670
14	$6,031	($145,265)	($139,234)	($1,560,492)	$36,665	$711,334
15	$6,031	($141,433)	($135,402)	($1,695,894)	$32,414	$743,748
16	$6,031	($143,732)	($137,701)	($1,833,595)	$29,968	$773,716
17	$6,031	($146,031)	($140,000)	($1,973,595)	$27,698	$801,414
18	$6,031	($148,330)	($142,299)	($2,115,894)	$25,594	$827,008
19	$6,031	($150,629)	($144,598)	($2,260,492)	$23,643	$850,651
20	$6,031	($152,928)	($146,897)	($2,407,389)	$21,835	$872,486
Total	**$90,470**	**($2,699,688)**	**($2,407,389)**		**$872,486**	

Life Cycle Costs

Ottawa - Large Office - LG

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures		
Simple Payback	3.22	year(s)
Actual Payback	3.98	year(s)
Internal Rate of Return	32.5%	
Net Present Value Savings	$964,966	
Discount Rate	10%	
Incremental Installed Capital Cost	$492,167	
Incremental Maintenance Cost	$2,937	
Electricity Savings	$111,538	
Fuel Savings	$44,048	

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$492,167	$492,167	($492,167)	($492,167)
1	$2,937	($157,017)	($154,079)	$338,088	$140,072	($352,095)
2	$2,937	($158,447)	($155,510)	$182,578	$128,521	($223,574)
3	$2,937	($159,878)	($156,941)	$25,637	$117,912	($105,662)
4	$2,937	($161,308)	($158,371)	($132,734)	$108,170	$2,507
5	$2,937	($162,739)	($159,802)	($292,536)	$99,224	$101,731
6	$2,937	($165,729)	($162,792)	($455,327)	$91,892	$193,623
7	$2,937	($168,719)	($165,782)	($621,109)	$85,072	$278,695
8	$2,937	($171,709)	($168,772)	($789,881)	$78,733	$357,428
9	$2,937	($174,699)	($171,762)	($961,643)	$72,844	$430,272
10	$2,937	($177,689)	($174,752)	($1,136,394)	$67,374	$497,647
11	$2,937	($192,617)	($189,680)	($1,326,075)	$66,482	$564,128
12	$2,937	($208,811)	($205,874)	($1,531,948)	$65,598	$629,726
13	$2,937	($203,413)	($200,476)	($1,732,424)	$58,071	$687,797
14	$2,937	($198,015)	($195,078)	($1,927,502)	$51,370	$739,167
15	$2,937	($192,617)	($189,680)	($2,117,182)	$45,408	$784,575
16	$2,937	($195,856)	($192,919)	($2,310,101)	$41,985	$826,560
17	$2,937	($199,095)	($196,158)	($2,506,258)	$38,809	$865,368
18	$2,937	($202,333)	($199,396)	($2,705,654)	$35,863	$901,231
19	$2,937	($205,572)	($202,635)	($2,908,289)	$33,132	$934,364
20	$2,937	($208,811)	($205,874)	($3,114,163)	$30,602	$964,966
Total	**$44,056**	**($3,665,072)**	**($3,114,163)**		**$964,966**	

Life Cycle Costs

Ottawa - Large Office - LH

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	9.31 year(s)
Actual Payback	17.58 year(s)
Internal Rate of Return	10.8%
Net Present Value Savings	$80,270
Discount Rate	10%
Incremental Installed Capital Cost	$1,386,804
Incremental Maintenance Cost	($4,511)
Electricity Savings	$30,308
Fuel Savings	$114,207

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$1,386,804	$1,386,804	($1,386,804)	($1,386,804)
1	($4,511)	($146,967)	($151,477)	$1,235,327	$137,707	($1,249,097)
2	($4,511)	($149,418)	($153,929)	$1,081,398	$127,214	($1,121,883)
3	($4,511)	($151,870)	($156,381)	$925,017	$117,491	($1,004,392)
4	($4,511)	($154,322)	($158,832)	$766,185	$108,485	($895,907)
5	($4,511)	($156,773)	($161,284)	$604,901	$100,145	($795,763)
6	($4,511)	($160,013)	($164,524)	$440,377	$92,869	($702,894)
7	($4,511)	($163,252)	($167,763)	$272,614	$86,089	($616,805)
8	($4,511)	($166,492)	($171,003)	$101,611	$79,774	($537,031)
9	($4,511)	($169,731)	($174,242)	($72,631)	$73,896	($463,135)
10	($4,511)	($172,971)	($177,482)	($250,112)	$68,427	($394,708)
11	($4,511)	($188,101)	($192,611)	($442,723)	$67,509	($327,199)
12	($4,511)	($204,939)	($209,450)	($652,173)	$66,737	($260,462)
13	($4,511)	($199,326)	($203,837)	($856,010)	$59,044	($201,418)
14	($4,511)	($193,713)	($198,224)	($1,054,234)	$52,199	($149,219)
15	($4,511)	($188,101)	($192,611)	($1,246,845)	$46,110	($103,109)
16	($4,511)	($191,468)	($195,979)	($1,442,824)	$42,651	($60,459)
17	($4,511)	($194,836)	($199,347)	($1,642,171)	$39,440	($21,019)
18	($4,511)	($198,204)	($202,714)	($1,844,885)	$36,460	$15,441
19	($4,511)	($201,571)	($206,082)	($2,050,968)	$33,696	$49,137
20	($4,511)	($204,939)	($209,450)	($2,260,417)	$31,133	$80,270
Total	**($67,660)**	**($3,557,008)**	**($2,260,417)**		**$80,270**	

Life Cycle Costs

Ottawa - Large Office - LI

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	9.58 year(s)
Actual Payback	18.90 year(s)
Internal Rate of Return	10.3%
Net Present Value Savings	$36,799
Discount Rate	10%
Incremental Installed Capital Cost	$1,531,903
Incremental Maintenance Cost	($3,742)
Electricity Savings	$41,908
Fuel Savings	$114,207

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$1,531,903	$1,531,903	($1,531,903)	($1,531,903)
1	($3,742)	($158,623)	($162,365)	$1,369,538	$147,604	($1,384,299)
2	($3,742)	($161,131)	($164,873)	$1,204,665	$136,258	($1,248,040)
3	($3,742)	($163,639)	($167,381)	$1,037,285	$125,756	($1,122,285)
4	($3,742)	($166,147)	($169,889)	$867,396	$116,036	($1,006,248)
5	($3,742)	($168,655)	($172,397)	$694,999	$107,045	($899,203)
6	($3,742)	($172,097)	($175,839)	$519,161	$99,256	($799,947)
7	($3,742)	($175,539)	($179,280)	$339,880	$91,999	($707,948)
8	($3,742)	($178,980)	($182,722)	$157,158	$85,241	($622,707)
9	($3,742)	($182,422)	($186,164)	($29,005)	$78,952	($543,755)
10	($3,742)	($185,864)	($189,605)	($218,611)	$73,101	($470,654)
11	($3,742)	($202,050)	($205,791)	($424,402)	$72,129	($398,526)
12	($3,742)	($220,015)	($223,757)	($648,159)	$71,296	($327,230)
13	($3,742)	($214,027)	($217,768)	($865,927)	$63,080	($264,150)
14	($3,742)	($208,038)	($211,780)	($1,077,707)	$55,768	($208,382)
15	($3,742)	($202,050)	($205,791)	($1,283,499)	$49,265	($159,117)
16	($3,742)	($205,643)	($209,385)	($1,492,883)	$45,568	($113,549)
17	($3,742)	($209,236)	($212,978)	($1,705,861)	$42,136	($71,412)
18	($3,742)	($212,829)	($216,571)	($1,922,432)	$38,952	($32,460)
19	($3,742)	($216,422)	($220,164)	($2,142,595)	$35,999	$3,538
20	($3,742)	($220,015)	($223,757)	($2,366,352)	$33,260	$36,799
Total	**($56,126)**	**($3,823,421)**	**($2,366,352)**		**$36,799**	

Life Cycle Costs

Ottawa - Large Office - LJ

SUMMARY OF ECONOMIC ANALYSIS Impact of Implementing Energy Efficiency Measures	
Simple Payback	11.76 year(s)
Actual Payback	> 20 year(s)
Internal Rate of Return	7.6%
Net Present Value Savings	($333,214)
Discount Rate	10%
Incremental Installed Capital Cost	$1,986,655
Incremental Maintenance Cost	($3,742)
Electricity Savings	$50,995
Fuel Savings	$114,207

SUMMARY OF LIFE-CYCLE COST ANALYSIS

YEAR	Maintenance	Energy Costs	Costs		Present-Value Savings	
			Net	Cumulative	Net	Cumulative
0	$0	$0	$1,986,655	$1,986,655	($1,986,655)	($1,986,655)
1	($3,742)	($167,754)	($171,496)	$1,815,159	$155,905	($1,830,750)
2	($3,742)	($170,306)	($174,048)	$1,641,111	$143,841	($1,686,908)
3	($3,742)	($172,858)	($176,600)	$1,464,511	$132,682	($1,554,226)
4	($3,742)	($175,411)	($179,152)	$1,285,359	$122,363	($1,431,863)
5	($3,742)	($177,963)	($181,704)	$1,103,654	$112,824	($1,319,038)
6	($3,742)	($181,563)	($185,305)	$918,349	$104,600	($1,214,439)
7	($3,742)	($185,163)	($188,905)	$729,445	$96,938	($1,117,501)
8	($3,742)	($188,763)	($192,505)	$536,940	$89,805	($1,027,696)
9	($3,742)	($192,363)	($196,105)	$340,835	$83,168	($944,528)
10	($3,742)	($195,963)	($199,705)	$141,130	$76,995	($867,533)
11	($3,742)	($212,977)	($216,719)	($75,589)	$75,959	($791,575)
12	($3,742)	($231,825)	($235,567)	($311,156)	$75,059	($716,516)
13	($3,742)	($225,542)	($229,284)	($540,440)	$66,415	($650,100)
14	($3,742)	($219,260)	($223,001)	($763,441)	$58,723	($591,377)
15	($3,742)	($212,977)	($216,719)	($980,160)	$51,881	($539,496)
16	($3,742)	($216,747)	($220,488)	($1,200,648)	$47,985	($491,512)
17	($3,742)	($220,516)	($224,258)	($1,424,906)	$44,368	($447,143)
18	($3,742)	($224,286)	($228,028)	($1,652,934)	$41,013	($406,131)
19	($3,742)	($228,055)	($231,797)	($1,884,731)	$37,901	($368,230)
20	($3,742)	($231,825)	($235,567)	($2,120,298)	$35,016	($333,214)
Total	**($56,126)**	**($4,032,118)**	**($2,120,298)**		**($333,214)**	