REPORT

City of Richmond South Arm Community Centre
Solar Thermal Preliminary Options Assessment

Prepared for:
City of Richmond
6911 No. 3 Road
Richmond, BC V6Y 2C1

Prepared by:
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June 5, 2012
File: 440-016.01

City of Richmond
6911 No. 3 Road
Richmond, BC V6Y 2C1

Attn: Levi Higgs, B.Sc. – Energy Manager

Dear Mr. Higgs,

Re: REPORT – City of Richmond South Arm Community Centre Solar Thermal Preliminary Options Assessment (POA)

Hemmera is pleased to submit the attached report to the City of Richmond. Included is a class-B engineering cost estimate for a potential future solar air heating system installation at South Arm Community Centre.

We trust that you find this submittal satisfactory. Should you have any questions or require more information, please do not hesitate to contact the undersigned.

Sincerely,
Hemmera

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EXECUTIVE SUMMARY

Hemmera was retained by the City of Richmond to provide a preliminary options assessment of solar air wall technology at South Arm Community Centre (SACC). The client objectives included:

A. Ensure selection of available technologies and system designs are well understood

B. Provide an overview of a range of solar thermal system sizing options supported by technology characteristic financial metrics, e.g. lifecycle costing, payback period, etc.

C. Gain insight into project capital cost options and obtain an engineering class cost "B" estimate for a selected possible future system installation

The "Old Building" and "New Building" provide the following renewable energy resource opportunities:

- **Site-specific Local Climate:** The local climate provides an economical opportunity for a solar thermal installation to preheat building fresh-air during two of four seasons
- **Shading:** Solar collector shading is considered negligible
- **Spatial Availability:** Ample space is available for a maximum of 400 m^2 solar air wall area
- **Roof Structural Integrity:** There were no concerns at the time of the site visit. Prior to construction sign-off by a structural engineer licensed in British Columbia is to be obtained
- **Load:** Space heating utility costs of $18,400 provide a strong opportunity for annual savings

In the following table, Option A is a smaller system option. Option C is the largest system option that fits the combined wall area. Option B provides a trade of between lower energy cost and a high internal rate of return (IRR).

Project Option	Solar Energy	GHG emit.	Investment Costs		
	eMWh thermal	tonnes	Gross	Grants	Client Net
Present case	**-**	**46.1**	**-**	**-**	**-**
A. 22% Solar, 125 m^2 Wall	87.7	35.3	$ 55,000	-	$ 55,000
B. 33% Solar, 275 m^2 Wall	**133.5**	**30.2**	**$ 99,000**	**-**	**$ 99,000**
C. 38% Solar, 400 m^2 Wall*	154.6	27.3	$ 136,000	-	$ 136,000

Note: * Option C assumes the use of a solar air wall canopy on the North Building

Hemmera recommends that a 275 m^2 commercial-type solar thermal system design be implemented utilizing transpired solar air wall technology for building fresh-air pre-heating. Its gross investment cost of $99,000 meets engineering class-B cost accuracy for design-build projects. Included are solar equipment costs, insulated ducting, mechanical accessories (e.g. dampers, booster fans), freight, design and installer labour costs as apply to the Old Building and New Building.

By reducing SACC heating related GHG emissions from presently 46.1 tonnes to 30.2 tonnes per year, this solar installation can add to Richmond's image as a leading municipality in climate change mitigation.

Below table illustrates system financial metrics for installation options A, B and C:

Preliminary Options	Savings Annually	Energy Cost $/ekWh	IRR	Payback Simple	Payback Actual
Present case	**-**	**$0.046**	**-**	**-**	**-**
A. 22% Solar, 125 m^2 Wall	$4,080	$0.034	11.3%	13	11
B. 33% Solar, 275 m^2 Wall	**$6,150**	**$0.029**	**10.0%**	**16**	**12**
C. 38% Solar, 400 m^2 Wall*	$7,160	$0.027	8.8%	19	14

Note: * Option C assumes the use of a solar air wall canopy on the North Building

Should the client wish to pursue the installation of a solar air wall system via a design-spec-tender process, detailed design may be developed prior to tendering (or issuing of an RFP) to arrive at a quality-installation. This will further avoid high bidder costs or bidder contingencies due to project unknowns.

Financial Subsidies

FortisBC may currently offer subsidies for a few select pilot solar air wall projects. Should the client wish to pursue a project, it is recommended that the client inquire with FortisBC's Energy Efficiency and Conservation (EEC) team about available subsidies for "Innovative Technologies" such as solar air walls.

Design Alternatives

- Should the client wish to pursue a smaller installation, a solar system comprised of 125 m^2 total wall area presents an alternative with strong financial and environmental benefits.
- Based on available site operational information at the time of this report, it appeared that CO^2 occupancy sensors are currently not part of the controls inventory. Further energy savings may be obtained by controlling building air changes via CO^2 occupancy sensors, especially in the less used Old Building. Should the client consider this measure it is strongly recommended that it'd be carried out in line with the solar retrofit project, in which case a smaller air wall may suffice.
- For the Old building, an industrial-type system design could be an alternative to the above commercial designs. It would consist of one or several duct runs that would penetrate through the concrete wall into the gym ceiling space and thermally destratify the indoor air via mixing, saving further energy (in the gym, only). Compared to other rooms, given a lower occupancy in the gym an industrial design option is anticipated to be less cost effective, especially if CO^2 sensors are retrofitted.

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1.0 INTRODUCTION

Hemmera was retained by the City of Richmond (the "Client") to prepare a Preliminary Options Assessment ("POA") in light of a potential future solar thermal ("solar") project at the following site:

Site: South Arm Community Centre ("SACC"), 8880 Williams Road, Richmond BC

1.1 OBJECTIVES

A. Ensure selection of available technologies and system designs are well understood

B. Provide an overview of a range of solar thermal system sizing options supported by technology characteristic financial metrics, e.g. lifecycle costing, payback period, etc.

C. Gain insight into project capital cost options and obtain an engineering class cost "B" estimate for a selected possible future system installation

1.2 SCOPE OF WORK

This report is based on the following scope of work.

Table A Scope of Work

Steps	Scope of Work
a. Project Kick-Off Onsite	• Meet Client and facility staff onsite for initial kick-off meeting (e.g. site engineer) • Gather understanding of Client project wish list , preferences, and facility usage and background information • Gather facility technical information and drawings as needed • Obtain insight into site specific construction opportunities and limitations
b. Renewable Energy Resource Assessment (Class Cost Estimate "B")	• Consolidate and analyse facility background material • Determine facility envelope integration and mechanical interconnection opportunities • Define available solar system sizing options as are suitable to the Site • Derive estimate of solar energy resource generation potential and environmental benefits (i.e. GHG emissions reductions) for pre-defined options • Derive project budget costs for Client-selected option per engineering class cost estimate "B" • Present conventional yearly financial performance metrics
c. Financial Sensitivity Analysis	• Analyze financial viability of solar energy technology over product lifecycle • Illustrate technology-characteristic lifecycle savings metrics for Client selection of their most economical option (e.g. ROI, resource energy cost, e.t.c.)
d. Recommendation	• Summarize solar project feasibility at this Site based on project findings • Recommend two to three project options that are financially attractive while satisfying the Client objectives • Present a report for Client review

1.3 Information Sources

This assessment is based on a site visit conducted on April 25th, 2012 that involved two buildings at SACC. Building rooftops and building exterior, as well as building interior spaces were examined.

- **Location:** 8880 Williams Road, Richmond BC
- **Site(s):** This site consists of two buildings, the "Old" (built in 1974) and the "New" building (built in 1990). They are connected through an enclosed north-south corridor ("Connection Link"); the New building is located north, while the Old building is located south.
- **Background Information:**
  - Monthly electricity and gas utility bills for North and South building (received from Levi Higgs)
  - Architectural and mechanical drawings for North and South building (from Martin Younis)
  - Mechanical equipment, commissioning and balancing files in binder (from Martin Younis)
  - Facility and room occupancy data (from Scott Schroeder)
  - Various site photos taken during site visit

1.4 General Assumptions and Methodologies

This assessment is based on the following general assumptions.

- **Building Thermal Load Applicable to Solar Air Wall:**
  - Preheating of outdoor fresh-air for space heating in the Old and New building
  - Building load analysis is available in **Appendix B**, "Gas Utility Bill for Old Building Heating", and in Appendix C, ("Electric Utility Bill for New Building Heating")
- **Equipment:**
  - Old building: (4) gas-electric rooftop units ("RTUs") provide heating and cooling
    New building: (16) heat pump RTUs provide heating and cooling to the various rooms
- **Energy Calculation Assumptions:**
  - Natural Gas: average utility cost $0.045/kWh ($12.4/GJ) for utility bill Jan 2006 to Dec 2011, greenhouse gas emission factor: 0.056 tonnes/GJ[1]
  - Electricity: average utility cost $0.069/kWh for utility bill Jan 2006 to Dec 2011, greenhouse gas emission factor: 0.0154 tonnes CO^2eq./MWh[2]
  - Heater seasonal efficiency: 70% estimate for natural-gas fired rooftop units on Old building (per NRCan, for spark-plug); 200% for electric heat pumps on New building

1 NRCan, Office of Energy Efficiency, CO^2 Emissions Factors
2 B.C. Ministry of Environment, Greenhouse Gas Inventory Report, Emission Factors for Electricity Generation in B.C.

- ▫ Weather station data: White Rock has been selected from hundreds of weather stations across North America as the nearest and most suitable location. Microclimatic local weather fluctuations can be assumed to be accounted for. Site-specific features that may impact wind speeds on the solar air wall (e.g. building geometry, adjacent trees) were taken into account. An attenuation factor of 0.5 has been applied to wind speed data of the local weather station
- ▫ Performance estimates: RETScreen[3] 4.0 simulation software was employed. Building heat recapture through the solar air wall area has been considered. NRCan recommends using version 4.0, as it accounts for variable wind speeds at different locations (omitted in previous revisions, resulting in overestimated performance)
- ▫ Solar collector data: the following data was employed for performance estimates representing various solar industry products: collector type = transpired; solar spectrum absorptivity (alpha) = 0.94 for black collectors; solar system performance factor (n) = 0.93 representing various equipment suppliers. Note: performance factor is subject to an outdated NRCan incentive program terminated in December 2010

- **Financial Assumptions and Calculation Methodologies:**
  - ▫ Class-B budget cost estimates include equipment and installation costs applicable to specialized solar air wall and general HVAC equipment suppliers as required. Costs apply to projects tendered as design-build arrangements. For design-spec-tender arrangements, per Hemmera experience cost increase may apply depending on third-party scope of work, e.g. specifications, construction management, quality control (QC), or project unknowns
  - ▫ Electricity consumption and costs for operating a solar booster fan have been considered negligible – an assumption that can be made due to normally very high coefficients of performance (COP) seen in solar thermal systems
  - ▫ Lifetime calculations and future natural gas and electricity costs have been estimated at average 5%[4] annual cost inflation
  - ▫ Over the lifetime of a solar system a booster fan may require servicing. A lifetime of 10 years and a service cost of $4,000 have been assumed, and cost escalation has been applied
  - ▫ Net Present Value (NPV), Internal Rate of Return (IRR) and Return on Investment (ROI) of solar energy have been based on solar air wall cladding and system lifetime of 40 years. For different system sizes these financial metrics can vary, which is a result of a relatively high energy yield of smaller installations (smaller solar fractions) versus the benefits of economies-of-scales of larger installations. For NPV calculations, based on current economic conditions a discount rate of 7% is assumed
  - ▫ Solar Energy Cost (a.k.a. levelized energy cost, or resource cost) is the total effective energy cost provided by the hybrid heating system. Solar energy cost is calculated through lifetime expenses (converted via inflation to today's value) divided by the energy produced. This number in $/kWh, compared with the today's energy cost in $/kWh, demonstrates the savings potential offered by select solar thermal installation sizes

[3] RETscreen is an internationally recognized simulation software and has herein been employed as a high-level screening tool for calculations of solar thermal system energy yield. It is published by Natural Resources Canada.

[4] Annual commodity inflation: 4% for natural gas, 6% for electricity [Metro Vancouver].

2.0 PRELIMINARY OPTIONS ASSESSMENT

2.1 RENEWABLE ENERGY RESOURCE ASSESSMENT

SACC consists of two buildings that were reviewed during the site visit. The following figure shows the southern wall of the Old Building (left) and of the New Building (right).

Figure 1 Installation Area

The site visit provided the necessary information for a high-level assessment of available solar renewable energy resource onsite. Initial findings are described as follows.

- **Site-specific Local Climate:** Geographic location and annual climate onsite will enable a solar thermal system to preheat building fresh-air during two of four seasons (design period). During this period both buildings' southern walls are unobstructed from receiving solar radiation and hence will contribute to building space heating.

  A performance report is available in section 2.3, "System Options". Weather data, including solar intensity, cloud coverage, wind speeds, local ambient temperatures, was selected from a database of several hundred weather stations across Canada, with White Rock being the closest match for this site.

- **Solar Collector Shading:** Obscuring effects by the surrounding building protrusions and existing site features are considered negligible during the design period in Spring and Fall.

  During the design period the sun is at an elevation of 17-65 degrees, providing full sun exposure to both the Old Building and New Building walls. During warmer afternoon hours, when building heating is commonly not required, the deciduous trees located to the west are expected to provide adequate shading.

- **Spatial Availability:** This site offers ample space for a solar installation.

  The Old Building provides maximum 150 m^2 of usable wall area and the New Building 215 m^2 (total 365 m^2). A maximum of 400 m^2 can be achieved via implementation of a solar air wall canopy on the North Building. A sample solar installation, as illustrated in **Table B** below, may use 70-80% of the currently usable wall area on the two buildings.

The solar air wall would connect via insulated ducts with the fresh-air intakes of the existing mechanical equipment located on the roof, i.e. the rooftop units / RTUs. There is adequate space available for the interconnecting duct runs. The New Building consists of a roof "trench" where the ducts may be routed to connect with the mechanical equipment.

- **Structural Integration:** During the site walk through no observations were made, nor were concerns raised by maintenance staff that building walls could potentially be weathered or structurally compromised. It can be assumed[5] that the structural integrity is sound for all walls.

  Structural approval of any selected system size is commonly obtained during the detailed design phase through a professional engineer licensed in British Columbia.

- **Ambient Reflections:** Benefits of additional solar radiation through ambient reflections from glass buildings, water features or snow fields are not available at this site.

The following **Table B** provides an overview of a sample solar renewable energy installation showing system characteristic parameters and traits.

Table B Resource Assessment

	Old/South Building (1974) Gym	New/North Building (1990) Squash & Racquet Court	Units
Location			
Weather Station Data	White Rock	White Rock	-
Latitude / Longitude	49 North / -122.8 West	49 North / -122.8 West	Degrees
Site-Specific Resource			
Average Air Temperature	10.7	10.7	degC
Avg. Daily Solar Radiation (horizontal)	3.5	3.5	$kWh/m^2/d$
Wind Speed [6]	0.9	0.9	m/s
Energy Basis			
Space Heating Equipment	Gas/Electric	Electric/El. Heat Pumps	-
Seasonal Efficiency (AFUE)	70%	200%	%
Annual Heating Demand [7]	153	251	eMWhr
Annual Space Heating Cost	$18,400		$

[5] Addition of solar equipment to the wall structure commonly adds approximately 2.5 psf of wall load. This additional wall load applies to the carrying capacity of many commercial type walls and is applicable to metal and concrete structural design. If the building has been professionally designed and is not subject to environmental issues such as rot and insect infestation, then it is highly unlikely for there to be a requirement for structural upgrade.

[6] Weather station wind speed data has been adjusted from 10m standard height to average solar air wall height

[7] Tertiary energy, i.e. building load side

	Old/South Building (1974) Gym	**New/North Building (1990) Squash & Racquet Court**	**Units**
Solar Thermal System			
Solar Energy Supply [7]	53	81	eMWhr
	34%	32%	%
Solar Collector Area	100	175	m^2
Max. Solar Air Wall Area	(150)	(250*)	m^2
Installation Angle	90	90	Degrees
Installation Orientation	South	South	-
Costs			
Capital Cost Estimate	$99,000		$
Annual Maintenance	$200	$200	$
Annual Operating Cost [8]	$0	$0	$
Annual Net Heating Cost [9]	$12,250		$
Simple Payback	16 years		-
Equipment Life Expectancy	40+ years	40+ years	Collectors
	20 years	20 years	Mechanical
GHG Emissions			
Annual (before)	44.1	2.0	tCO^{2}e
Annual (after)	28.9	1.4	tCO^{2}e

Note: * Assumes the use of a solar air wall canopy on the North Building

It is demonstrated that a solar air wall size of 70-80% of available wall area (150 m^2 and 250 m^2 area, respectively) could reduce building annual heating costs by approximately 33%. How this system compares to other available installation size options, is discussed later.

A solar thermal installation is technically feasible at this site. A detailed investigation follows.

2.1.1 Thermal Loads

Unlike traditional mechanical systems, the energy generation potential of solar thermal systems is subject to fluctuations in daily and seasonally available sunshine. In order to *right-size* a solar thermal system, its energy supply needs to relate to the building's annual thermal energy demand (energy supply needs be less or equal to the thermal load). The following **Table C** lists any *key* design parameters.

8 No operations staff required
9 Secondary energy, i.e. utility supply

Table C Thermal Load

	Old/South Building (1974) Gym	New/North Building (1990) Squash & Racquet Court	Units
Energy			
Utility	Natural Gas	Electricity	-
Utility Cost	$0.045	$0.069	$
Utility Secondary Energy Use	313	639	MWh
Space Heating Share [10]	70% [30% DHW]	28% [72% other elec.]	%
IHG Adjustment [11]	N/A	70%	%
Utility Heating Use (Second.)	219	125	MWh
Space Heating Est. Cost	$9,790	$8,610	$
Heater Seasonal Efficiency	70% (spark-plug burner)	200% (air heat pump)	%
Thermal Load (Tertiary)	**153**	**251**	**eMWh**
Supply Air			
Flow Rate	**5,300**	**7,200**	**CFM**

The total annual thermal load for space heating at SACC is 403 eMWh (153 and 251 eMWh, respectively). The corresponding total utility cost is $18,400 ($CO^2$ emissions are 46.1 tonnes per year), and total (tertiary) energy cost is $0.046/ekWh.

The total flow rate in CFM estimated to be drawn by the solar thermal systems and supplied to the RTUs is 12,500 CFM (5,300 and 7,200 CFM, respectively). This is based on the current building mechanical design; detailed data has been obtained from the exhaust fan schedule of both buildings.

Detailed thermal load information is available in **Appendix A**, **B** and **C**.

2.2 System Sizing Guide

Economics of renewable energy technology are represented by two characteristic parameters, a) solar energy cost as per **Figure 2** below, and b) return on investment (ROI) per **Figure 3**. Solar energy cost is the levelized cost of energy over the system lifetime considering capital cost, operation & maintenance cost, and cost for conventional fuel input.

10 NRCan "Comprehensive Energy Use Database": Arts, Entertainment and Recreation Secondary Energy Use
11 Internal Heat Gains (IHG) adjustment from baseline facility type (Arts, Entertainment and Recreation) to recreation centre

Figure 2 System Sizing Guide – Energy Cost

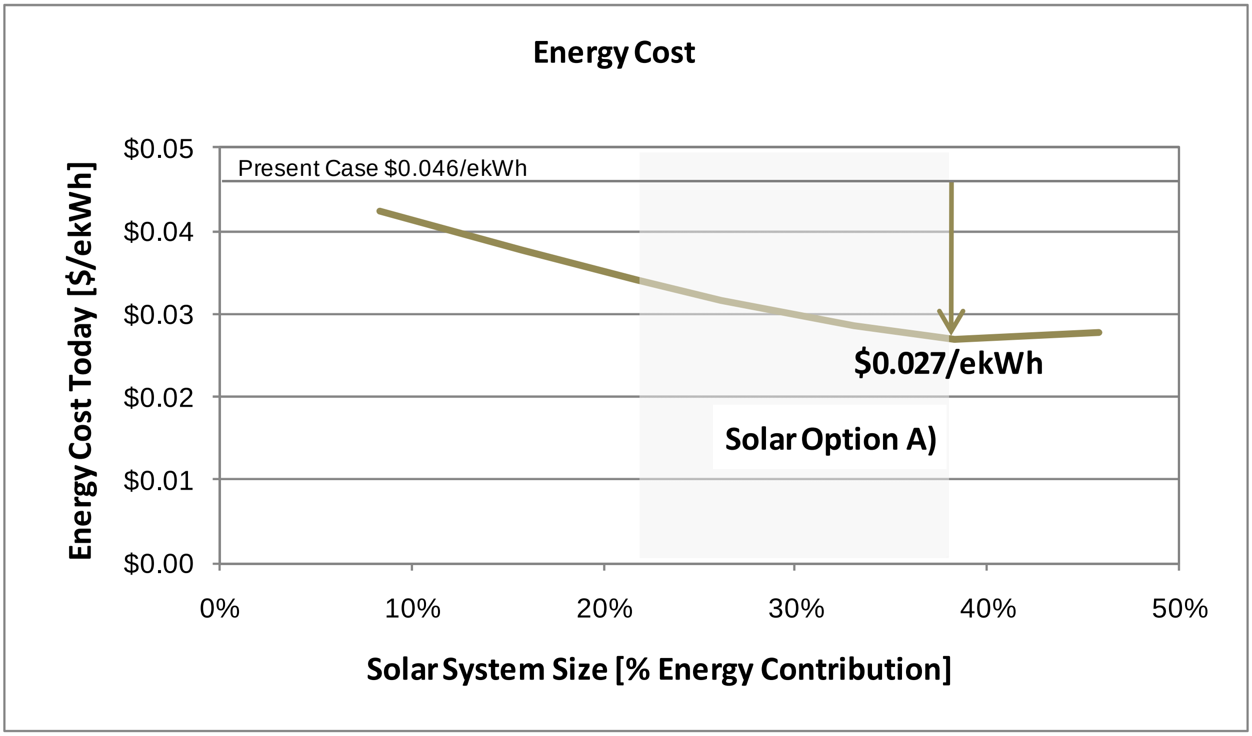


Figure 2 illustrates the energy cost for various solar system sizes. It can be observed that with a larger solar installation energy costs may drop significantly, from currently $0.046/ekWh to $0.027/ekWh. The shaded area between 22-38% is characterized by Option A on the right side, and by Option C on the left side (see **Figure 3**, below).

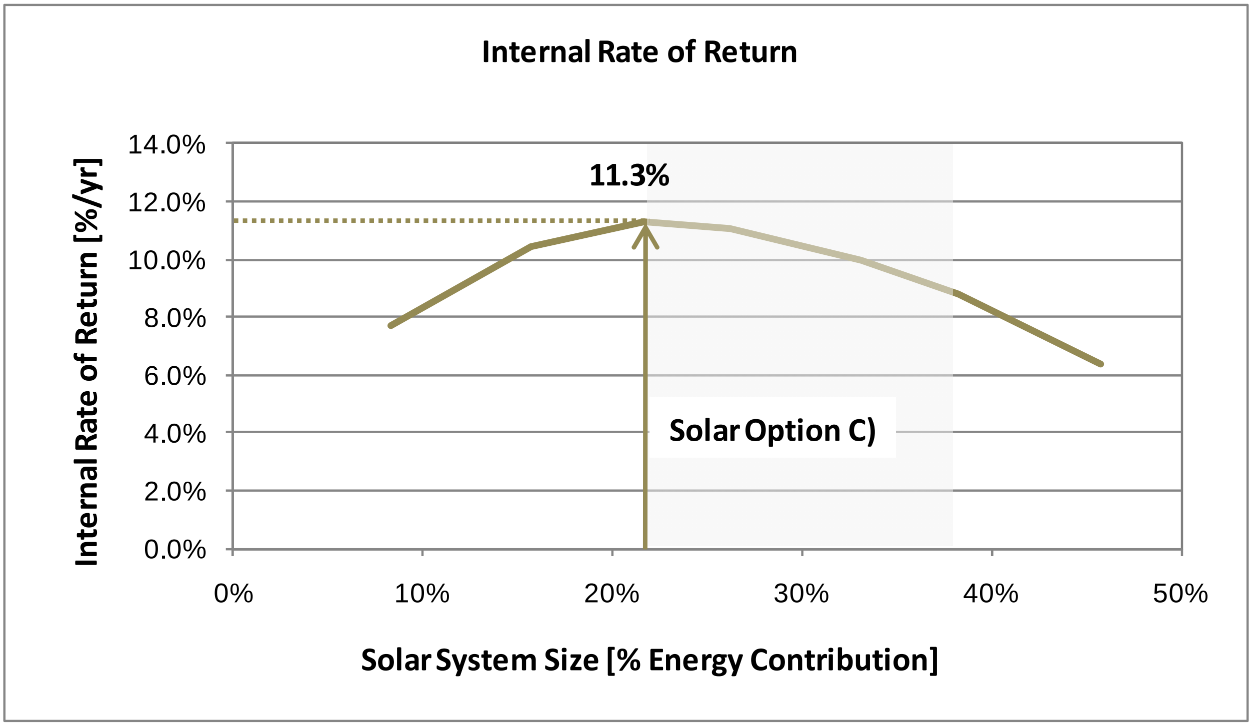
Energy costs will increase for larger solar installations, i.e. above approx. 38% solar fraction. Experience shows that a solar system with an annual solar fraction of 38% may supply more heat than needed in the summer months. But, to match the load demand of winter, a larger solar thermal would be needed. The capital cost involved in upsizing the system to meet the winter demand will outweigh the savings; this is the reason for higher energy costs of installations above 38%.

Guide: the Client may choose a solar system size that is smaller than indicated by the lowest point on the curve, i.e. 38% solar fraction for Option A. (Note: it is further recommended that at this site the solar installation be limited to 38% as a result of wall spatial constraints.)

Figure 3 below shows the return on investment or annual rate of return (annual internal rate of return, IRR). Compared with the previous energy cost curve, energy cost is better for large solar systems (38%) but ROI is better for smaller solar systems (22% solar fraction).

Guide: the Client may choose a solar system size providing a trade off between strong energy cost and a strong ROI – while considering their primary objective of attaining noticeable yearly utility cost savings.

Figure 3 System Sizing Guide – ROI



For Option C with 22% solar fraction, an annual ROI of 11.3% is estimated. For large solar systems ROI may diminish to as low as 6.4% (at 46% solar fraction, or annual energy contribution).

Guide: In summary, this section highlights that at SACC the most cost-effective project options are estimated to fall within solar fractions between 22% and 38%.

2.3 SYSTEM OPTIONS

As a result of lifecycle system sizing described in the previous section, the following solar thermal system options have been derived. Presented in **Table D** are three economical options that suit the thermal load requirements onsite.

Option A is a smaller system option. Option C is the largest system option that fits within the available wall area. Option B provides a trade of between low energy cost benefits and high internal rate of return.

Table D System Options

Project Option	Solar Energy	GHG emit.	Investment Costs		
	eMWh thermal	tonnes	Gross	Grants	Client Net
Present case	**-**	**46.1**	**-**	**-**	**-**
A. 22% Solar, 125 m^2 Wall	87.7	35.3	$ 55,000	-	$ 55,000
B. 33% Solar, 275 m^2 Wall	**133.5**	**30.2**	**$ 99,000**	**-**	**$ 99,000**
C. 38% Solar, 400 m^2 Wall*	154.6	27.3	$ 136,000	-	$ 136,000

Note: * Option C assumes the use of a solar air wall canopy on the North Building

Option B is highlighted in the above table as the **recommended option**. Its gross investment cost of $99,000 meets engineering class-B cost accuracy for design-build projects. Further details including system conceptual specifications are provided in Section 3.1, "System Specification".

Above retrofit options include solar equipment for the Old Building and New Building, insulated ducting, mechanical accessories (e.g. dampers, booster fans), freight, design and installer labour costs.

2.4 Economic Assessment

The economic benefits for options A-C are available in the following **Table E**. Presented are annual savings and lifetime financial metrics. Current annual utility costs have been estimated at $18,400 and at $0.046/ekWh (equivalent kWh, based on tertiary energy use).

The below table illustrates lifecycle financial benefits provided by the various solar system sizes.

Table E Financial Metrics

Preliminary Options	Savings	Energy Cost	IRR	Payback	Payback
	Annually	$/ekWh		Simple	Actual
Present case	**-**	**$0.046**	**-**	**-**	**-**
A. 22% Solar, 125 m^2 Wall	$4,080	$0.034	11.3%	13	11
B. 33% Solar, 275 m^2 Wall	**$6,150**	**$0.029**	**10.0%**	**16**	**12**
C. 38% Solar, 400 m^2 Wall*	$7,160	$0.027	8.8%	19	14

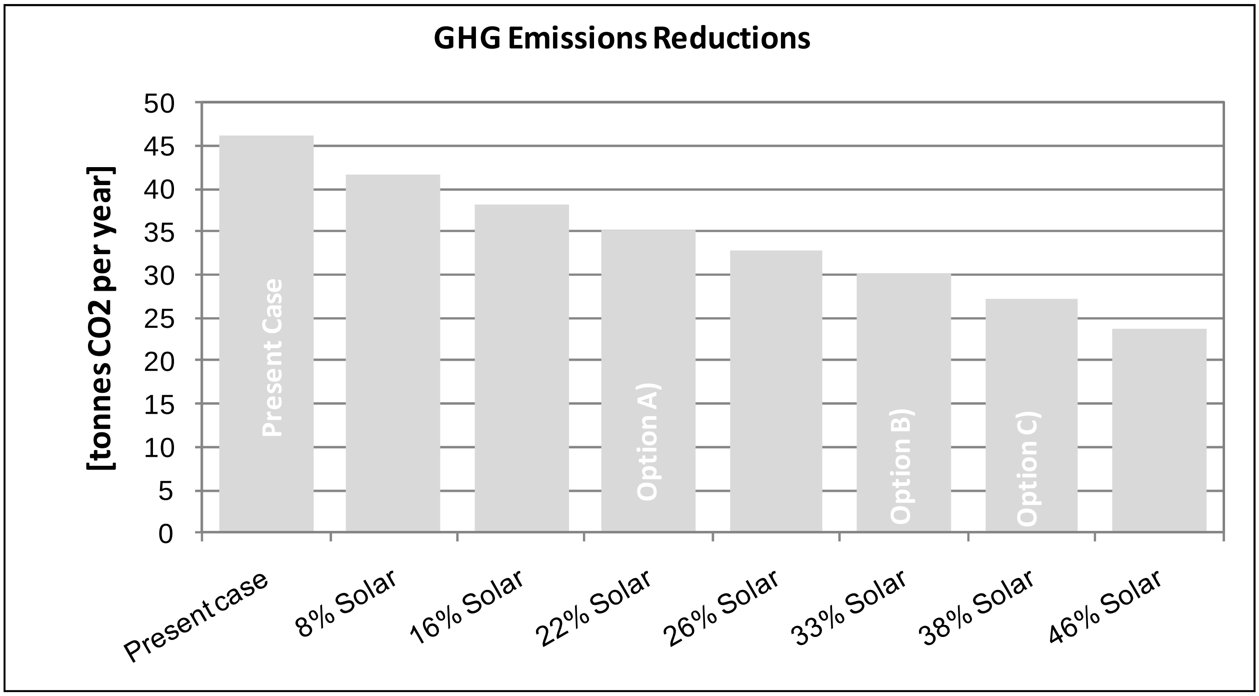
Note: * Option C assumes the use of a solar air wall canopy on the North Building

The recommended Option B is estimated to provide annual savings of $6,150 over the current $18,400, amounting to a remaining heating related utility cost of $12,250 per year. It is estimated that the Client can anticipate lifecycle energy costs of $0.029/ekWh, compared with the current $0.046/ekWh. Actual payback (including energy cost inflation) is 12 years. IRR is estimated at 10.0% annual return.

2.5 ENVIRONMENTAL ASSESSMENT

With increasing solar thermal system size the amount of GHG emissions is reduced proportionally to the renewable energy supply. Options A, B and C are estimated to reduce GHG emissions from currently 44.1, to 33.3, 28.3 and 25.4 tonnes per year. The below figure illustrates the GHG reduction potential.

Figure 4 GHG Emissions Reductions



3.0 RECOMMENDATIONS

Hemmera recommends that the Client pursue a solar thermal system installation at Richmond South Arm Community Centre.

3.1 SYSTEM SPECIFICATION

A commercial-type solar heating system design may be implemented by connecting to the rooftop mechanical heating equipment. Due to the mild local climate, transpired unglazed solar air wall technology for fresh-air pre-heating is recommended. This system comprises of a total of 275 m2 solar air wall area and suits approximately 70-80% of the available southern wall area on the Old Building and New Building.

Table F Concept Specification

	Old/South Building (1974) Gym	New/North Building (1990) Squash & Racquet Court
System Design	**Commercial**	**Commercial**
Total Solar Collector Area	100 m^2	175 m^2
Wall Location	Gym south wall	Racquetball Court south wall (2^{nd} floor)
Current Wall Assembly	• 6" concrete, reinf. steel at centre • 2x4 strapping, lined w/ 1-1/2" batt insulation • 1/2" painted ply • 1x4" cedar panel int. finish	• Metal cladding+ TYVEC • Z-bar, lined w 1-1/2" rigid insulation • 6" steel studs • 5/8" drywall (1-2 layers) • 6" batt insulation • Vapor barrier • 7/8" particle board • Trowel finish on fiberglass mesh Note: all walls subdivided by 10x10x.25 HSS beams in conc. columns
Wall Integration	Solar supplier provides wall and Z-bar design and construction information	
Cladding Profile	• Transpired unglazed; non-selective black coating, 0.94 absorptive coeff. • Galvanized steel profile suits existing standard building envelope panels • Specified panel gauge and coating type will achieve min. 40 years lifetime • Perimeter sealing of solar air wall is required	
Mechanical Integration	West duct branch: to AV-1 (Gym) East duct branch: to AC-1, AC-2 (other building zones)	Master duct in trench w/ booster fan Split into two runs Branches: connect to RTUs w large S/A fractions, i.e. RTU #4-7 and 9-15 (total: 11 RTUs of 16),
Auxiliary Heating System	RTUs gas/electric	RTU electric/electric heat pumps
Overtemperature Protection	Motorized damper	Motorized damper
Supply Air	5,300 CFM est. (design: 4.9 CFM/ft^2)	7,200 CFM (est.) (design: 3.8 CFM/ft^2)
Solar Industry Best Practices	• 8 CFM/ft^2: higher efficiency / high volumetric flow • 5 CFM/ft^2: nominal efficiency / standard temp. rise • 2 CFM/ft^2: lower efficiency / high temperature rise	
Maintenance Est.	• Dependant on supplier design • Booster fan and motorized damper service/replacement aprox. every 10 years	
System Life Expectancy	40+ years	40+ years

This solar thermal system is estimated to reduce current annual utility costs from $18,400 to $12,250, or save $6,150. Throughout its minimum lifetime of 40 years, the effective energy cost of the hybrid heating system is estimated to be reduced from presently $0.046/ekWh to $0.029/ekWh. The reduction in energy cost is attributable to the cost-free solar energy contribution following the initial investment.

By reducing SACC heating related GHG emissions from presently 46.1 tonnes to 30.2 tonnes per year, this solar installation can add to Richmond's image as a leading municipality in climate change mitigation.

3.2 SYSTEM COST

Project gross cost amounts to $99,000.

The information provided herein (Class B cost estimate) is neither detailed design nor is it a system specification document. Prior to tendering, any such information may be developed by accurately specifying mechanical design and equipment requirements. This will avoid high bidder costs or bidder contingencies due to project unknowns.

3.2.1 Financial Subsidies

FortisBC may currently offer subsidies on very few solar air wall installations. Should the client wish to pursue a project, it is recommended that the client inquire with their Energy Efficiency and Conservation (EEC) team about available subsidies for "Innovative Technologies", such as solar air wall installations.

Under the previous ecoENERGY for Renewable Heat program, incentives for commercial scale installations were available. However, the program has since been terminated – this alongside a performance rating scheme for select solar air wall products.

3.3 DESIGNS ALTERNATIVES

- Should the client wish to pursue a smaller installation, a solar system comprised of 125 m^2 total wall area presents an alternative with strong financial and environmental benefits
- Based on available site operational information at the time of this report, it appeared that CO^2 occupancy sensors are currently not part of the controls inventory. Further energy savings may be obtained by controlling building air changes via CO^2 occupancy sensors, especially in the less used Old Building. Should the client consider this measure it is strongly recommended that it'd be carried out in line with the solar retrofit project, in which case a smaller air wall may suffice
- For the Old Building, an industrial-type system design could be an alternative to the mentioned commercial design. It would consist of one or several duct runs that penetrate the concrete wall into the gym ceiling space, and thermally destratify the indoor air via mixing, saving further energy (in the gym, only). However, compared to the other rooms, given a lower occupancy in the gym an industrial design option is anticipated to be less cost effective, especially if CO^2 sensors are retrofitted

4.0 NEXT STEPS

Should the client decide they would like to implement a solar thermal heating system, to arrive at a high-quality installation detailed design work may be carried out prior to tendering (or issuing of an RFP). The financial, technical and environmental benefits highlighted in this report may therefore be obtained with minimal maintenance and over the solar system's 40 year lifetime.

5.0 CLOSURE

Hemmera thanks the City of Richmond for the opportunity to submit this work, and we trust that you will find this submittal satisfactory.

Should you have any questions or require more information, please do not hesitate to contact the undersigned.

Sincerely,
Hemmera

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6.0 STATEMENT OF LIMITATIONS

Hemmera has performed the Services in a manner consistent with the level of care and skill normally exercised by members of the renewable energy profession practicing under similar conditions at the time the work was performed. Client recognizes that opinions are based on limited data and that actual conditions and performance may vary from those encountered at the times and locations where the data was obtained, despite the use of due professional care. Any opinions provided represent a reasonable review of the information available to Hemmera within the established Scope, work schedule and budgetary constraints. Although the information obtained from this investigation is believed to be generally representative, the nature of renewable energy systems can be considered variable due to their interaction with the environment. No investigation – no matter how comprehensive – can wholly eliminate uncertainty regarding the possible presence of unidentified features or processes that may ultimately affect the performance of an actual full-scale renewable energy system during its operational life.

While providing the Services, Hemmera has relied in good faith on information provided by others as noted, and has assumed that the information provided by those individuals is both factual and accurate. Hemmera accepts no responsibility for any deficiency, mis-statement or inaccuracy in our Reports resulting from the information provided by those individuals.

Hemmera is responsible to Client for Services provided by Hemmera and the services of Hemmera subcontractors. Hemmera is not responsible for the acts or omissions of other parties engaged by Client nor for their construction means, methods, techniques, sequences, or procedures, or their health and safety precautions and programs. This agreement has not created any rights or benefits to parties other than Client and Hemmera. No third party has the right to rely on Hemmera opinions rendered in connection with the Services without Hemmera written consent and the third party's agreement bound to the same conditions and limitations as Client. Any use that a third party makes of these opinions, or any reliance on or decision made based on it, is the responsibility of such third parties. Hemmera accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on these opinions.

7.0 COPYRIGHT NOTICE

APPENDIX A
Building Supply Air CFM Rates

Purpose	CURRENT DESIGN		VERIFICATION				
Basis	Per Exhaust Fan Schedule		Per Occupancy				
Reference	Design Drawings	Balancing Report	Site Staff				
OLD/SOUTH BUILDING (1974)	CFM	CFM	Occupancy per day	Hours used	Avg. Stay	Occupancy instantaneous	CFM
TOTAL	**5265**	N/A					764.3
MAIN FLR			-				
Gymnasium			150	14	1	10.7	214.3
Day Care [lounge, games rm]			30	10	4	12.0	240.0
Work Rms			-				
Community Policing E-4.1	800		10	10	3	3.0	60.0
Wash Rms E-1	1100						
Arts (Change Rm E-2, female)	1000		20	8	2	5.0	100.0
Change Rm E-3 (male)	1000		-				
Kitchen E-11 (n/a.)	N/A		20	8	1	2.5	50.0
Janitor E-12	90						
UPPER FLR			-				
Multi-Pps Rm			60	12	1	5.0	100.0
Wash Rms E-6	350						
Janitor Rm E-7	90						
Storage E-4.2	600						
Utility Rm E-5	145						
Kitchen E-8 (n/a.)	N/A						
Range Hood E-9	N/A						
Wash Rms E-10	90						
NEW/NORTH BUILDING (1990)	CFM	CFM	Occupancy per day	Hours used	Avg. Stay	Occupancy instantaneous	CFM
TOTAL	10670	**11988**					2502.9
MAIN FLR			-				
Corridor							
Lounge [Board Rm]			50	12	0.5	2.1	41.7
Admin			10	8	1	1.3	25.0
Office			1	8	8	1.0	20.0
Preschool [Day Care]			60	5	2.5	30.0	600.0
Wash Rms Day Care EF-3	200	320					
Seniors Activity			30	9	2	6.7	133.3
Seniors Lounge			50	9	0.5	2.8	55.6
Wash Rms Seniors EF-4	200	320					
Multi-pps Fitness Cardio			100	12	0.5	4.2	83.3
Wash Rms All. EF-1	800	1020					
Storage, Elec. EF-5	250	390					
Storage, Mech. Rm EF-9	220	400					
Janitor EF-6 (roof)	600	680					
Family Games Rm/Youth			200	13	1	15.4	307.7
Food prep EF-10	N/A	N/A	10	11	1	0.9	18.2
Food prep EF-11	N/A	N/A	10	11	1	0.9	18.2
UPPER FLR							
Corridor							
Squash Courts			40	10	1	4.0	80.0
Multi-pps Aerobics, Storage			250	15	1	16.7	333.3
Cardio [sauna] AHU-1	5000	4770	500	15	0.5	16.7	333.3
Change Rms			500	15	0.1	3.3	66.7
Cardio [whirlpool]			-				
Pool Equip. Rm EF-8	400	625					
Wash Rms All., Jan EF-2	1000	1088					
Fitness Weight EF-7	2000	2375	500	15	0.4	13.3	266.7
Racquet Courts			60	10	1	6.0	120.0

APPENDIX B

Gas Utility Bill for Old Building Heating

OLD/SOUTH BUILDING (1974)			Use	Cost	Gas Cost
		Avg:	312,654		0.045
Date	Read Usage (GJ)	Gas Cost ($)	[kWh]	[$]	[$/kWh]
Jan-06	123.7	1,764.23			
Feb-06	129.3	1,836.97			
Mar-06	124.8	1,773.99			
Apr-06	88.5	1,147.80			
May-06	43.3	551.86			
Jun-06	30.7	399.03			
Jul-06	24.9	325.81			
Aug-06	30.2	389.52			
Sep-06	32.4	415.99			
Oct-06	59.7	744.2			
Nov-06	94.2	1,158.96			
Dec-06	187.3	2,278.20	269,167	12,787	0.048
Jan-07	196.6	2,436.32			
Feb-07	128.5	1,614.93			
Mar-07	117.2	1,475.21			
Apr-07	92.2	1,166.05			
May-07	51.2	659.07			
Jun-07	28.5	378.36			
Jul-07	28.7	380.85			
Aug-07	24.3	326.43			
Sep-07	34.6	455			
Oct-07	76.5	922.3			
Nov-07	121.6	1,493.45			
Dec-07	0	0	249,972	11,308	0.045
Jan-08	346.5	4,306.34			
Feb-08	158.8	2,021.01			
Mar-08	139.1	1,773.61			
Apr-08	96.9	1,242.10			
May-08	59.7	775.05			
Jun-08	41.3	544.28			
Jul-08	0	0			
Aug-08	28.4	397.28			
Sep-08	42.2	577.54			
Oct-08	84.5	1,130.17			
Nov-08	136.47	1,809.50			
Dec-08	178.69	2,360.81	364,600	16,938	0.046
Jan-09	149.63	1,943.32			
Feb-09	167.45	2,152.71			
Mar-09	170.32	2,188.21			
Apr-09	110.63	1,427.06			
May-09	57.76	758.2			
Jun-09	29.05	394.33			
Jul-09	31.8	435.23			
Aug-09	24.59	345.14			
Sep-09	31.09	428.98			
Oct-09	55.97	750.07			
Nov-09	111.92	1,470.93			
Dec-09	163.27	2,133.76	306,522	14,428	0.047
Jan-10	172.94	2,368.45			
Feb-10	120.4	1,709.78			
Mar-10	135.1	1,915.12			
Apr-10	67.33	968.02			
May-10	55.6	804.6			
Jun-10	42.42	620.2			
Jul-10	27.38	416.05			
Aug-10	29.35	445.41			
Sep-10	49.92	739.01			
Oct-10	77.19	1,128.10			
Nov-10	126.07	1,538.38			
Dec-10	176	2,038.68	299,917	14,692	0.049

Jan-11	193.72	2,139.74			
Feb-11	219.43	2,373.59			
Mar-11	184.77	2,003.66			
Apr-11	134.22	1,462.65			
May-11	76.55	846.81			
Jun-11	41.4	470.47			
Jul-11	30.7	362.04			
Aug-11	25.7	309.75			
Sep-11	25	302.07			
Oct-11	69	748.21			
Nov-11	169.5	1,780.33			
Dec-11	218.7	0	385,747	12,799	0.033
Jan-12	237	4,817.68			
Feb-12	173.9	1,874.81			

APPENDIX C

Electric Utility Bill for New Building Heating

AER-Facility (typ.)		Fuel Use		Share	Equipment	Eff. est.	Load	
NRCan OEE Sector Specific Facility Average Energy Consumption in B.C.								
Sector: Commercial, Institutional								
Facility Type: Arts, Entertainment and Recreation								
Intensity	358	ekWh/m2						
	1.29	GJ/m2						
TOTAL		1039	eMWh	100%			922	eMWh
Space Heating		519	eMWh	50%	Gas + El.	75%	389	eMWh
Water Heating		79	eMWh	8%	Gas + El.	75%	59	eMWh
Auxiliary Equip.		171	eMWh	17%	El.	100%	171	eMWh
Auxiliary Motors		106	eMWh	10%	El.	100%	106	eMWh
Lighting		132	eMWh	13%	El.	100%	132	eMWh
Space Cooling		32	eMWh	3%	El.	200%	64	eMWh

SACC New (scaled)		Fuel Use (El.)			Equipment	Eff. est.		
Floor Area:	31214	ft2						
	2900	m2						
TOTAL		695	eMWh	100%			922	eMWh
Space Heating		194	eMWh	28%	El.	200%	389	eMWh
Water Heating		59	eMWh	9%	El.	100%	59	eMWh
Auxiliary Equip.		171	eMWh	25%	El.	100%	171	eMWh
Auxiliary Motors		106	eMWh	15%	El.	100%	106	eMWh
Lighting		132	eMWh	19%	El.	100%	132	eMWh
Space Cooling		32	eMWh	5%	El.	200%	64	eMWh

SACC New (per utility bill)			
Utility Use Total Facility	639,200	kWh	
Baseline Fraction	28%	Space Heating	* Space heating fraction as per SACC New (scaled)
IHG Adjustment	70%		* Accounts for Internal Heat Gains in high activity recreation facilities
Utility Use	125,283	kWh	

NEW/NORTH BUILDING (1990)			Use	Cost	Gas Cost
		Avg:	639,200		0.069
Date	Read Usage (kWh)	Total Elec Cost ($)	[kWh]		
Jan-06	62,400.00	3,311.92			
Feb-06	60,000.00	3,338.91			
Mar-06	57,000.00	3,181.39			
Apr-06	57,600.00	3,133.00			
May-06	48,000.00	2,774.47			
Jun-06	42,600.00	2,525.57			
Jul-06	49,800.00	2,957.85			
Aug-06	50,400.00	3,044.98			
Sep-06	45,600.00	2,735.74			
Oct-06	52,200.00	3,114.54			
Nov-06	48,000.00	2,877.85			
Dec-06	76,200.00	4,420.51	649,800	37,417	0.058
Jan-07	81,000.00	4,559.46			
Feb-07	61,800.00	3,612.81			
Mar-07	59,400.00	3,523.80			
Apr-07	58,800.00	3,317.81			
May-07	46,200.00	2,678.58			
Jun-07	43,800.00	2,636.36			
Jul-07	50,400.00	2,956.63			
Aug-07	42,600.00	2,591.35			
Sep-07	47,400.00	2,724.09			
Oct-07	48,000.00	2,794.11			

Nov-07	58,800.00	3,501.46			
Dec-07	67,800.00	3,838.78	666,000	38,735	0.058
Jan-08	76,800.00	4,505.30			
Feb-08	65,400.00	3,715.56			
Mar-08	64,800.00	3,640.93			
Apr-08	54,000.00	3,272.06			
May-08	46,800.00	2,903.50			
Jun-08	45,600.00	2,805.43			
Jul-08	43,200.00	2,710.10			
Aug-08	42,600.00	2,686.14			
Sep-08	43,800.00	2,683.74			
Oct-08	43,200.00	2,709.93			
Nov-08	48,600.00	2,949.32			
Dec-08	75,000.00	4,377.97	649,800	38,960	0.060
Jan-09	74,400.00	4,353.96			
Feb-09	67,200.00	4,065.53			
Mar-09	81,600.00	4,822.59			
Apr-09	41,400.00	2,379.31			
May-09	45,600.00	1,796.94			
Jun-09	45,600.00	2,971.09			
Jul-09	48,600.00	3,151.70			
Aug-09	46,200.00	3,388.15			
Sep-09	47,400.00	3,047.63			
Oct-09	42,600.00	2,845.27			
Nov-09	60,000.00	3,576.87			
Dec-09	59,400.00	3,942.40	660,000	40,341	0.061
Jan-10	63,000.00	4,042.85			
Feb-10	51,600.00	3,276.78			
Mar-10	70,800.00	4,348.82			
Apr-10	35,400.00	2,598.56			
May-10	45,000.00	3,220.27			
Jun-10	57,000.00	4,059.46			
Jul-10	29,400.00	2,150.18			
Aug-10	44,400.00	3,239.97			
Sep-10	48,000.00	3,405.36			
Oct-10	44,400.00	3,181.55			
Nov-10	54,600.00	4,187.28	603,000	41,653	0.069
Dec-10	78,600.00	5,574.24			
Jan-11	48,000.00	3,339.86			
Feb-11	55,800.00	3,923.75			
Mar-11	67,800.00	4,131.67			
Apr-11	45,000.00	3,065.37			
May-11	28,800.00	2,257.56			
Jun-11	46,200.00	3,276.71			
Jul-11	45,000.00	3,404.68			
Aug-11	48,600.00	3,489.88			
Sep-11	45,000.00	3,336.80			
Oct-11	42,000.00	2,994.62			
Nov-11	55,800.00	3,896.13	606,600	42,691	0.070
Dec-11	50,400.00	3,529.59			
Jan-12	64,800.00	4,667.78			
Feb-12	50,400.00	3,611.12			
Mar-12	54,000.00	3,884.00			

APPENDIX D

Lifecycle Financial Charts

Figure D-1 Lifetime Cost Savings

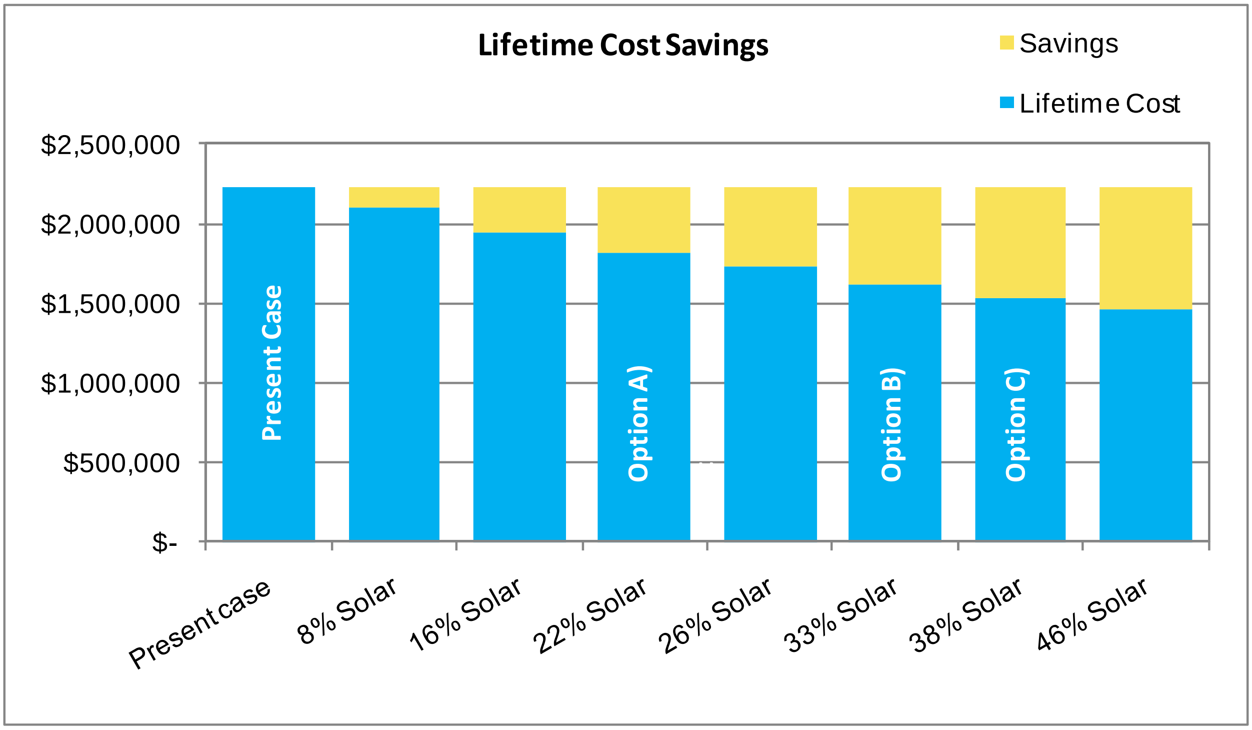
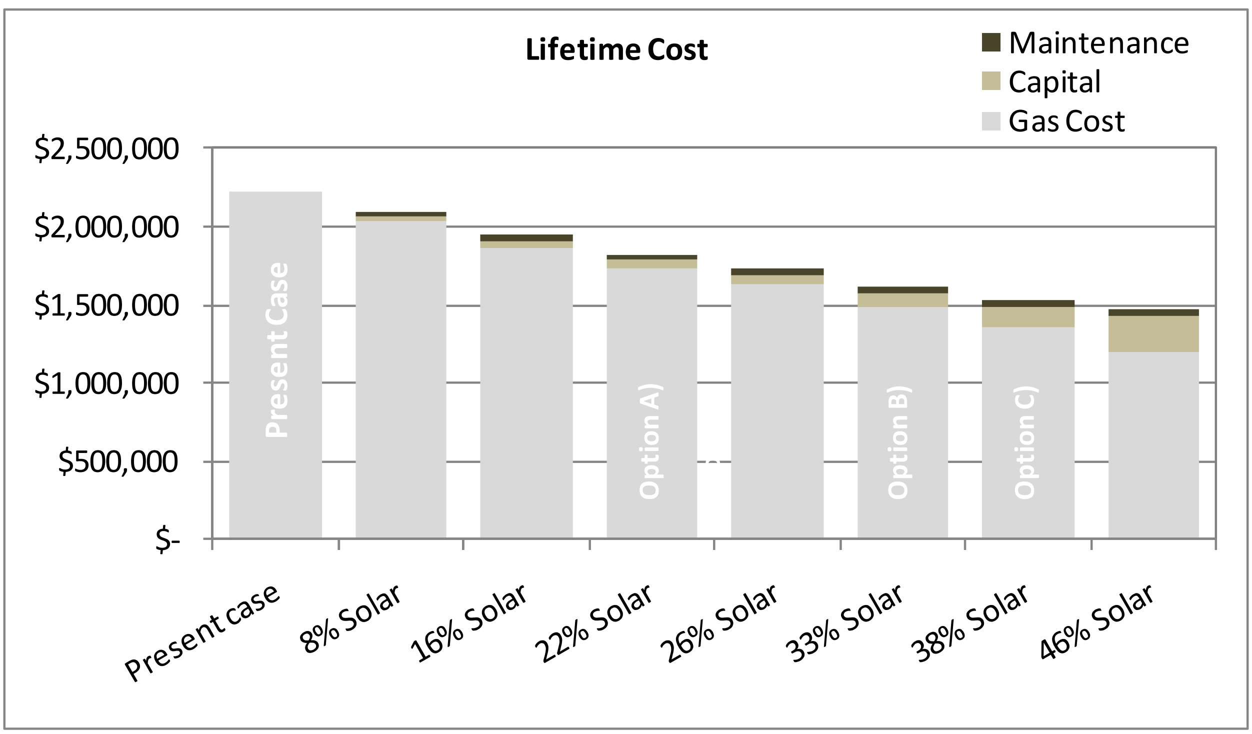


Figure D-2 Lifetime Cost



APPENDIX E

Solar Thermal Installation Examples

Project Title	Project Description
Northlands Golf Course Club House Location: North Vancouver, BC Client: District of North Vancouver	 **Solar Thermal Installation:** In response to the District of North Vancouver's request for quotations (RFQ), Hemmera submitted, won and built in a very short period of two weeks this solar hot water system. It successfully met the client's deadline of officially starting-up the system during the annual celebration of BC Solar Days. Hemmera managed design, structural engineering, permit applications, and ecoENERGY and SolarBC grant applications for the client, and was commended by the District of North Vancouver's Energy Manager Dominica Babicki for their "speedy deployment and professional installation".
Parkgate Community Centre Location: North Vancouver, BC Client: District of North Vancouver	**Solar Thermal System Design-Build:**  With the District of North Vancouver's ongoing commitment as a carbon neutral government, Hemmera helped the Client implement their second solar thermal system. A 12-collector solar array was planned in collaboration with the District's recreation commission; the project was designed and completed, and ecoENERGY and SolarBC grants were obtained. Hemmera was pleased to hear that the District of North Vancouver's multiple solar projects ultimately resulted in being awarded by SolarBC "Solar Community of the Year" for their climate leadership. **Testimonial:** "Dominica and I are very thankful for the contributions of both Hemmera and Renew Energy in the District's own Solar hot water projects. These five installations, perhaps the greatest number of separate projects by one municipality in 2011, were a significant factor in the District receiving the award. Your firms' diligent work on these projects has been very much appreciated." – Paul Forsyth **Contact:** Paul Forsyth Energy Specialist, District of North Vancouver 604.990.2254 – forsythp@dnv.org
Coast Tsawwassen Inn Location: Tsawwassen, BC Client: Tsawwassen Inn	 **Solar Thermal Retrofit:** The 30-panel solar thermal system at the Coast Tsawwassen Hotel is estimated to provide enough energy to reduce annual energy costs and emissions of the very large domestic hot water load by 30%. The system was designed and optimized for minimal maintenance. The installation was carried out by Hemmera's contracting Partner Renew Energy.
Sherwood Residence Location: Tsawwassen, BC Client: Century Group	**Multi-Unit Residential Building (MURB) Retrofit:** This system was designed to reduce the natural gas bill by 30% year-after-year throughout the 30-year life of this solar thermal system. This project received a 25% grant credit from the ecoENERGY for Renewable Heat program through Natural Resources Canada (NRCan). Hemmera's contracting partner Renew Energy installed the large 60-panel solar thermal system for the 100-suite residential building.