Solar Energy Feasibility Study at Park Board Buildings and Facilities

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EXECUTIVE SUMMARY

Project Objectives

The Greenest City 2020 Action Plan (GCAP) is divided into 10 goal areas, each with a long-term goal and 2020 targets. The GCAP goal directly associated with this project is Climate and Renewables which aims to eliminate the dependence on fossil fuels. In order for Vancouver to achieve it's 2020 target, a reduction of "33% from the 2007 greenhouse gas (GHG) levels" is to be met (Greenest City, 2015).

The purpose of this project is to examine the feasibility of utilizing solar thermal and solar photovoltaic (PV) systems across the Park Board's real estate in order to reach the 2020 target as well as to reduce utility bills. This will involve a high-level design approach through software calculators used for modelling along with a cost-benefit analysis showing the energy potential, monetary savings, and payback period for each option. A summary of the possible implementation approaches ranked by their effectiveness will also be included. Finally, hurdles to overcome and conclusions will be discussed.

Background

The Vancouver Park Board has jurisdiction on "230+ parks and a large public recreation system of community centers, outdoor pools, rinks, fitness centers, golf courses, marinas, playing fields, and skateboard parks" (City of Vancouver, n.d.). Vehicles and park machinery also form part of the Park Board's fixed asset inventory making them vital for field maintenance crew daily operations. The fuel needed to operate all these assets, whether it is electricity, gasoline, diesel, propane or natural gas, all contribute to Vancouver's GHG emissions. In 2015, the Park Board consumed 33.3 Gigawatt hours of electricity and 164,722 Gigajoules of natural gas across all its facilities. The combined building and transportation emissions totaled just over 10,000 tonnes of carbon dioxide (CO_2) into the atmosphere. Figure 1 below shows the Park Board's CO_2 emissions in the last eight years.

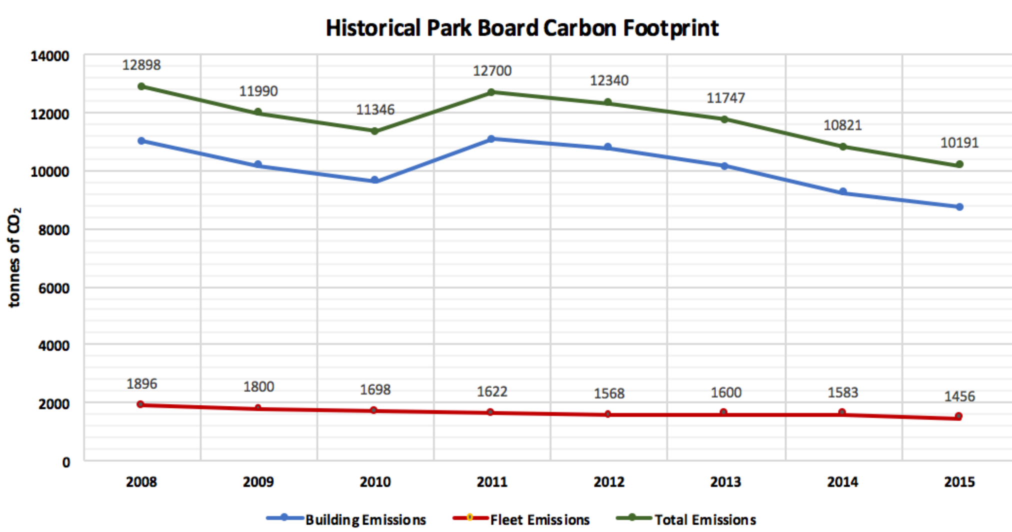

Figure 1 - Historical Park Board CO_2 emissions

Solar thermal and PV systems are not innovative energy solutions for the Park Board. In fact, since 2008 there have been several buildings across the Park Board that have adopted such systems and the majority continue to operate. These include:

a) VanDusen Botanical Garden Visitor's Center (VC) which targets the Living Building Challenge and addresses sustainability in the built environment. The VC has both thermal and PV arrays allowing it to also hold a LEED Platinum certification and is short of becoming fully Net Zero.
b) Creekside Community Center incorporated a large thermal collector array for domestic hot water (DHW), space heating and cooling after the 2010 Winter Olympics. These additions enabled it to become LEED Platinum certified.
c) Templeton Park Pool incorporated a thermal system to reduce GHG emissions as a result of the Corporate Climate Change Action Plan years ago. Currently, the thermal system is not operating and needs repair.
d) Brockton Oval Fieldhouse integrated a thermal system for DHW as pilot project across the Park Board. This project was aimed to serve as a knowledge base for such technology.
e) Adanac Park installed a PV module on a lamp post off Adanac Street to power a pump used to irrigate one of its fields. Over the years, there have been a few maintenance costs associated with faulty inverter's but overall, the system operates effectively.

Framework

The research for this project considered retrofitting five community centers (CC's) with both thermal and PV systems as well as a solar canopy at the VanDusen Botanical Gardens parking lot. This CC selection was based on real estate ownership, 2015 electricity and gas consumptions, rooftop area, and building lifespan. Site visits to each of the CC's were conducted and building specific data was gathered. This included equipment capacities in the boiler and mechanical rooms, 2015 water consumptions and pool attendance, and an overview of the system operation. The solar systems were then modelled through licensed software calculators; multiple simulations were performed for each option to yield potential energy outputs. Note: uncertainty revolves around the daily pool attendance, volumes of daily DHW, and pool make up water usage; all of which have an impact in the thermal system output. Regarding PV, shadow or soiling losses were not simulated.

A financial model was then developed in order to calculate Simple Payback, Equity Payback, Net Present Value (NPV), and Internal Rate of Return (IRR). Key assumptions in this model were: the electricity and gas rates selected, the solar module depreciation factor applied, the fuel inflation rate applied, system maintenance was not included, net metering exportation and carbon tax fee reductions were not considered, and a 5% discount rate was applied in a 25-year project lifespan. Below are the summarized project results. Note: Since the VanDusen Botanical Garden VC electric meter serves both the VC and the Garden Pavilion, the load at the VC was estimated to be 300,000 kWh. Also, it is important to note that the cost benefit analysis serves as a starting point to get a preliminary idea of the scope of solar projects. However, the need for a Triple Bottom Line framework is indispensable as it will provide a broader perspective to create greater business value.

Table 1 – Summarized Thermal System Results

Location	Installed Capacity (KW)	Energy Produced (GJ)	Load Offset	CO_2 Offset	Project Cost	Simple Payback (years)	Equity Payback (years)	NPV	IRR
Kitsilano CC	70	162	5%	7%	$120k	105.7	39.7	-$91k	-4.70%
Renfrew Park CC	79	191	3%	6%	$135k	100.8	38.7	-$101k	-4.20%
Killarney CC	176	436	3%	4%	$300k	97.5	37.2	-$222k	-4.30%
Hillcrest CC	176	551	2%	3%	$300k	72.7	33.3	-$201k	-2.90%
Kensington CC	35	101	2%	3%	$60k	80.9	35.7	-$42k	-3.40%

Table 2 – Summarized PV System Results

Location	Installed Capacity (KW)	Energy Produced (MWh /year)	Load Offset	Project Cost	Simple Payback (years)	Equity Payback (years)	NPV	IRR
VanDusen Botanical Garden VC	300	326	109%	$1.2M	45	25.7	-$590k	-0.30%
Kitsilano CC	100	124	31%	$290k	28	18.9	-$67k	2.80%
Kensington CC	100	126	21%	$290k	27.5	18.7	-$64k	3%
Renfrew Park CC	100	119	15%	$290k	29.3	19.5	-$76k	2.50%
Killarney CC	100	125	4%	$290k	27.8	18.8	-$66k	2.90%
Hillcrest CC	100	125	2%	$290k	27.8	18.8	-$66k	2.90%

Hurdles to Overcome

Solar energy technologies in Vancouver face several hurdles that can be categorized as: Public Awareness, Economics, and Policy. Research shows that Vancouver does receive less sunlight on average when compared to major cities across the Alberta, Saskatchewan, Manitoba, Ontario and Quebec. However, Vancouver is sunnier than most major German cities, which lead the world in solar rooftop installation per capita. Second, fuel price plays a critical role in solar energy economics. The higher the fuel rates, the higher the cash flow and the shorter the payback period. Finally, British Columbia (BC) lacks policy measures such as an expedited building permit process laws, tax incentives or Feed-in-Tariffs, all promoting solar energy deployment.

Conclusions

Overall, solar PV is simpler and more cost effective than solar thermal as far as installation, operation and simple payback are concerned. Due to economies of scale, the subsidized nature of the hydroelectric operation in BC, and lack of support policies aiming to drive the solar market, thermal and PV systems will continue to have long payback periods and be seen as unviable solutions. If the Park Board is committed to the New Zero Building Plan, then harvesting sunlight for electricity is a better proposal than hot water. On other hand, if the priority is reduction of GHG's, then harvesting sunlight for hot water is more rational.

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1. Introduction

1.1 Project Scope

This project ties in with the Climate and Renewables goal mandated by the Greenest City Action Plan (GCAP), which sets to eliminate the dependence of fossil fuels through solar energy harvesting. According to BC Hydro, in 2015, “98% of their electricity supply came from clean energy sources – hydroelectricity, solar, wind, and biomass” (Revenues are down, 2016). Therefore, the focus of this project will be on eliminating natural gas used for domestic hot water (DHW) and pools. All together, the three objectives set for this project were:

- Analyze the effectiveness of solar thermal systems to reduce Greenhouse Gas (GHG) emissions.
- Analyze the effectiveness of solar PV systems to reduce utility bills.
- Identify the hurdles to overcome.

GHG emissions are composed of many different gases and compounds such as water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other trace gases in the atmosphere. Out of all those gases, CO_2 is the most abundant one and therefore directly associated with the ‘GHG emission’ term. In order to put things into perspective with regards to GHG emissions, please refer to Appendix S for some interesting facts on CO_2.

1.2 Project Methodology

Following below is the procedure specific to each objective in order to meet the GCAP goal of this project.

For objective 1, the following systematic tasks were performed:

- Based on the data from the quarterly Real Estate Facility Management (REFM) Building Energy and Water Performance Report issued by the Energy and Utilities group, a list of buildings was selected. The parameters used were natural gas consumption, GHG emissions, and the GHG Performance Index.
- Given that the REFM report above includes all city owned and operated buildings, the building list was validated with the Park Board real estate database. It was then validated with building lifespan and rooftop databases. The rooftop area cut-off was set to 400m^2 and the lifespan cut-off was 15+ years.
- Site visits and surveys with mechanical technicians on-site and the mechanical superintendent (as applicable), were arranged. This served to determine building suitability in the project analysis as well for data collection required for the software calculator.
- Water consumption and pool usage attendance data was gathered from the appropriate departments, which were also needed as input parameters in the software calculator. Please refer to Appendix L to view the data gathered.
- A thermal system was then modeled for each building and different simulations were performed to accurately calculate the system yield over an annual cycle. Please refer to Appendix M to view the software calculator used (TSOL).

For objective 2, the following systematic tasks were performed:

- Based on the data from the quarterly REFM Building Energy and Water Performance Report issued by the Energy and Utilities group, a list of buildings was selected. The parameter used was electricity consumption.
- Given that the REFM report above includes all city owned and operated buildings, the building list was validated with the Park Board real estate database. It was then validated with building lifespan and rooftop databases. The rooftop area cut-off was set to $400m^2$ and the lifespan cut-off was chosen 15+ years.
- Site visits with mechanical technicians on-site were arranged. This served to determine building suitability in the project analysis.
- A PV system was then modeled for each building and different simulations were performed to accurately calculate the system yield over an annual cycle. Please refer to Appendix M to view the software calculator used (PVSYST).

For objective 3, there was no systematic plan to be followed. The following tasks were performed:

- Online research was conducted to identify a wide range of related issues to both thermal and PV systems. This also included a review on how other municipalities, provinces, and countries have addressed related issues.
- Informational interviews were conducted with Park Board staff, industry professionals, solar installers, home owners, technicians, and academic researchers to discuss related topics accordingly. These interviews provided a wide range of perspectives associated with the use of solar energy technologies. Information gained in these interviews was integrated into the report.

2. Solar Thermal Case Studies

2.1 Hillcrest CC

Existing Facility Description

The Hillcrest complex is located in between Hillcrest Park, Riley Park, and Queen Elizabeth Park. Having hosted part of the 2010 Winter Olympics, this multi-million facility has an aquatic center, fitness center, ice rink, gymnasium, indoor cycling, multi-purpose rooms, a games room, dance studio, playgrounds, childcare center, and a café. The focus will lie in the DHW system and indoor pools only.

There are two indoor pools (lap and leisure), a hot tub, and an outdoor pool in this complex. Pool water heating for these pools is provided by two large storage tanks which are fed by a heat exchanger which uses heat from the refrigeration plant on-site. Two boilers feed three Hot Water Tanks (HWT) for all the DHW in the complex (showers, faucets). Every Tuesday, the three HWT are heated up to 60 degC as part of the legionella program. The seasonal outdoor swimming pool opens from May 1st and goes up till September 15th. The indoor pools, on the other hand, are closed during the entire month of April as they undergo maintenance. Please refer to Appendix A for the complete site data.

The CC has a south facing sloping roof over the indoor pools with a large rooftop making it ideal for a large thermal system installation. Additionally, the roof is free of any shading or obstacles that could potentially affect the energy output of such system. The positioning of the flat-plate collectors on the roof would protect the installation from any form of vandalism and interference from the public in the Net Bailey Stadium Parking lot.

Proposed System Summary

Figure 2 below shows what a typical solar thermal system would look like on the CC rooftop at Hillcrest. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters, energy outputs for the DHW and pool analysis, please refer to Appendix A.

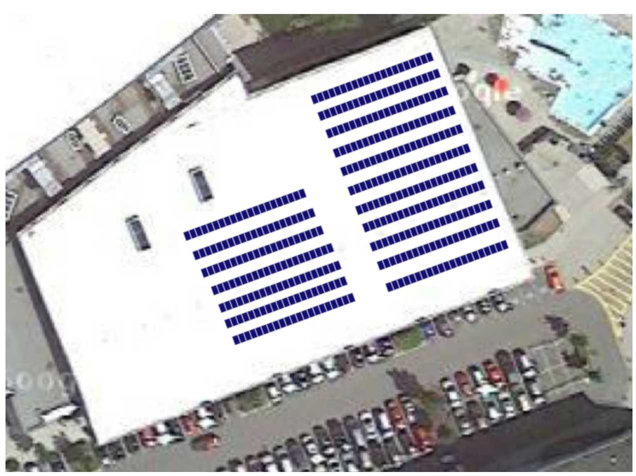

Figure 2 – Solar Thermal System Layout at Hillcrest CC

Budget

A local thermal system supplier was approached for some direction on project pricing. Typical installed price in Vancouver for residential and light commercial is around $3.23/W for up to 20 flat plate collectors. For 20+ collectors, the installed price ranges from $2.5/W to $3/W. For the 100 flat-plate collector system being proposed, the price translates to $2500/collector to $3000/collector. This includes all the equipment, labor, racking, piping, except building permits. Given that the proposed system is a retrofit to the existing building, some demolition and civil engineering work may be necessary. For this reason, $2700/collector would have been a decent value to choose but going a little more conservative, $3000/collector was chosen as the final price. The total price for the project was set to $300,000.

GHG Emission Reductions

The GHG emission reduction can be calculated based on the fuel source being replaced. Below is a summary of the annual GHG reduction potential (in tonnes of CO_2) at the Hillcrest CC under the proposed system.

Building	**2015 Total Emissions (tonnes)**	**CO_2 reductions (tonnes /year)**	**CO_2 offset**
Hillcrest CC	1,337	43	3%

2.2 Killarney CC

Existing Facility Description

The Killarney CC is located next to Killarney Park in the southeast corner of the lower mainland. This multi-million facility has a childcare, computer lab, games room, youth center, snack bar, dance studio, indoor pools, ice rink, and a fitness center with a steam room and a whirlpool. Outside, there is a tennis court and playground nearby Killarney Park. The focus will lie in the DHW system and indoor pools only.

There are two indoor pools (main and leisure) and a hot tub in this complex. Pool water heating for the indoor pools is provided by two boilers which which feed two storage tanks and two heat exchangers. A 400-gallon electric HWT feeds the showers, faucets, and the hot tub. The pools operate all year long except between November 15th and December 15th. Please refer to Appendix B for the complete site data.

The roof at the fitness center is 10deg east of south sloping over the indoor pools with a large rooftop for a large thermal system installation. The roof is free of any shading or obstacles that could potentially affect the energy output of such system. The positioning of the flat-pate collectors on the roof would protect the installation from any form of vandalism and interference from the public in the nearby school.

Proposed System Summary

Figure 3 below shows what a typical solar thermal array would look like on the fitness center rooftop at Killarney. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters, energy outputs for the DHW and pool analysis, please refer to Appendix B.

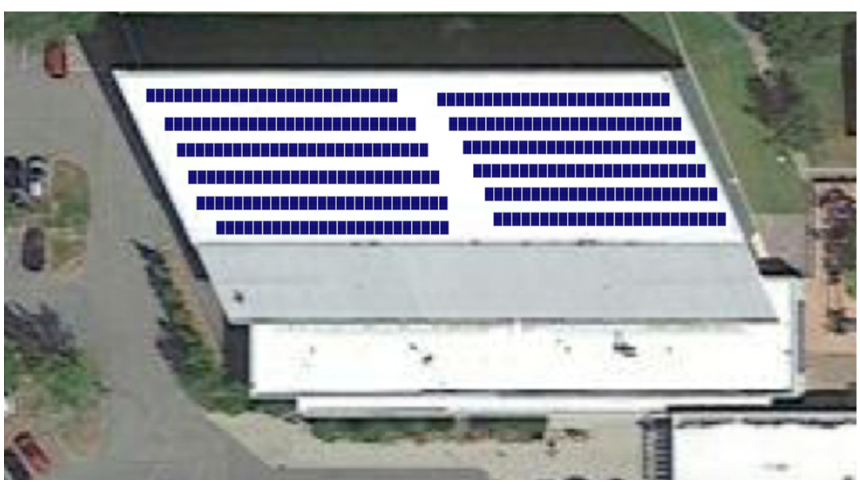

Figure 3 – Solar Thermal System Layout at Killarney CC

Budget

A local thermal system supplier was approached for some direction on project pricing. Typical installed price in Vancouver for residential and light commercial is around $3.23/W for up to 20 flat plate collectors. For 20+ collectors, the installed price ranges from $2.5/W to $3/W. For the 100 flat-plate collector system being proposed, the price translates to $2500/collector to $3000/collector. This includes all the equipment, labor, racking, piping, except building permits. Given that the proposed system is a retrofit to the existing building, some demolition and civil engineering work may be necessary. For this reason, $2700/collector would have been a decent value to choose but going a little more conservative, $3000/collector was chosen as the final price. The total price for the project was set to $300,000.

GHG Emission Reductions

The GHG emission reduction can be calculated based on the fuel source being replaced. Below is a summary of the annual GHG reduction potential (in tonnes of CO_2) at Killarney CC under the proposed system.

Building	**2015 Total Emissions (tonnes)**	**CO_2 reductions (tonnes /year)**	**CO_2 offset**
Killarney CC	812	34	4%

2.3 Kensington CC

Existing Facility Description

The Kensington CC is located next to Kensington Park across the Tecumseh Annex Elementary School. This facility has a preschool, pottery studio, dance studio, seniors center, an indoor pool, and a fitness center with a sauna and a whirlpool. Outside of the facility, there is a nearby skateboard park. The focus will lie in the indoor pool only.

Kensington CC is unique as it has two distinct DHW systems; one for the fitness center and for the changing rooms (e.g., showers and faucets) in the CC. Pool water and hot tub heating is provided by a HWT which is fed by two boilers. This HWT also supplies the DWH in the fitness center. Additionally, there are two electric HWT that supply the DHW for the changing rooms. Both the pool and hot tub operate all year long except on holidays. Please refer to Appendix C for the complete site data.

The roof at the fitness center is facing south laying flat over the indoor pool. The western side of the fitness center is shaded by a large tree standing about 10 feet above the roof. The southern side of the fitness center is also shaded by a number trees. Similarly, the north side of the CC is shaded by a number of trees which stand about 10 feet above the roof of the building. The positioning of the flat-plate collectors on either roof would protect the installation from any form of vandalism and interference from the public in the nearby school or skateboard park. However, given the proximity to the mechanical room, the fitness center is the ideal location in this case (e.g., less piping losses).

Proposed System Summary

Figure 4 below shows what a typical solar thermal array would look like on the fitness center rooftop at Kensington. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters, energy outputs for pool analysis, please refer to Appendix C.

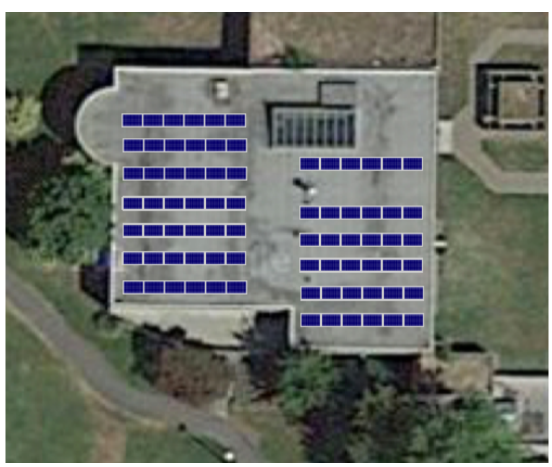

Figure 4 – Solar Thermal System Layout at Kensington CC

Budget

A local thermal system supplier was approached for some direction on project pricing. Typical installed price in Vancouver for residential and light commercial is around $3.23/W for up to 20 flat plate collectors. For 20+ collectors, the installed price ranges from $2.5/W to $3/W. For this 20 collector proposed system, the price translates to $2500/collector to $3000/collector. This includes all the equipment, labor, racking, piping, except building permits. Given that the proposed system is a retrofit to the existing building, some demolition and civil engineering work may be necessary. For this reason, $2700/collector would have been a decent value to choose but going a little more conservative, $3000/collector was chosen as the final price. The total price for the project was set to $60,000.

GHG Emission Reductions

The GHG emission reduction can be calculated based on the fuel source being replaced. Below is a summary of the annual GHG reduction potential in tonnes of CO_2 at Kensington under the proposed system.

Building	**2015 Total Emissions (tonnes)**	**CO_2 reductions (tonnes /year)**	**CO_2 offset**
Kensington CC	257	7	3%

2.4 Renfrew Park CC

Existing Facility Description

The Renfrew Park CC is located next to Vancouver Public Library in the Renfrew Heights community. This facility has a games room, computer lab, multi-purpose rooms, an indoor pool, fitness center, sauna, and whirlpool. The focus will lie in DHW system only.

Renfrew Park CC has an indoor pool and a hot tub in this complex. DHW and pool water heating is provided by two boilers which feed six HWT. Additionally, a heat exchanger heats up the hot tub and as well as the pool water. Both the pool and hot tub operate all year long except between August 22nd and September 16th. Please refer to Appendix D for the complete site data.

The roof at both the fitness and community centers is 45 deg west of south laying flat over the indoor pools and multi-purpose rooms, respectively. Since DHW will be the focus, the fitness center is the best roof option as it is closest to the mechanical room. Also, the fitness center roof is less affected by tree shading. The positioning of the flat-plate collectors on the roof would protect the installation from any form of vandalism and interference from the public in the nearby library.

Proposed System Summary

Figure 5 below shows what a typical solar thermal array would look like on the fitness center rooftop at Renfrew Park. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters, energy outputs for the DHW, please refer to Appendix D.

Figure 5 – Solar Thermal System Layout at Renfrew Park CC

Budget

A local thermal system supplier was approached for some direction on project pricing. Typical installed price in Vancouver for residential and light commercial is around $3.23/W for up to 20 flat plate collectors. For 20+ collectors, the installed price ranges from $2.5/W to $3/W. For the 45 flat-plate collector system being proposed, the price translates to $2500/collector to $3000/collector. This includes all the equipment, labor, racking, piping, except building permits. Given that the proposed system is a retrofit to the existing building, some demolition and civil engineering work may be necessary. For this reason, $2700/collector would have been a decent value to choose but going a little more conservative, $3000/collector was chosen as the final price. The total price for the project was set to $135,000.

GHG Emission Reductions

The GHG emission reduction can be calculated based on the fuel source being replaced. Below is a summary of the annual GHG reduction potential (in tonnes of CO_2) at Renfrew Park CC under the proposed system.

Building	**2015 Total Emissions (tonnes)**	**CO_2 reductions (tonnes/year)**	**CO_2 offset**
Renfrew Park CC	257	7	3%

2.5 Kitsilano CC

Existing Facility Description

The Kitsilano CC is located next to Connaught Park across the Kitsilano Secondary School. This facility has a full-size indoor ice rink, gymnasium, dance studio, youth lounge, sauna, whirlpool, seniors lounge, and a preschool. For the sakes of this project, the focus will lie in the DHW and hot tub.

The hot tub is located in the fitness center which is opposite to the skating arena. DHW and hot tub heating is provided by two HWT which are fed by two boilers. The hot tub operates all year long except for two weeks in August. Please refer to Appendix E for the complete site data.

The roof at both the fitness center and skating arena faces south laying flat. The fitness center is the best roof option as it is closest to the mechanical room. The western side of the fitness center is shaded by a several trees along Larch Street. The southern side of the fitness center is shaded by a number trees along 12th Ave W. The positioning of the flat-plate collectors on this roof would protect the installation from any form of vandalism and interference from the public in the nearby school.

Proposed System Summary

Figure 6 below shows what a typical solar thermal array would look like on the fitness center rooftop at Kitsilano. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters, energy outputs for the DHW and pool analysis, please refer to Appendix E.

Figure 6 – Solar Thermal System Layout at Kitsilano CC

Budget

A local thermal system supplier was approached for some direction on project pricing. Typical installed price in Vancouver for residential and light commercial is around $3.23/W for up to 20 flat plate collectors. For 20+ collectors, the installed price ranges from $2.5/W to $3/W. For the 40 flat-plate collector system being proposed, the price translates to $2500/collector to $3000/collector. This includes all the equipment, labor, racking, piping, except building permits. Given that the proposed system is a retrofit to the existing building, some demolition and civil engineering work may be necessary. For this reason, $2700/collector would have been a decent value to choose but going a little more conservative, $3000/collector was chosen as the final price. The total price for the project was set to $120,000.

GHG Emission Reductions

The GHG emission reduction can be calculated based on the fuel source being replaced. Below is a summary of the annual GHG reduction potential (in tonnes of CO_2) at Kitsilano CC under the proposed system.

Building	**2015 Total Emissions (tonnes)**	**CO_2 reductions (tonnes/year)**	**CO_2 offset**
Kitsilano CC	165	12	7%

3. Solar PV Case Studies

3.1 Hillcrest CC

Existing Facility Description

The CC has a south facing sloping roof over the indoor pools with a large enough rooftop area for a large PV system. The roof is free of any shading or obstacles that could potentially affect the energy output of such system. The positioning of a PV array on the roof would protect the installation from any form of vandalism and interference from the public in the Net Bailey Stadium Parking lot.

Proposed System Summary

Figure 7 below shows what a typical PV system would look like on the CC rooftop at Hillcrest. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters and energy outputs, please refer to Appendix F.

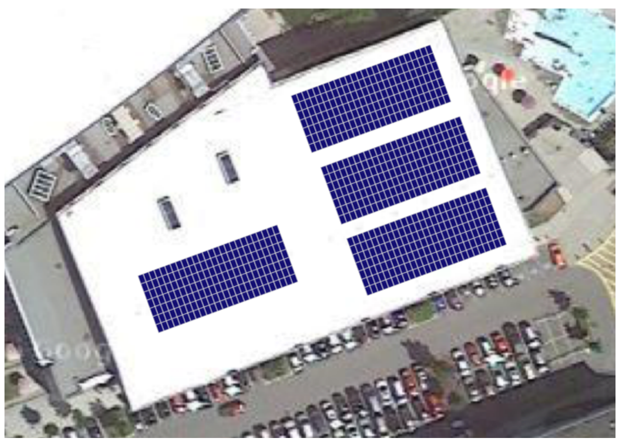

Figure 7 – Solar PV System Layout at Hillcrest CC

Budget

Several local PV installers was approached for some direction on project pricing. Typical installed PV price in Vancouver for residential systems (e.g., systems up to 15 KW) ranges from \$3.5/W to \$4/W. Higher capacity projects can be priced between \$2.8/W - \$3/W. These prices include equipment, racking, labor, and wiring except building permits. Therefore, for this 100 KW system, the final project cost was calculated to \$290,000. For a detailed financial payback model, please refer to Appendix F.

3.2 Killarney CC

Existing Facility Description

The roof at the fitness center is 10deg east of south sloping over the indoor pools with a large enough rooftop for a large PV system. The roof is free of any shading or obstacles that could potentially affect the energy output of such system. The positioning of a PV array on the roof would protect the installation from any form of vandalism and interference from the public in the nearby school.

Proposed System Summary

Figure 8 below shows what a typical PV system would look like on the CC rooftop at Killarney. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters and energy outputs, please refer to Appendix G.

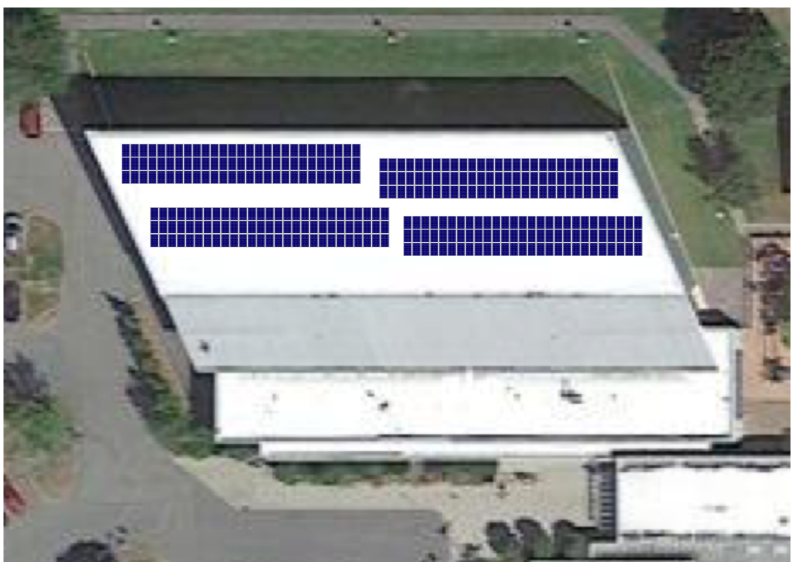

Figure 8 – Solar PV System Layout at Killarney CC

Budget

Several local PV installers was approached for some direction on project pricing. Typical installed PV price in Vancouver for residential systems (e.g., systems up to 15 KW) ranges from \$3.5/W to \$4/W. Higher capacity projects can be priced between \$2.8/W - \$3/W. These prices include equipment, racking, labor, and wiring except building permits. Therefore, for this 100 KW system, the final project cost was calculated to \$290,000. For a detailed financial payback model, please refer to Appendix G.

3.3 Kensington CC

Existing Facility Description

The roof at the fitness center is facing south laying flat over the indoor pools. The western side of the fitness center is shaded by a large tree which is right next to the building and standing about 10 feet above the roof. The southern side of the fitness center is shaded by a number trees, Similarly, the north side of the CC is shaded by a number of trees which stand about 10 feet above the roof of the building. However, due to area, the CC is the best option out of the two. The positioning of the PV modules on either roofs would protect the installation from any form of vandalism and interference from the public in the nearby school and skateboard park.

Proposed System Summary

Figure 9 below shows what a typical PV system would look like on the CC rooftop at Kensington. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters and energy outputs, please refer to Appendix H.

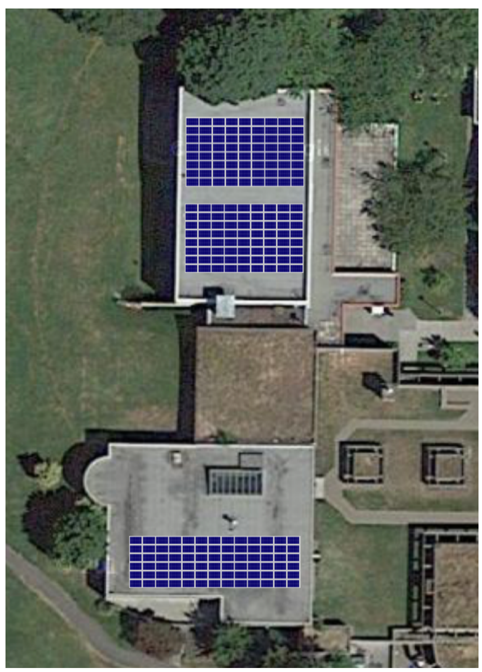

Figure 9 – Solar PV System Layout at Kensington CC

Budget

Several local PV installers was approached for some direction on project pricing. Typical installed PV price in Vancouver for residential systems (e.g., systems up to 15 KW) ranges from \$3.5/W to \$4/W. Higher capacity projects can be priced between \$2.8/W - \$3/W. These prices include equipment, racking, labor, and wiring except building permits. Therefore, for this 100 KW system, the final project cost was calculated to \$290,000. For a detailed financial payback model, please refer to Appendix H.

3.4 Renfrew Park CC

Existing Facility Description

The roof at both the fitness and community centers is 45 deg west of south laying flat over the indoor pools and multi-purpose rooms, respectively. The fitness center is the best roof option as it has a larger area and it less affected by tree shading. The positioning of the PV modules on the roof would protect the installation from any form of vandalism and interference from the public in the nearby library.

Proposed System Summary

Figure 10 below shows what a typical PV system would look like on the CC rooftop at Renfrew Park. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters and energy outputs, please refer to Appendix I.

Figure 10 – Solar PV System Layout at Renfrew Park CC

Budget

Several local PV installers was approached for some direction on project pricing. Typical installed PV price in Vancouver for residential systems (e.g., systems up to 15 KW) ranges from \$3.5/W to \$4/W. Higher capacity projects can be priced between \$2.8/W - \$3/W. These prices include equipment, racking, labor, and wiring except building permits. Therefore, for this 100 KW system, the final project cost was calculated to \$290,000. For a detailed financial payback model, please refer to Appendix I.

3.5 Kitsilano CC

Existing Facility Description

The roof at both the fitness center and skating arena faces south laying flat. The fitness center is the best roof option as it has a larger area. The positioning of the PV modules on this roof would protect the installation from any form of vandalism and interference from the public in the nearby school.

Proposed System Summary

Figure 11 below shows what a typical PV system would look like on the CC rooftop at Kitsilano. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters and energy outputs, please refer to Appendix J.

Figure 11 – Solar PV System Layout at Kitsilano CC

Budget

Several local PV installers was approached for some direction on project pricing. Typical installed PV price in Vancouver for residential systems (e.g., systems up to 15 KW) ranges from \$3.5/W to \$4/W. Higher capacity projects can be priced between \$2.8/W - \$3/W. These prices include equipment, racking, labor, and wiring except building permits. Therefore, for this 100 KW system, the final project cost was calculated to \$290,000. For a detailed financial payback model, please refer to Appendix J.

3.6 VanDusen Botanical Garden's VC

Existing Facility Description

VanDusen Botanical Garden's has an existing PV array pointing south next to the parking lot. The solar canopy was selected to occupy the parking lot space just north of 37th Ave W. Due to the nature of the real estate, the parking lot is covered by many trees which if not dealt with, will offset the the energy output of the system.

Proposed System Summary

Figure 12 below shows what a typical PV solar canopy system would look like in the parking lot at VanDusen Botanical Garden's. Note: this is not a true representation of the actual installed capacity being proposed. For a summary of the system input parameters and energy outputs, please refer to Appendix K.

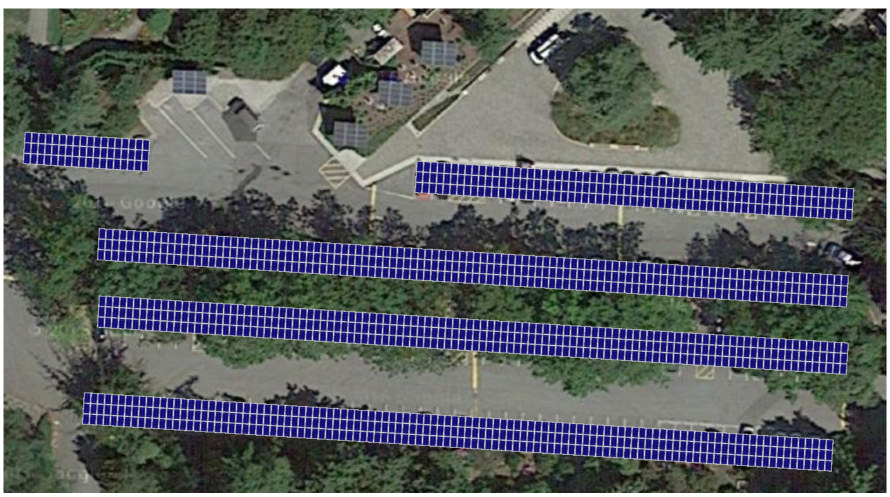

Figure 12 – Solar PV System Layout at VanDusen Botanical Garden's VC

Budget

For a project of this magnitude, Novo Solar was the only installer able to provide an estimate. The project was quoted at $1M and includes equipment, racking, labor, carports, concrete structures, wiring except building permits and the BC Hydro fees involved with the Micro-SOP application. Thus, the total project cost was calculated at $1.2 M. To view the estimate and sample carport layout, please refer to Appendix Q. For a detailed financial payback model, please refer to Appendix K. Finally, to view sample solar canopy schematic layouts and designs, refer to Appendix R.

4. Hurdles to overcome

Based on the research for this project, the hurdles that solar energy technologies are facing in Vancouver, BC can be categorized in three sectors: Public Awareness, Economics, and Policy.

4.1 Public Awareness

The amount of solar energy that arrives at a specific area at a specific time is referred to as solar irradiance. Solar irradiance is only available during the day and it is affected by clouds making it an intermittent source of energy. Furthermore, sunlight varies day to day, month to month, year to year but most importantly, it varies per location. According to Environment Canada, "between 1980 and 2010, Vancouver received a yearly average of 1938 hours of bright sunshine and 289 days of measurable bright sunshine which corresponded to 41% of possible daylight hours with bright sunshine (e.g., daylight hours that are sunny)" (Government of Canada, 2016). Table 3 below shows the same dataset across other cities in Canada. It can be inferred that the solar potential is lower in coastal areas, and higher in the central regions.

Table 3 – Average annual sunlight hours and sunny days

City	**Province**	**# days**	**# hours**	**% sun**
Calgary	AB	333	2396	52
Winnipeg	MB	316	2353	51
Edmonton	AB	325	2345	50
Regina	SK	322	2318	50
Saskatoon	SK	319	2268	49
Thunder Bay	ON	305	2121	46
Fort St John	BC	304	2095	44
Ottawa	ON	304	2084	45
Kamloops	BC	316	2080	43
Toronto	ON	305	2066	44
Montréal	QC	305	2051	44
Vancouver	BC	289	1938	41

Public misconceptions that Vancouver is a gloomy city and therefore not suited for solar harvesting was found to be somewhat high. To prove this misconception wrong, PVSYS meteorological data was plotted for a large set of North American cities along with four German cities. Figure 13 below shows the average annual global horizontal irradiance, which is the sum of direct, diffused, and reflected radiation. Note the four German cities at the right hand side of the graph which rank lower than Vancouver. This will be discussed in the subsequent section.

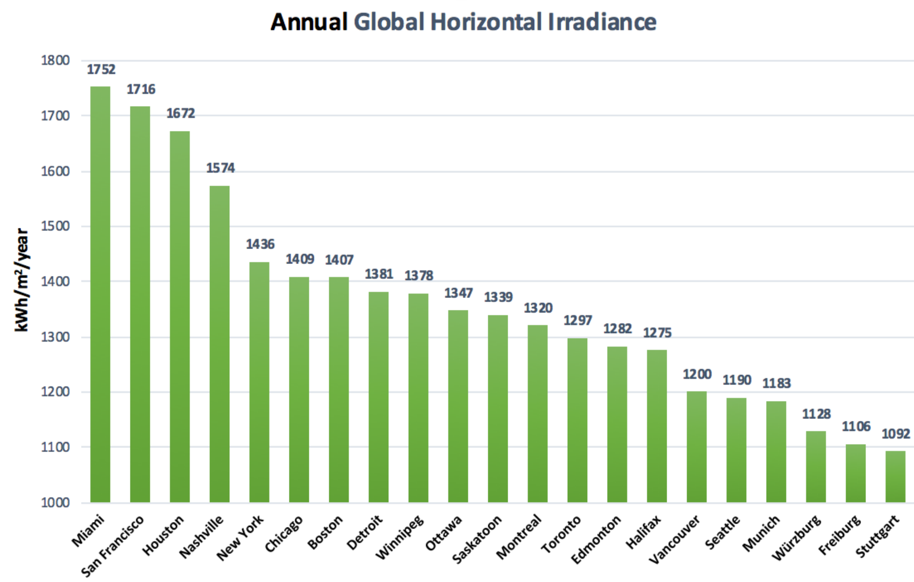

Figure 13 – Global Irradiance using PVSYST meteorological data

Finally, when it comes to solar panel deployment in green areas such as parks or open fields, there were a mix of responses from Park Board staff; mostly negative feedback. These individuals claimed that the aesthetics component of PV panels played a critical role in their views. They argued that people go to a park for a number of reasons - to relax, to exercise, to enjoy the natural beauty and surroundings, and to play with their kids; not to have their views obstructed by a solar panel array. Also, there is the environmental aspect too - the threatened ecosystems and interference of natural habitats caused by the solar panel installation. Other reasons provided were safety, vandalism, and risk management. On the other hand, there seems to be no objection to solar panels provided that they are non-visible to the human eye (e.g., laid on top of a roof).

4.2 Economics

Some people argue that the more sunlight received, the more electricity or hot water will be produced and therefore, the more profit will be made, but that is not how it works. For any solar installation, the savings are the avoided costs to the utility company moving forward. Therefore, the cost of electricity or gas has a direct effect in the solar system's economics. Take for example Germany; Stuttgart, Freiburg and Würzburg and Munich whom receive less sunlight on average than Vancouver, however, Germany leads the world in rooftop installation per capita (Gifford, 2015). In general, the higher the electricity or gas rates, the higher the savings. Germany doubled their electricity rates from 0.14€/kWh in 2000 to 0.29 €/kWh in 2014 (Istvan, 2015).

Shown below in Table 4 obtained from a yearly report by Hydro-Québec showing the average electricity rates among 21 North American cities for Large Power customers in April 2015 (Hydro Québec, 2015). Note: Prices are in Canadian dollars. Note that the cheapest electricity rates in that report are in Canada.

Table 4 – 2015 Average Electricity Prices

City	Province/State	¢ / kWh
Winnipeg	MB	4.67
Calgary	AB	4.76
Montreal	QC	5.17
Edmonton	AB	6.97
Vancouver	BC	7.04
Moncton	NB	7.48
Regina	SK	7.81
Houston	TX	7.92
Portland	OR	8.05
Seattle	WA	8.2
Chicago	IL	8.21
Detroit	MI	8.5
Miami	FL	8.61
St Johns	NL	8.65
Charlottetown	PE	8.9
Toronto	ON	9.22
Ottawa	ON	9.3
Halifax	NS	10.02
Nashville	TN	11.37
San Francisco	CA	12.69
Boston	MA	14.26
New York	NY	16.97

To calculate the highest electricity savings, multiply the electricity rate (¢/kWh) with the irradiance (kWh/m^2/year). For this dataset, the highest savings per PV install would occur in New York City (\$2.43/year/m^2). Even though Miami, San Francisco, and Nashville are the sunniest cities in the dataset, it does not make up for the high electricity rate in New York City.

In spite of that, there is another factor that has an impact on the viability of solar energy systems and that is, permits (building and electrical). According to the Society Promoting Environmental Conservation (SPEC), a non-profit organization in BC with 45+ years advocating environmental concerns to policy makers, the cost of permitting a 5KW residential rooftop PV system in Vancouver in 2014 was “6 times the cost of an equivalent system in Toronto or Calgary” (Solar Energy Best Practices, n.d.).

4.3 Policy

After engaging in conversation with local installers, it was perceived that the reason behind the high building permits in Vancouver is due to liability on behalf of the municipal government. If Vancouver wants to adopt solar energy into their mix of renewable energy generation, the BC government needs to consider adopting permitting policies of neighboring cities like Toronto or Calgary. Similarly, in 2014 the state of California passed the “AB 2188 bill (Expedited Solar Permitting Act) which modified the existing Solar Rights Act and required each city or county to adopt an expedited solar permitting process intended to simplify the structural and electrical review of a small solar energy project and minimize the need for detailed engineering studies and unnecessary delays" (California Solar Permitting, 2016).

In order to drive local solar investment, the BC government needs to provide incentives either through tax credits, rebates, or Feed-in-tariffs (FIT). Such is the case in the United States, where a "30% Federal Investment Tax Credit" for investments in renewable energy projects was passed and not only has it increased the solar and wind penetration across the nation but it also has created many jobs in the renewable energy industry (Energy, n.d.). Moreover, currently in Western Canada there are no FIT programs like there is in Ontario. A FIT is one the most efficient and cost-effective ways to foster renewable energy. Governments who are committed about promoting renewable energy need to seriously consider a FIT. A FIT provides long-term security to renewable energy producers whereby the government sets a price per kWh of clean energy that is produced and fed back into the grid. BC has a similar mechanism called Net Metering which operates at a net load basis. This means only the electricity produced in excess of the energy consumed during the same hour will be eligible for sale to BC Hydro. So clearly, a FIT is more profitable than Net Metering.

Furthermore, there is no regulation in BC protecting property owners from the neighboring trees casting a shadow over their solar systems. This has a minimal effect in the local industry, but take the state of California as an example. In 1978, California issued the Solar Shade Control Act which prohibits a property owner from allowing trees or shrubs to shade an existing solar energy system installed on a neighboring property, provided the shading trees or shrubs were planted after the solar collecting device was installed. The Act specifies that solar collectors must be set back "not less than five feet from the property line, and not less than 10 feet above the ground" (Anders, 2010). More importantly, "section 25982 of the Act prohibits certain tree owners from planting or allowing a newly planted tree or shrub to cast a shadow over more than ten percent of a solar collector on a neighboring property at any one time during the hours of 10:00 a.m. and 2:00 p.m." (Anders, 2010).

Finally, any municipal clean energy project in BC "above 100KW up to 1MW of capacity" must apply to the Micro-SOP program with BC Hydro (BC Hydro, 2016). The application process can take months to years and it also increases the cost of the PV project itself. Under this program, BC Hydro allows for 150 GWh/year among all applicants based on the commercial operation date indicated in the application. A system impact study along with associated costs are to be covered by the developer. Interconnection requirements and engineering costs also need to be included.

5. Additional Research Needs

Data gathering played a critical role when attempting to achieve the objectives in this project. About half of the data was obtained from the Energy Utilities Management Department. One fourth of the remaining data was obtained from other departments within the Park Board and across the City of Vancouver (CoV). The remaining dataset was obtained on-site through the maintenance technicians. The most challenging piece was the latter due to the lack of technology or metering available.

Water Usage

Daily water volume for both DHW and pool make-up water were required for the thermal models. The challenge here was that there is no water sub-metering in place, other than at Hillcrest CC. Furthermore, both the maintenance technicians on-site and the Park Board Plumbing Department were unable to provide this data. Consequently, calculations were made in attempt to accurately represent the daily water usages across the building selection. The bottom line is that not having the actual data leaves margin for error and skews the output.

Pool Attendance

Similar to water volumes, pool attendance is an input parameter to the model. In May 2015, the Board of Parks and Recreation replaced their old recreation software system (Safari) with a new one one called ActiveNet. During this transition, some buildings were using both ActiveNet and Safari; some were registering dual entry. Additionally, private user group attendance (e.g., those that attend as part of a swim club) and passive users (e.g., parents that come into the pool to watch their children in swimming lessons) are not counted as attendees. This leaves room for error which will affect the software output.

6. Recommendations

Triple Bottom Line (TBL)

Conduct a TBL assessment to embrace the three aspects of a renewable energy project. Typically, everyone is focused on the bottom line (e.g., profits). Everything is about money, cash flow, payback periods, IRR, ROI, but not much focus is given to other aspects - the number of indirect jobs created, the environmental benefits, and the wealth created. A TBL looks at a project's impact in terms of social (e.g., people), environmental (e.g., planet) values along with financial returns (e.g., profit). In summary, a TBL aims at reaching economical success while being socially and environmentally responsible and sustainable.

Solar System Optimization

Certified solar installers understand the solar business, know the permitting process and have the field experience on how to properly size a system. However, they do not dive into the system details to maximize efficiencies and outputs. For example, there is a trade-off between energy density and power density (e.g., adjusting the angle of inclination to obtain the most energy possible vs adding more modules on the roof). Here is where a solar energy optimizing firm comes into the equation. A solar optimizer uses sophisticated tools and algorithms to simulate different array orientations, dimensions and equipment brands, to obtain an optimal solution. During this project, a relationship with Dr. Martin Ordoñez, Associate Professor at the University of British Columbia (UBC), was initiated. Dr. Ordoñez currently leads the Renewable Energy Optimization Research group at UBC and has expressed an interest in developing a long-term relationship with the CoV by participating in energy optimization projects. Refer to Appendix P to view how PV efficiency at the laboratory level has evolved with time.

Geothermal Heat Pumps (GHP)

The Park Board can examine the use of a GHP to offset natural gas load used for space heating, DHW and pool heating. Recall that a GHP exchanges heat with the ground; used as a heat source in the winter (e.g., the ground is warmer than the ambient temperature) and as a heat sink in the summer (e.g., the ground is cooler than the ambient temperature). GHP's are characterized by low maintenance but high capital costs due to the excavating involved. A feasibility study would be necessary to determine the gas and CO_2 savings in comparison to the thermal systems results in this analysis. Please refer to Appendix N to read more on the Drake Landing Solar Community (DLSC) project which is closely related to the use of GHP's.

Electric Boilers vs. Gas Fired Boilers

If the Park Board is determined to reduce GHG emissions in its entirety, then retrofitting current buildings with electric boilers may be a better option. Typically, gas is a cheaper fuel per kWh than electricity, thus, a feasibility study aimed at looking at the long-term expenditures as result of switching fuels would be necessary. If the electricity in BC came from coal plants, it would make more sense to burn gas to produce heat than to inefficiently burn coal to generate electricity and use the electricity to produce heat. However, since BC's electricity is clean, and with the prevailing low electricity rates, it may be more logical to use electrical boilers.

Lower DHW and Pool Temperature Requirements

A thermal system's efficiency is directly related to the working temperature of the system. Temperature change (ΔT) is critical to the system's performance. Typically, there are two ΔT's in a thermal system, between the DHW tank and the collector and between the collector and the environment. The higher the ΔT, the higher the system losses. A higher temperature means a higher heat transfer rate at the heat exchanger. Therefore, in order to improve the system efficiency and reduction of gas consumption, the DHW delivery requirements and pool temperature requirements may be lowered by a few degrees. This way the boilers will work less because by having a lower ΔT, the pump would constantly be operating, cycling the glycol through the pipe into the heat exchangers and back to the collector compensating for the high usage.

Implement water sub-metering

The Park Board could consider developing a water sub-metering initiative across their buildings to increase water efficiency and conservation. As noted in the Additional Research Needs section, there was direct access to annual building water consumption values only. This served as a starting point when calculating daily building specific water usages required in the modelling software. Given the uncertainty in these daily values, simulation outputs will be skewed. Therefore, to accurately calculate GHG emissions, the model must align with the actual building behavior and that is achieved through water sub-metering.

Radio Frequency Identification (RFID) System

The Park Board could consider implementing a pilot RFID enabled management system at a CC. As noted in the Additional Research Needs section, pool attendance is not trustworthy data. An RFID system is composed of four components: tags, antenna, readers and a computer or server (with a licensed software). The advantages of having an RFID enabled management system are speed, convenience, control, security, and data management. In order to record user attendance, the RFID tag on the user is read by a wireless reader which communicates to the server via an antenna. The process is instantaneous and there is no swiping or scanning involved. This provides an effective control of entry, exit, and tracking of users by readers placed throughout the building. The tag is provided in many forms including a key fob that can be attached to a keychain and waterproof wristbands. Also, the RFID tag does not carry any personal information and can be easily replaced if lost. Finally, daily, weekly, monthly and/or yearly reports can be generated which serve for metrics, planning and budgeting. The cost of such system was quoted at $43,000, however, a test kit can be purchased in lieu of, at a much lower price before committing to an entire system. More details can be found in Appendix Q.

Structural Assessment

A structural engineering assessment for additional loading from the solar panel mounting structure onto the roof will be necessary. Typically, building roofs have an additional capacity to support extra loads such as dead, live or environmental loads. However, a structural inspection or audit to determine the amount of that additional capacity compared to all loads being applied with the installation of panels, is recommended.

Maintain Industry Relationships

Earlier this summer, BC Hydro joined a partnership with PowerTech Labs to design and deploy a “Smart Bench” that will serve as a cellphone charging station. The group is composed of Rick Truong (Key Account Manager - BC Hydro), Dawn Teasdale (Communications Advisor - BC Hydro), Danielle Van Huizen (Senior Business Advisor - BC Hydro), Vidya Vankayala (Director of Grid Modernization - PowerTech Labs) and Brad Badelt (Sustainability Assistant Director - CoV). Maintaining ties with BC Hydro for future solar innovative solutions is key if the Park Board is determined to embrace solar innovation across their real estate.

7. Conclusions

In Canada, the solar irradiance and heating load curves are inversely proportional to each other. In other words, during the winter months, the heating demand is typically at it's maximum and there are less sunlight hours due to the Earth's position with respect to the sun. Therefore, the heat demand cannot be met by thermal systems alone. Even if systems were sized for the winter with evacuated tube collectors, that would result in a heavily oversized system in the summer, resulting in excess heat which would have to be steamed, drained, or dumped. This is a major hurdle for solar thermal solutions in Canada.

Similarly, in winter, a PV system would have a reduced electricity supply compared to the summer due to low sunlight hours. Therefore, thermal and PV systems are only capable of reducing the use of fossil fuels but not eliminating them in their entirety, making them ineffective to reduce GHG's. A solution worth exploring would be to replace gas boilers with electric boilers and use PV generated electricity to offset the electrical load.

The VanDusen Botanical Garden VC can become the first Net Zero building in the CoV under the new Building Zero Emissions Plan which was recently approved by City Council in July of 2016. With a 300 KW solar canopy in the parking lot, not only would the VC export electricity to the grid but it could meet one of the amendments in the Building Zero Emissions plan. This amendment requires renewable energy educational demonstration projects in city-owned buildings that will increase and promote the use of renewable energy. There are some environmental hurdles on-site that need to be considered if this project would move forward.

Due to economies of scale, the subsidized nature of the hydroelectric operation, and lack of support policies (federal, provincial, and municipal) aiming to drive the solar market, thermal and PV systems will continue to have long payback periods and be seen as unviable solutions.

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9. Appendices

9.1 Appendix A

This section includes building survey data, software modelling parameters, results, and the payback for Hillcrest CC.

Table 5 – Hillcrest CC site survey data and Input parameter into TSOL

Site Survey	Input Parameters
2 x Viessmann Vitocrossal 300 Boilers rated at 947 KW each	Average DHW Consumption: 37.74 m3
3 x MAXIM HWT with 250 gallon capacity at 50 degC	Desired temp: 45degC
2 x PVI Storage Tanks with 1250 gallon capacity @ 40.6 degC	Consumption Profile: Indoor Pool
DHW Delivery Temp: 57 degC	Circulation: Yes
Lap Pool: 487,027 gallons at 27 degC	Pool Area: 160 m^2
Leisure Pool: 115,000 gallons at 31 degC	Auxiliary Heating: Yes
Hot Pool: 15,450 gallons at 39.5 degC	Daily fresh water requirement: 94 m^3
Outdoor Pool: 64,406 gallons at 27 degC	Desired pool temp: 28 degC
Total Volume: 681,883 gallons	Max pool temp: 32 degC
Indoor Temp: 25 degC	Shape of Pool: Free form
Indoor Humidity: 55%	Pool Length: 40m
	Pool Mean Depth: 2.15m
	Collector Manufacturer: Viessmann Werke GmbH & Co
	Collector Type: Vitosol 100-F
	Number Collectors: 100
	Total gross surface area: 251.8 m^2
	Total active solar surface are: 232.9 m^2
	Inclination: 45 deg
	Orientation: 180 deg
	Azimuth: 0 deg
	Hot water Tank manufacturer: Standard
	Tank Volume: 6 x 0.95 m^3
	Auxiliary Heating manufacturer: Standard
	Type: Gas-fired boiler
	Nominal Output: 1894 KW

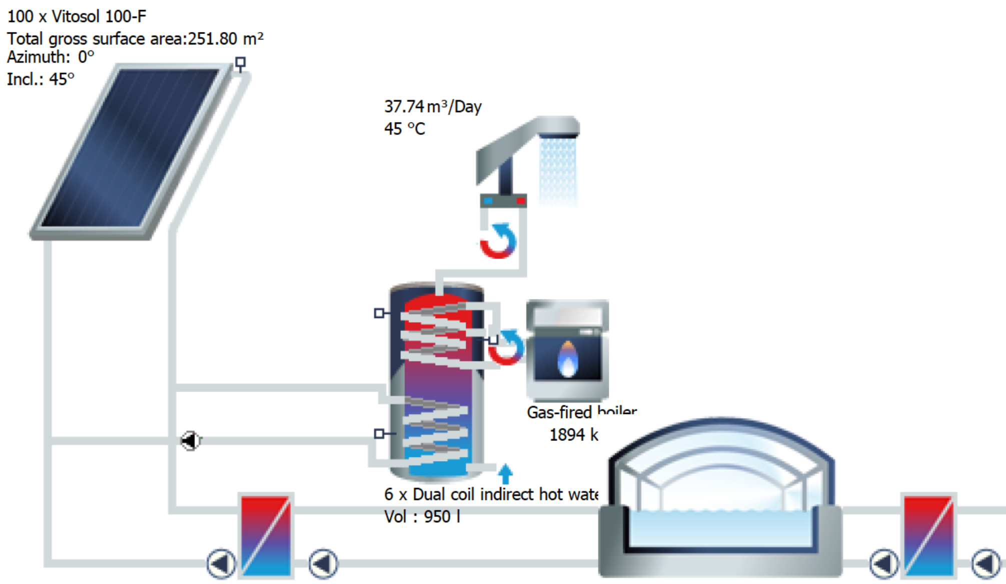


Table 6 – Hillcrest CC Thermal system output

Results
Installed collector power: 176.26 kW
Installed solar surface area (gross): 251.8 m²
Irradiation on collector surface (active): 310,487.24 kWh
Energy delivered by collectors: 154,116.35 kWh
Energy delivered by collector loop: 153,144.39 kWh
DHW heating energy supply: 548,617.89 kWh
Solar energy contribution to DHW: 150,271.93 kWh
Solar energy contribution to swimming pool : 2,872.46 kWh
Energy from auxiliary heating: 1,316,372.3 kWh
Natural gas (H) savings: 20,335.2 m³
CO2 emissions avoided: 43,001.56 kg
DHW solar fraction: 26.7 %
Swimming pool solar fraction: 0.3 %
Total solar fraction: 10.4 %
System efficiency: 49.2 %

Year	Degra-dation	Energy (GJ)	$/GJ	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	551	9.000	4,959.00	4,959.00	1.7%	1.7%	-$295,277.14	-98.3%
2	1.5%	543	9.360	5,080.00	10,039.00	1.7%	3.3%	-$290,669.43	-86.1%
3	0.5%	540	9.734	5,256.78	15,295.78	1.8%	5.1%	-$286,128.43	-71.3%
4	0.5%	537	10.124	5,439.72	20,735.50	1.8%	6.9%	-$281,653.16	-58.6%
5	0.5%	535	10.529	5,629.02	26,364.52	1.9%	8.8%	-$277,242.67	-48.5%
6	0.5%	532	10.950	5,824.91	32,189.44	1.9%	10.7%	-$272,896.03	-40.6%
7	0.5%	529	11.388	6,027.62	38,217.06	2.0%	12.7%	-$268,612.31	-34.3%
8	0.5%	527	11.843	6,237.38	44,454.44	2.1%	14.8%	-$264,390.61	-29.3%
9	0.5%	524	12.317	6,454.44	50,908.88	2.2%	17.0%	-$260,230.02	-25.2%
10	0.5%	521	12.810	6,679.06	57,587.93	2.2%	19.2%	-$256,129.66	-21.8%
11	0.5%	519	13.322	6,911.49	64,499.42	2.3%	21.5%	-$252,088.66	-19.0%
12	0.5%	516	13.855	7,152.01	71,651.42	2.4%	23.9%	-$248,106.15	-16.6%
13	0.5%	514	14.409	7,400.90	79,052.32	2.5%	26.4%	-$244,181.30	-14.5%
14	0.5%	511	14.986	7,658.45	86,710.77	2.6%	28.9%	-$240,313.26	-12.8%
15	0.5%	508	15.585	7,924.96	94,635.73	2.6%	31.5%	-$236,501.22	-11.2%
16	0.5%	506	16.208	8,200.75	102,836.48	2.7%	34.3%	-$232,744.36	-9.9%
17	0.5%	503	16.857	8,486.14	111,322.61	2.8%	37.1%	-$229,041.89	-8.7%
18	0.5%	501	17.531	8,781.45	120,104.07	2.9%	40.0%	-$225,393.01	-7.7%
19	0.5%	498	18.232	9,087.05	129,191.11	3.0%	43.1%	-$221,796.96	-6.8%
20	0.5%	496	18.962	9,403.28	138,594.39	3.1%	46.2%	-$218,252.96	-6.0%
21	0.5%	493	19.720	9,730.51	148,324.90	3.2%	49.4%	-$214,760.27	-5.2%
22	0.5%	491	20.509	10,069.13	158,394.04	3.4%	52.8%	-$211,318.14	-4.5%
23	0.5%	489	21.329	10,419.54	168,813.58	3.5%	56.3%	-$207,925.84	-3.9%
24	0.5%	486	22.182	10,782.14	179,595.71	3.6%	59.9%	-$204,582.64	-3.4%
25	0.5%	484	23.070	11,157.36	190,753.07	3.7%	63.6%	-$201,287.84	-2.9%
26	0.5%	481	23.993	11,545.63	202,298.70	3.8%	67.4%	-$198,040.74	-2.4%
27	0.5%	479	24.952	11,947.42	214,246.13	4.0%	71.4%	-$194,840.64	-2.0%
28	0.5%	476	25.950	12,363.19	226,609.32	4.1%	75.5%	-$191,686.87	-1.6%
29	0.5%	474	26.988	12,793.43	239,402.75	4.3%	79.8%	-$188,578.76	-1.3%
30	0.5%	472	28.068	13,238.64	252,641.39	4.4%	84.2%	-$185,515.63	-0.9%
31	0.5%	469	29.191	13,699.35	266,340.74	4.6%	88.8%	-$182,496.85	-0.6%
32	0.5%	467	30.358	14,176.08	280,516.82	4.7%	93.5%	-$179,521.77	-0.3%
33	0.5%	465	31.573	14,669.41	295,186.23	4.9%	98.4%	-$176,589.76	-0.1%
34	0.5%	462	32.835	15,179.91	310,366.14	5.1%	103.5%	-$173,700.19	0.2%

9.2 Appendix B

This section includes building survey data, software modelling parameters, results, and the payback for Killarney CC.

Table 8 – Killarney CC site survey data and input parameters into TSOL

Site Survey	Input Parameters
2 x Cleaver Brooks Boilers rated at 397 KW each	Pool Area: 240 m^2
1 x AquaPlex HWT with 400 gallon capacity at 55 degC	Auxiliary Heating: Yes
2 x AO Smith Electric HWT with 100 gallon capacity at 60 degC	Daily fresh water requirement: 31.7 m^3
DHW Delivery Temp: 55 degC	Desired pool temp: 31.9 degC
Leisure Pool: 39,000 gallons at 31.9 degC	Max pool temp: 33 degC
Hot Tub: 2,000 gallons at 39.2 degC	Shape of Pool: Free form
Total Volume: 41,000 gallons	Pool Length: 15m
Indoor Temp: 26.1 degC	Pool Mean Depth: 1.6m
Indoor Humidity: 65.6%	Pool Surface: 240m^2
	Collector Manufacturer: Viessmann Werke GmbH & Co
	Collector Type: Vitosol 200-F SH2A
	Number Collectors: 20
	Total gross surface area: 50.2 m^2
	Total active solar surface are: 46.6 m^2
	Inclination: 45 deg
	Orientation: 180 deg
	Azimuth: 0 deg
	Type: Gas-fired boiler
	Nominal Output: 794 KW

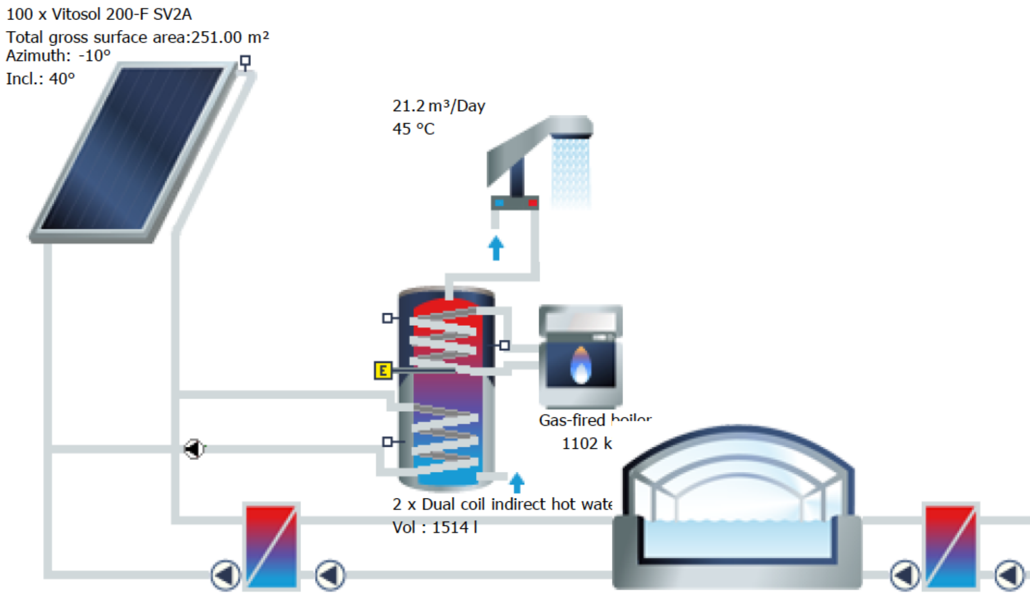


Table 9 - Killarney CC Thermal system output

Results
Installed collector power: 35.14 kW
Installed solar surface area (gross): 50.2 m²
Irradiation on collector surface (active): 62,124.11 kWh
Energy delivered by collectors: 28,260.21 kWh
Energy delivered by collector loop: 27,704.45 kWh
Solar energy contribution to swimming pool : 27,704.45 kWh
Energy from auxiliary heating: 791,149.3 kWh
Natural gas (H) savings: 3,128.0 m³
CO2 emissions avoided: 6,614.54 kg
Swimming pool solar fraction: 3.4 %
System efficiency: 44.6 %

Table 10 - Killarney CC Thermal system Equity Payback model

Year	Degra-dation	Energy (GJ)	$/GJ	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	436	9.000	3,920.40	3,920.40	1.3%	1.3%	-$296,266.29	-98.7%
2	1.5%	429	9.360	4,016.06	7,936.46	1.3%	2.6%	-$292,623.60	-87.8%
3	0.5%	427	9.734	4,155.82	12,092.27	1.4%	4.0%	-$289,033.65	-73.7%
4	0.5%	425	10.124	4,300.44	16,392.71	1.4%	5.5%	-$285,495.67	-61.3%
5	0.5%	423	10.529	4,450.09	20,842.81	1.5%	6.9%	-$282,008.91	-51.3%
6	0.5%	421	10.950	4,604.96	25,447.77	1.5%	8.5%	-$278,572.62	-43.4%
7	0.5%	418	11.388	4,765.21	30,212.98	1.6%	10.1%	-$275,186.07	-37.0%
8	0.5%	416	11.843	4,931.04	35,144.01	1.6%	11.7%	-$271,848.55	-31.9%
9	0.5%	414	12.317	5,102.64	40,246.65	1.7%	13.4%	-$268,559.34	-27.7%
10	0.5%	412	12.810	5,280.21	45,526.87	1.8%	15.2%	-$265,317.75	-24.2%
11	0.5%	410	13.322	5,463.96	50,990.83	1.8%	17.0%	-$262,123.08	-21.2%
12	0.5%	408	13.855	5,654.11	56,644.94	1.9%	18.9%	-$258,974.66	-18.7%
13	0.5%	406	14.409	5,850.87	62,495.81	2.0%	20.8%	-$255,871.82	-16.6%
14	0.5%	404	14.986	6,054.48	68,550.29	2.0%	22.9%	-$252,813.90	-14.8%
15	0.5%	402	15.585	6,265.18	74,815.47	2.1%	24.9%	-$249,800.24	-13.2%
16	0.5%	400	16.208	6,483.21	81,298.67	2.2%	27.1%	-$246,830.21	-11.7%
17	0.5%	398	16.857	6,708.82	88,007.50	2.2%	29.3%	-$243,903.17	-10.5%
18	0.5%	396	17.531	6,942.29	94,949.79	2.3%	31.6%	-$241,018.51	-9.4%
19	0.5%	394	18.232	7,183.88	102,133.67	2.4%	34.0%	-$238,175.60	-8.4%
20	0.5%	392	18.962	7,433.88	109,567.54	2.5%	36.5%	-$235,373.85	-7.5%
21	0.5%	390	19.720	7,692.58	117,260.12	2.6%	39.1%	-$232,612.66	-6.8%
22	0.5%	388	20.509	7,960.28	125,220.40	2.7%	41.7%	-$229,891.44	-6.0%
23	0.5%	386	21.329	8,237.30	133,457.70	2.7%	44.5%	-$227,209.61	-5.4%
24	0.5%	384	22.182	8,523.96	141,981.66	2.8%	47.3%	-$224,566.60	-4.8%
25	0.5%	382	23.070	8,820.59	150,802.25	2.9%	50.3%	-$221,961.86	-4.3%
26	0.5%	380	23.993	9,127.55	159,929.79	3.0%	53.3%	-$219,394.82	-3.8%
27	0.5%	379	24.952	9,445.18	169,374.98	3.1%	56.5%	-$216,864.95	-3.3%
28	0.5%	377	25.950	9,773.88	179,148.85	3.3%	59.7%	-$214,371.69	-2.9%
29	0.5%	375	26.988	10,114.01	189,262.86	3.4%	63.1%	-$211,914.53	-2.5%
30	0.5%	373	28.068	10,465.98	199,728.84	3.5%	66.6%	-$209,492.94	-2.1%
31	0.5%	371	29.191	10,830.19	210,559.03	3.6%	70.2%	-$207,106.40	-1.8%
32	0.5%	369	30.358	11,207.08	221,766.11	3.7%	73.9%	-$204,754.42	-1.5%
33	0.5%	367	31.573	11,597.09	233,363.20	3.9%	77.8%	-$202,436.48	-1.2%
34	0.5%	365	32.835	12,000.67	245,363.87	4.0%	81.8%	-$200,152.09	-0.9%
35	0.5%	364	34.149	12,418.29	257,782.16	4.1%	85.9%	-$197,900.78	-0.7%

36	0.5%	362	35.515	12,850.45	270,632.60	4.3%	90.2%	-$195,682.05	-0.5%
37	0.5%	360	36.935	13,297.64	283,930.25	4.4%	94.6%	-$193,495.45	-0.2%
38	0.5%	358	38.413	13,760.40	297,690.65	4.6%	99.2%	-$191,340.49	0.0%
39	0.5%	356	39.949	14,239.26	311,929.91	4.7%	104.0%	-$189,216.74	0.2%

9.3 Appendix C

This section includes building survey data, software modelling parameters, results, and the payback for Kensington CC.

Table 12 – Kensington CC site survey data and input parameters into TSOL

Site survey	Input Parameters
2 x Viessmann Vitrocrossal 300 Boilers rated at 632 KW and 637 KW	Average DHW Consumption: 10.87 m3
6 x HWT with 120 gallon capacity at 61 degC	Desired temp: 42degC
DHW Delivery Temp: 42.3 degC	Consumption Profile: Indoor Pool
Leisure Pool: 159,000 gallons at 27.3 degC	Circulation: Yes
Hot Tub: 6,000 gallons 38 degC	Collector Manufacturer: Viessmann Werke GmbH & Co
Total Volume: 165,000 gallons	Collector Type: Vitosol 200-F SV2A
Indoor Temp: 29 degC	Number Collectors: 45
Indoor Humidity: 60%	Total gross surface area: 112.95 m^2
	Total active solar surface are: 104.85 m^2
	Inclination: 45 deg
	Orientation: 225 deg
	Azimuth: 45 deg
	Hot water Tank manufacturer: Standard
	Tank Volume: 6 x 0.45m^3
	Solar preheating tank manufacturer: Standard
	Type: Solar preheating
	Volume: 0.45 m^3
	Auxiliary Heating Type: direct-fired
	Nominal Output: 9.67 KW

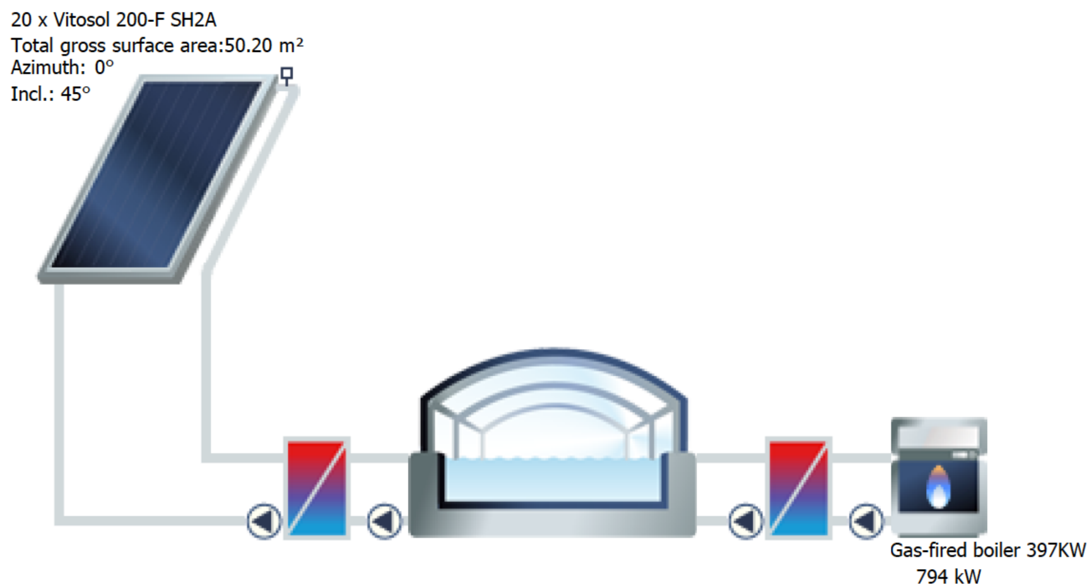


Table 13 - Kensington CC Thermal system output

Results
Installed collector power: 79.07 kW
Installed solar surface area (gross): 112.95 m^2
Irradiation on collector surface (active): 132,572.00 kWh
Energy delivered by collectors: 55,006.07 kWh
Energy delivered by collector loop: 52,691.10 kWh
DHW heating energy supply: 149,641.21 kWh
Solar energy contribution to DHW: 52,408.80 kWh
Energy from auxiliary heating: 105,468.2 kWh
Natural gas (H) savings: 10,059.3 m^3
CO_2 emissions avoided: 21,271.75 kg
DHW solar fraction: 33.2 %
System efficiency: 39.7 %

Table 14 - Kensington CC Thermal system Equity Payback model

Year	Degra-dation	Energy (GJ)	$/GJ	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	101	9.000	909.00	909.00	1.5%	1.5%	-$59,134.29	-98.5%
2	1.5%	99	9.360	931.18	1,840.18	1.6%	3.1%	-$58,289.68	-86.8%
3	0.5%	99	9.734	963.58	2,803.76	1.6%	4.7%	-$57,457.30	-72.2%
4	0.5%	98	10.124	997.12	3,800.88	1.7%	6.3%	-$56,636.97	-59.6%
5	0.5%	98	10.529	1,031.82	4,832.70	1.7%	8.1%	-$55,828.51	-49.6%
6	0.5%	98	10.950	1,067.72	5,900.42	1.8%	9.8%	-$55,031.76	-41.6%
7	0.5%	97	11.388	1,104.88	7,005.30	1.8%	11.7%	-$54,246.54	-35.3%
8	0.5%	97	11.843	1,143.33	8,148.64	1.9%	13.6%	-$53,472.69	-30.3%
9	0.5%	96	12.317	1,183.12	9,331.75	2.0%	15.6%	-$52,710.04	-26.1%
10	0.5%	96	12.810	1,224.29	10,556.05	2.0%	17.6%	-$51,958.43	-22.7%
11	0.5%	95	13.322	1,266.90	11,822.94	2.1%	19.7%	-$51,217.70	-19.8%
12	0.5%	95	13.855	1,310.98	13,133.93	2.2%	21.9%	-$50,487.70	-17.4%
13	0.5%	94	14.409	1,356.61	14,490.53	2.3%	24.2%	-$49,768.26	-15.3%
14	0.5%	94	14.986	1,403.82	15,894.35	2.3%	26.5%	-$49,059.24	-13.5%
15	0.5%	93	15.585	1,452.67	17,347.02	2.4%	28.9%	-$48,360.48	-12.0%
16	0.5%	93	16.208	1,503.22	18,850.24	2.5%	31.4%	-$47,671.83	-10.6%
17	0.5%	92	16.857	1,555.53	20,405.78	2.6%	34.0%	-$46,993.16	-9.4%
18	0.5%	92	17.531	1,609.67	22,015.45	2.7%	36.7%	-$46,324.31	-8.3%
19	0.5%	91	18.232	1,665.68	23,681.13	2.8%	39.5%	-$45,665.14	-7.4%
20	0.5%	91	18.962	1,723.65	25,404.78	2.9%	42.3%	-$45,015.52	-6.6%
21	0.5%	90	19.720	1,783.63	27,188.41	3.0%	45.3%	-$44,375.29	-5.8%
22	0.5%	90	20.509	1,845.70	29,034.12	3.1%	48.4%	-$43,744.34	-5.1%
23	0.5%	90	21.329	1,909.93	30,944.05	3.2%	51.6%	-$43,122.52	-4.5%
24	0.5%	89	22.182	1,976.40	32,920.45	3.3%	54.9%	-$42,509.70	-3.9%
25	0.5%	89	23.070	2,045.18	34,965.63	3.4%	58.3%	-$41,905.76	-3.4%
26	0.5%	88	23.993	2,116.35	37,081.98	3.5%	61.8%	-$41,310.55	-2.9%
27	0.5%	88	24.952	2,190.00	39,271.98	3.6%	65.5%	-$40,723.97	-2.5%
28	0.5%	87	25.950	2,266.21	41,538.19	3.8%	69.2%	-$40,145.87	-2.1%
29	0.5%	87	26.988	2,345.08	43,883.26	3.9%	73.1%	-$39,576.14	-1.7%
30	0.5%	86	28.068	2,426.68	46,309.95	4.0%	77.2%	-$39,014.66	-1.4%
31	0.5%	86	29.191	2,511.13	48,821.08	4.2%	81.4%	-$38,461.31	-1.1%
32	0.5%	86	30.358	2,598.52	51,419.60	4.3%	85.7%	-$37,915.97	-0.8%
33	0.5%	85	31.573	2,688.95	54,108.55	4.5%	90.2%	-$37,378.52	-0.5%

34	0.5%	85	32.835	2,782.52	56,891.07	4.6%	94.8%	-$36,848.86	-0.3%
35	0.5%	84	34.149	2,879.36	59,770.43	4.8%	99.6%	-$36,326.86	0.0%
36	0.5%	84	35.515	2,979.56	62,749.98	5.0%	104.6%	-$35,812.41	0.2%

9.4 Appendix D

This section includes building survey data, software modelling parameters, results, and the payback for Renfrew Park CC.

Table 15 – Renfrew Park CC site survey data and input parameters into TSOL

Site Survey	Input Parameters
1 x Teledyne Laars Boiler rated at 449 KW	Average DHW Consumption: 5.83 m3
1 x Hydrotherm Boiler rated at 102 KW	Desired temp: 60degC
2 x AO Smith Gas HWT with 100 gallon capacity at 57 degC	Consumption Profile: Indoor Pool
DHW Delivery Temp: 60 degC	Circulation: Yes
Hot Tub: 1944 gallons at 39.5 degC	Pool Area: 8.31m^2
Indoor Temp: 25 degC	Auxiliary Heating: Yes
Indoor Humidity: 60%	Daily fresh water requirement: 2926 L
	Desired pool temp: 39degC
	Max pool temp: 40 degC
	Shape of Pool: Free form
	Pool Length: 4m
	Pool Mean Depth: 1m
	Pool Surface: 8.31m^2
	Collector Manufacturer: Viessmann Werke GmbH & Co
	Collector Type: Vitosol 200-F SH2A
	Number Collectors: 40
	Total gross surface area: 100.4 m^2
	Total active solar surface are: 93.2 m^2
	Inclination: 45 deg
	Orientation: 180 deg
	Azimuth: 0 deg
	Hot water Tank manufacturer: Standard
	Tank Volume: 4 x 0.38 m^3
	Auxiliary Heating manufacturer: Standard
	Type: Gas-fired boiler
	Nominal Output: 550 KW

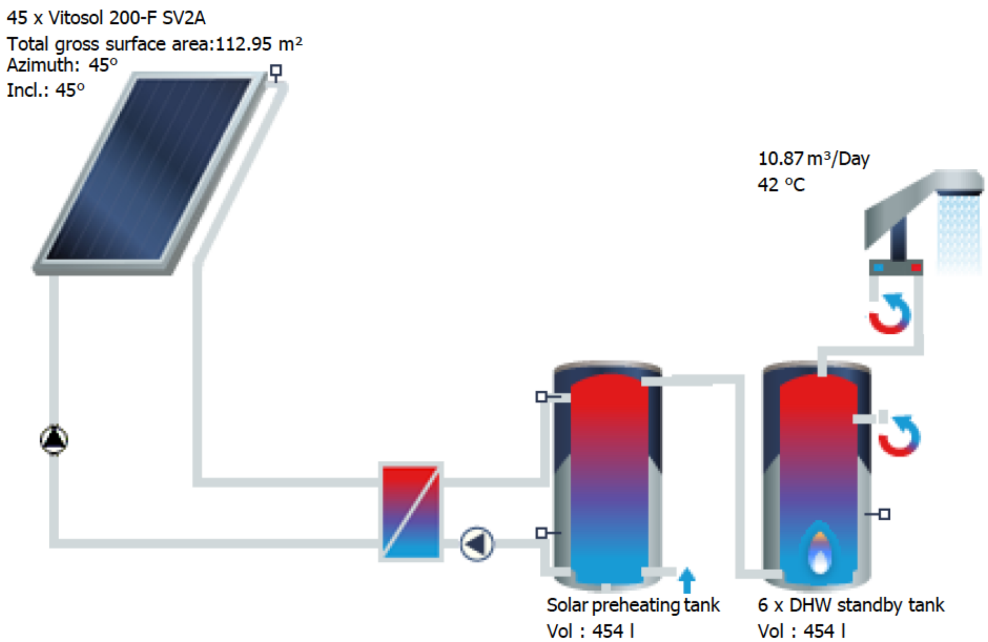


Table 16 – Renfrew Park CC Thermal system output

Results
Installed collector power: 70.28 kW
Installed solar surface area (gross): 100.4 m²
Irradiation on collector surface (active): 124,248.22 kWh
Energy delivered by collectors: 46,706.85 kWh
Energy delivered by collector loop: 45,181.52 kWh
DHW heating energy supply: 123,474.34 kWh
Solar energy contribution to DHW: 42,427.41 kWh
Solar energy contribution to swimming pool : 2,754.11 kWh
Energy from auxiliary heating: 167,509.3 kWh
Natural gas (H) savings: 5,838.2 m³
CO2 emissions avoided: 12,345.62 kg
DHW solar fraction: 32.5 %
Swimming pool solar fraction: 3.3 %
Total solar fraction: 21.0 %
System efficiency: 36.0 %

Table 17 - Renfrew Park CC Thermal system Equity Payback model

Year	Degra-dation	Energy (GJ)	$/GJ	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	191	9.000	1,719.00	1,719.00	1.3%	1.3%	-$133,362.86	-98.7%
2	1.5%	188	9.360	1,760.94	3,479.94	1.3%	2.6%	-$131,765.63	-87.7%
3	0.5%	187	9.734	1,822.22	5,302.17	1.3%	3.9%	-$130,191.52	-73.5%
4	0.5%	186	10.124	1,885.64	7,187.81	1.4%	5.3%	-$128,640.20	-61.2%
5	0.5%	185	10.529	1,951.26	9,139.06	1.4%	6.8%	-$127,111.34	-51.2%
6	0.5%	184	10.950	2,019.16	11,158.23	1.5%	8.3%	-$125,604.61	-43.2%
7	0.5%	183	11.388	2,089.43	13,247.65	1.5%	9.8%	-$124,119.70	-36.9%
8	0.5%	183	11.843	2,162.14	15,409.80	1.6%	11.4%	-$122,656.27	-31.7%
9	0.5%	182	12.317	2,237.38	17,647.18	1.7%	13.1%	-$121,214.04	-27.5%
10	0.5%	181	12.810	2,315.24	19,962.42	1.7%	14.8%	-$119,792.68	-24.0%
11	0.5%	180	13.322	2,395.81	22,358.24	1.8%	16.6%	-$118,391.89	-21.1%
12	0.5%	179	13.855	2,479.19	24,837.43	1.8%	18.4%	-$117,011.39	-18.6%
13	0.5%	178	14.409	2,565.46	27,402.89	1.9%	20.3%	-$115,650.87	-16.5%
14	0.5%	177	14.986	2,654.74	30,057.63	2.0%	22.3%	-$114,310.04	-14.7%
15	0.5%	176	15.585	2,747.13	32,804.76	2.0%	24.3%	-$112,988.63	-13.1%
16	0.5%	175	16.208	2,842.73	35,647.49	2.1%	26.4%	-$111,686.34	-11.7%
17	0.5%	175	16.857	2,941.66	38,589.15	2.2%	28.6%	-$110,402.91	-10.4%
18	0.5%	174	17.531	3,044.02	41,633.17	2.3%	30.8%	-$109,138.05	-9.3%
19	0.5%	173	18.232	3,149.96	44,783.13	2.3%	33.2%	-$107,891.51	-8.3%
20	0.5%	172	18.962	3,259.58	48,042.70	2.4%	35.6%	-$106,663.01	-7.5%
21	0.5%	171	19.720	3,373.01	51,415.71	2.5%	38.1%	-$105,452.29	-6.7%
22	0.5%	170	20.509	3,490.39	54,906.10	2.6%	40.7%	-$104,259.10	-6.0%
23	0.5%	169	21.329	3,611.85	58,517.95	2.7%	43.3%	-$103,083.19	-5.3%
24	0.5%	168	22.182	3,737.55	62,255.50	2.8%	46.1%	-$101,924.29	-4.7%
25	0.5%	168	23.070	3,867.61	66,123.12	2.9%	49.0%	-$100,782.17	-4.2%
26	0.5%	167	23.993	4,002.21	70,125.32	3.0%	51.9%	-$99,656.59	-3.7%
27	0.5%	166	24.952	4,141.48	74,266.81	3.1%	55.0%	-$98,547.30	-3.2%
28	0.5%	165	25.950	4,285.61	78,552.41	3.2%	58.2%	-$97,454.07	-2.8%
29	0.5%	164	26.988	4,434.75	82,987.16	3.3%	61.5%	-$96,376.67	-2.4%
30	0.5%	163	28.068	4,589.08	87,576.24	3.4%	64.9%	-$95,314.86	-2.1%
31	0.5%	163	29.191	4,748.78	92,325.01	3.5%	68.4%	-$94,268.42	-1.8%
32	0.5%	162	30.358	4,914.03	97,239.04	3.6%	72.0%	-$93,237.13	-1.4%
33	0.5%	161	31.573	5,085.04	102,324.08	3.8%	75.8%	-$92,220.77	-1.2%
34	0.5%	160	32.835	5,262.00	107,586.08	3.9%	79.7%	-$91,219.12	-0.9%

35	0.5%	159	34.149	5,445.12	113,031.20	4.0%	83.7%	-$90,231.98	-0.6%
36	0.5%	159	35.515	5,634.61	118,665.81	4.2%	87.9%	-$89,259.12	-0.4%
37	0.5%	158	36.935	5,830.69	124,496.50	4.3%	92.2%	-$88,300.34	-0.2%
38	0.5%	157	38.413	6,033.60	130,530.10	4.5%	96.7%	-$87,355.45	0.0%
39	0.5%	156	39.949	6,243.57	136,773.67	4.6%	101.3%	-$86,424.23	0.2%

9.5 Appendix E

This section includes building survey data, software modelling parameters, results, and the payback for Kitsilano CC.

Table 18 – Kitsilano CC site survey data and input parameters into TSOL

Site Survey	Input Parameters
2 x Viessmann VSB-57 Boilers rated at 551 KW	Average DHW Consumption: 21.2 m3
1 x Electric HWT with 400 gallon capacity at 90 degC	Desired temp: 45 degC
2 x Storage Tanks with 1211 gallons capacity	Consumption Profile: Indoor Pool
DHW Delivery Temp: 45 degC	Circulation: No
Main Pool: 179,675 gallons at 29 degC	Days without consumption: 30
Leisure Pool: 75,509 gallons at 32 degC	Pool Area: 660 m^2
Hot Tub: 6107 gallons at 40 degC	Auxiliary Heating: Yes
Total Volume: 261,291 gallons	Daily fresh water requirement: 23.73 m^3
Indoor Temp: 30 degC	Desired pool temp: 28 degC
Indoor Humidity: 60%	Max pool temp: 33 degC
	Shape of Pool: Free form
	Pool Length: 30m
	Pool Mean Depth: 1.5m
	Collector Manufacturer: Viessmann Werke GmbH & Co
	Collector Type: Vitosol 200-F SV2A
	Number Collectors: 100
	Total gross surface area: 251m^2
	Total active solar surface are: 233 m^2
	Inclination: 40 deg
	Orientation: 170 deg
	Azimuth: -10 deg
	Hot water Tank manufacturer: Standard
	Tank Volume: 2 x 1.51 m^3
	Auxiliary Heating manufacturer: Standard
	Type: Gas-fired boiler
	Nominal Output: 1102 KW

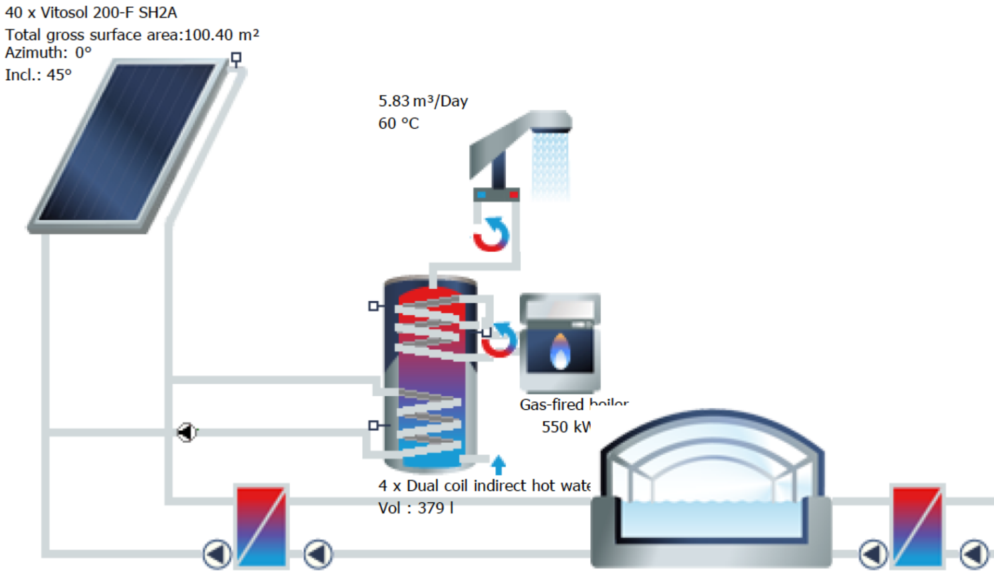


Table 19 – Kitsilano CC Thermal system output

Results
Installed collector power: 175.70 kW
Installed solar surface area (gross): 251 m²
Irradiation on collector surface (active): 313,233.62 kWh
Energy delivered by collectors: 122,491.09 kWh
Energy delivered by collector loop: 120,829.56 kWh
DHW heating energy supply: 293,443.27 kWh
Solar energy contribution to DHW: 107,601.55 kWh
Solar energy contribution to swimming pool : 13,228.00 kWh
Energy from auxiliary heating: 1,020,479.3 kWh
Natural gas (H) savings: 16,226.8 m³
CO2 emissions avoided: 34,313.87 kg
DHW solar fraction: 36.4 %
Swimming pool solar fraction: 1.6 %
Total solar fraction: 10.6 %
System efficiency: 38.4 %

Table 20 - Kitsilano CC Thermal system Equity Payback model

Year	Degra-dation	Energy (GJ)	$/GJ	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	162	9.000	1,458.00	1,458.00	1.2%	1.2%	-$118,611.43	-98.8%
2	1.5%	160	9.360	1,493.58	2,951.58	1.2%	2.5%	-$117,256.71	-88.2%
3	0.5%	159	9.734	1,545.55	4,497.13	1.3%	3.7%	-$115,921.61	-74.4%
4	0.5%	158	10.124	1,599.34	6,096.46	1.3%	5.1%	-$114,605.83	-62.1%
5	0.5%	157	10.529	1,654.99	7,751.46	1.4%	6.5%	-$113,309.10	-52.1%
6	0.5%	156	10.950	1,712.59	9,464.04	1.4%	7.9%	-$112,031.14	-44.2%
7	0.5%	156	11.388	1,772.19	11,236.23	1.5%	9.4%	-$110,771.68	-37.8%
8	0.5%	155	11.843	1,833.86	13,070.09	1.5%	10.9%	-$109,530.45	-32.6%
9	0.5%	154	12.317	1,897.68	14,967.76	1.6%	12.5%	-$108,307.19	-28.4%
10	0.5%	153	12.810	1,963.71	16,931.48	1.6%	14.1%	-$107,101.64	-24.9%
11	0.5%	153	13.322	2,032.05	18,963.53	1.7%	15.8%	-$105,913.54	-21.9%
12	0.5%	152	13.855	2,102.77	21,066.30	1.8%	17.6%	-$104,742.64	-19.4%
13	0.5%	151	14.409	2,175.94	23,242.24	1.8%	19.4%	-$103,588.69	-17.2%
14	0.5%	150	14.986	2,251.67	25,493.91	1.9%	21.2%	-$102,451.45	-15.4%
15	0.5%	150	15.585	2,330.02	27,823.93	1.9%	23.2%	-$101,330.67	-13.7%
16	0.5%	149	16.208	2,411.11	30,235.04	2.0%	25.2%	-$100,226.11	-12.3%
17	0.5%	148	16.857	2,495.02	32,730.06	2.1%	27.3%	-$99,137.54	-11.0%
18	0.5%	147	17.531	2,581.84	35,311.90	2.2%	29.4%	-$98,064.73	-9.9%
19	0.5%	147	18.232	2,671.69	37,983.59	2.2%	31.7%	-$97,007.46	-8.9%
20	0.5%	146	18.962	2,764.67	40,748.26	2.3%	34.0%	-$95,965.48	-8.0%
21	0.5%	145	19.720	2,860.88	43,609.14	2.4%	36.3%	-$94,938.59	-7.2%
22	0.5%	144	20.509	2,960.43	46,569.57	2.5%	38.8%	-$93,926.57	-6.5%
23	0.5%	144	21.329	3,063.46	49,633.03	2.6%	41.4%	-$92,929.19	-5.8%
24	0.5%	143	22.182	3,170.07	52,803.10	2.6%	44.0%	-$91,946.26	-5.2%
25	0.5%	142	23.070	3,280.38	56,083.48	2.7%	46.7%	-$90,977.55	-4.7%
26	0.5%	141	23.993	3,394.54	59,478.02	2.8%	49.6%	-$90,022.87	-4.2%
27	0.5%	141	24.952	3,512.67	62,990.69	2.9%	52.5%	-$89,082.00	-3.7%
28	0.5%	140	25.950	3,634.91	66,625.61	3.0%	55.5%	-$88,154.76	-3.3%
29	0.5%	139	26.988	3,761.41	70,387.01	3.1%	58.7%	-$87,240.94	-2.9%
30	0.5%	139	28.068	3,892.30	74,279.32	3.2%	61.9%	-$86,340.35	-2.5%
31	0.5%	138	29.191	4,027.76	78,307.08	3.4%	65.3%	-$85,452.79	-2.2%
32	0.5%	137	30.358	4,167.92	82,475.00	3.5%	68.7%	-$84,578.09	-1.8%
33	0.5%	137	31.573	4,312.97	86,787.97	3.6%	72.3%	-$83,716.05	-1.6%
34	0.5%	136	32.835	4,463.06	91,251.02	3.7%	76.0%	-$82,866.48	-1.3%
35	0.5%	135	34.149	4,618.37	95,869.40	3.8%	79.9%	-$82,029.21	-1.0%

36	0.5%	135	35.515	4,779.09	100,648.49	4.0%	83.9%	-$81,204.07	-0.8%
37	0.5%	134	36.935	4,945.40	105,593.89	4.1%	88.0%	-$80,390.87	-0.6%
38	0.5%	133	38.413	5,117.50	110,711.40	4.3%	92.3%	-$79,589.44	-0.3%
39	0.5%	133	39.949	5,295.59	116,006.99	4.4%	96.7%	-$78,799.61	-0.1%
40	0.5%	132	41.547	5,479.88	121,486.87	4.6%	101.2%	-$78,021.22	0.0%

9.6 Appendix F

This section includes PV input software parameters, outputs, and the payback for Hillcrest CC.

Table 21 – Hillcrest CC input parameters into PV SYST

Input Parameters
2 arrays
Inclination: 38 deg
Azimuth: 10 deg
Module Manufacturer: SunPower
Module Model: Mono-Si SPR-300NE-BLK-D
Number Modules: 168 x 2
Inverter Manufacturer: SMA
Inverter Model: Sunny Tripower 10000TLEE-JP-10
Number Inverters: 5 x 2
Array 1 configuration: 21 strings in parallel with 8 of modules in series
Array 2 configuration: 24 strings in parallel with 7 modules in series
Module area: 548m^2

Hillcrest Variant 1
Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E Load	E User	E_Grid
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh
January	24.6	2.78	44.6	43.3	4176	523025	4008	0.000
February	42.6	4.56	62.1	60.2	5752	475104	5569	0.000
March	88.0	6.41	112.8	109.6	10296	473928	9976	0.000
April	127.5	8.98	147.3	142.8	13205	427680	12789	0.000
May	174.1	12.56	175.8	170.5	15322	483600	14828	0.000
June	183.1	15.53	175.5	169.8	15174	497520	14690	0.000
July	197.3	18.22	194.4	188.2	16477	520056	15948	0.000
August	165.2	17.91	181.3	176.1	15458	540144	14970	0.000
September	112.1	14.57	142.1	138.0	12382	524880	11998	0.000
October	63.2	10.28	93.0	90.4	8382	531960	8118	0.000
November	29.7	6.22	56.6	55.1	5204	513360	5013	0.000
December	20.0	2.99	38.4	37.2	3596	523032	3444	0.000
Year	1227.4	10.12	1423.9	1381.0	125424	6034289	121352	0.000

GlobHor Horizontal Global Irradiation
T amb Ambient Temp
GlobInc Global incident Irradiance
GlobEff Effective Global Irradiance
EArray Effective energy at array output
E Load User Energy (Load)
E User Energy supplied to user
E Grid Energy exported to the grid

Table 22 – Hillcrest CC PV System Equity Payback model

ear	Degra-dation	Energy (kWh)	¢/KWh	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	125,000	0.090	$11,250.00	$11,250.00	3.9%	3.9%	-$278,785.71	-96.1%
2	1.5%	123,125	0.094	$11,524.50	$22,774.50	4.0%	7.9%	-$268,332.65	-78.0%
3	0.5%	122,509	0.097	$11,925.55	$34,700.05	4.1%	12.0%	-$258,030.91	-60.2%
4	0.5%	121,897	0.101	$12,340.56	$47,040.61	4.3%	16.2%	-$247,878.30	-46.5%
5	0.5%	121,287	0.105	$12,770.01	$59,810.63	4.4%	20.7%	-$237,872.66	-36.3%
6	0.5%	120,681	0.109	$13,214.41	$73,025.04	4.6%	25.2%	-$228,011.87	-28.7%
7	0.5%	120,078	0.114	$13,674.27	$86,699.31	4.7%	29.9%	-$218,293.82	-22.9%
8	0.5%	119,477	0.118	$14,150.14	$100,849.44	4.9%	34.8%	-$208,716.45	-18.4%
9	0.5%	118,880	0.123	$14,642.56	$115,492.01	5.1%	39.9%	-$199,277.72	-14.8%
10	0.5%	118,285	0.128	$15,152.12	$130,644.13	5.2%	45.1%	-$189,975.63	-11.9%
11	0.5%	117,694	0.133	$15,679.42	$146,323.54	5.4%	50.5%	-$180,808.20	-9.5%
12	0.5%	117,105	0.139	$16,225.06	$162,548.60	5.6%	56.1%	-$171,773.48	-7.5%
13	0.5%	116,520	0.144	$16,789.69	$179,338.29	5.8%	61.9%	-$162,869.55	-5.9%
14	0.5%	115,937	0.150	$17,373.97	$196,712.27	6.0%	67.9%	-$154,094.52	-4.5%
15	0.5%	115,358	0.156	$17,978.59	$214,690.85	6.2%	74.2%	-$145,446.51	-3.3%
16	0.5%	114,781	0.162	$18,604.24	$233,295.09	6.4%	80.6%	-$136,923.69	-2.3%
17	0.5%	114,207	0.169	$19,251.67	$252,546.76	6.6%	87.2%	-$128,524.25	-1.4%
18	0.5%	113,636	0.175	$19,921.63	$272,468.39	6.9%	94.1%	-$120,246.40	-0.6%
19	0.5%	113,068	0.182	$20,614.90	$293,083.29	7.1%	101.2%	-$112,088.39	0.1%
20	0.5%	112,502	0.190	$21,332.30	$314,415.59	7.4%	108.6%	-$104,048.47	0.7%
21	0.5%	111,940	0.197	$22,074.66	$336,490.25	7.6%	116.2%	-$96,124.94	1.3%
22	0.5%	111,380	0.205	$22,842.86	$359,333.11	7.9%	124.1%	-$88,316.11	1.7%
23	0.5%	110,823	0.213	$23,637.79	$382,970.91	8.2%	132.3%	-$80,620.32	2.2%
24	0.5%	110,269	0.222	$24,460.39	$407,431.29	8.4%	140.7%	-$73,035.94	2.6%
25	0.5%	109,718	0.231	$25,311.61	$432,742.90	8.7%	149.5%	-$65,561.35	2.9%
26	0.5%	109,169	0.240	$26,192.45	$458,935.36	9.0%	158.5%	-$58,194.97	3.2%
27	0.5%	108,623	0.250	$27,103.95	$486,039.31	9.4%	167.9%	-$50,935.22	3.5%
28	0.5%	108,080	0.260	$28,047.17	$514,086.47	9.7%	177.6%	-$43,780.57	3.8%
29	0.5%	107,540	0.270	$29,023.21	$543,109.68	10.0%	187.6%	-$36,729.48	4.0%
30	0.5%	107,002	0.281	$30,033.22	$573,142.90	10.4%	198.0%	-$29,780.47	4.2%

9.7 Appendix G

This section includes PV input software parameters, outputs, and the payback for Killarney CC.

Table 23 – Killarney CC input parameters into PV SYST

Input Parameters
2 arrays
Inclination: 38 deg
Azimuth: 10 deg
Module Manufacturer: SunPower
Module Model: Mono-Si SPR-300NE-BLK-D
Number Modules: 168 x 2
Inverter Manufacturer: SMA
Inverter Model: Sunny Tripower 10000TLEE-JP-10
Number Inverters: 5 x 2
Array 1 configuration: 21 strings in parallel with 8 of modules in series
Array 2 configuration: 24 strings in parallel with 7 modules in series
Module area: 548m^2

Killarney Variant 1

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E Load	E User	E_Grid
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh
January	24.9	2.46	45.4	44.1	4254	261144	4085	0.000
February	43.0	4.36	63.9	62.0	5921	241248	5725	0.000
March	88.1	6.31	112.7	109.4	10282	251472	9959	0.000
April	128.0	8.88	148.4	144.1	13267	221040	12845	0.000
May	174.6	12.45	174.9	169.2	15223	216504	14738	0.000
June	183.3	15.41	174.9	168.7	15117	206640	14643	0.000
July	198.0	18.11	194.9	188.7	16502	215016	15975	0.000
August	166.9	17.81	183.6	178.3	15666	240312	15175	0.000
September	112.1	14.46	142.8	138.9	12427	257040	12035	0.000
October	63.1	10.18	94.6	92.0	8505	273792	8234	0.000
November	29.6	6.11	48.7	47.2	4486	235440	4324	0.000
December	20.2	2.61	36.8	35.6	3430	237336	3288	0.000
Year	1231.8	9.96	1421.4	1378.3	125079	2856984	121024	0.000

GlobHor — Horizontal Global Irradiation
T amb — Ambient Temperature
GlobInc — Global incident Irradiance
GlobEff — Effective Global Irradiance
EArray — Effective energy at array output
E Load — User Energy (Load)
E User — Energy supplied to user
E Grid — Energy exported to the grid

Table 24 – Killarney CC PV System Equity Payback model

Year	Degra-dation	Energy (kWh)	¢/KWh	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	125,000	0.090	11,250.00	11,250.00	3.9%	3.9%	-$278,785.71	-96.1%
2	1.5%	123,125	0.094	11,524.50	22,774.50	4.0%	7.9%	-$268,332.65	-78.0%
3	0.5%	122,509	0.097	11,925.55	34,700.05	4.1%	12.0%	-$258,030.91	-60.2%
4	0.5%	121,897	0.101	12,340.56	47,040.61	4.3%	16.2%	-$247,878.30	-46.5%
5	0.5%	121,287	0.105	12,770.01	59,810.63	4.4%	20.7%	-$237,872.66	-36.3%
6	0.5%	120,681	0.109	13,214.41	73,025.04	4.6%	25.2%	-$228,011.87	-28.7%
7	0.5%	120,078	0.114	13,674.27	86,699.31	4.7%	29.9%	-$218,293.82	-22.9%
8	0.5%	119,477	0.118	14,150.14	100,849.44	4.9%	34.8%	-$208,716.45	-18.4%
9	0.5%	118,880	0.123	14,642.56	115,492.01	5.1%	39.9%	-$199,277.72	-14.8%
10	0.5%	118,285	0.128	15,152.12	130,644.13	5.2%	45.1%	-$189,975.63	-11.9%
11	0.5%	117,694	0.133	15,679.42	146,323.54	5.4%	50.5%	-$180,808.20	-9.5%
12	0.5%	117,105	0.139	16,225.06	162,548.60	5.6%	56.1%	-$171,773.48	-7.5%
13	0.5%	116,520	0.144	16,789.69	179,338.29	5.8%	61.9%	-$162,869.55	-5.9%
14	0.5%	115,937	0.150	17,373.97	196,712.27	6.0%	67.9%	-$154,094.52	-4.5%
15	0.5%	115,358	0.156	17,978.59	214,690.85	6.2%	74.2%	-$145,446.51	-3.3%
16	0.5%	114,781	0.162	18,604.24	233,295.09	6.4%	80.6%	-$136,923.69	-2.3%
17	0.5%	114,207	0.169	19,251.67	252,546.76	6.6%	87.2%	-$128,524.25	-1.4%
18	0.5%	113,636	0.175	19,921.63	272,468.39	6.9%	94.1%	-$120,246.40	-0.6%
19	0.5%	113,068	0.182	20,614.90	293,083.29	7.1%	101.2%	-$112,088.39	0.1%
20	0.5%	112,502	0.190	21,332.30	314,415.59	7.4%	108.6%	-$104,048.47	0.7%
21	0.5%	111,940	0.197	22,074.66	336,490.25	7.6%	116.2%	-$96,124.94	1.3%
22	0.5%	111,380	0.205	22,842.86	359,333.11	7.9%	124.1%	-$88,316.11	1.7%
23	0.5%	110,823	0.213	23,637.79	382,970.91	8.2%	132.3%	-$80,620.32	2.2%
24	0.5%	110,269	0.222	24,460.39	407,431.29	8.4%	140.7%	-$73,035.94	2.6%
25	0.5%	109,718	0.231	25,311.61	432,742.90	8.7%	149.5%	-$65,561.35	2.9%
26	0.5%	109,169	0.240	26,192.45	458,935.36	9.0%	158.5%	-$58,194.97	3.2%
27	0.5%	108,623	0.250	27,103.95	486,039.31	9.4%	167.9%	-$50,935.22	3.5%
28	0.5%	108,080	0.260	28,047.17	514,086.47	9.7%	177.6%	-$43,780.57	3.8%
29	0.5%	107,540	0.270	29,023.21	543,109.68	10.0%	187.6%	-$36,729.48	4.0%
30	0.5%	107,002	0.281	30,033.22	573,142.90	10.4%	198.0%	-$29,780.47	4.2%

9.8 Appendix H

This section includes PV input software parameters, outputs, and the payback for Kensington CC.

Table 25 – Kensington CC input parameters into PV SYST

Input Parameters
2 arrays
Inclination: 36 deg
Azimuth: 0 deg
Module Manufacturer: SunPower
Module Model: Mono-Si SPR-300NE-BLK-D
Number Modules: 168 x 2
Inverter Manufacturer: SMA
Inverter Model: Sunny Tripower 10000TLEE-JP-10
Number Inverters: 5 x 2
Array 1 configuration: 21 strings in parallel with 8 of modules in series
Array 2 configuration: 24 strings in parallel with 7 modules in series
Module area: 548m^2

Kensington Variant 1

Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E Load kWh	E User kWh	E_Grid kWh
January	24.7	2.57	44.1	42.7	4129	51038	3963	0.0
February	42.8	4.37	62.2	60.3	5770	46825	5567	16.7
March	88.1	6.31	113.5	110.1	10355	50778	9793	237.2
April	127.8	8.88	148.4	144.0	13279	48463	12459	401.7
May	174.7	12.45	177.0	171.7	15455	48851	14069	892.6
June	183.9	15.42	177.8	171.9	15384	45122	14096	804.0
July	198.1	18.11	196.2	189.6	16729	46455	15309	893.1
August	166.6	17.81	182.8	177.2	15672	46290	14393	800.3
September	112.3	14.46	143.9	139.8	12628	44302	11643	598.4
October	63.3	10.18	93.9	91.2	8423	48077	7965	187.5
November	29.7	6.10	53.9	52.2	4966	49882	4789	0.0
December	20.1	2.71	35.4	34.2	3282	50860	3145	0.0
Year	1232.2	9.98	1429.1	1385.0	126072	576944	117190	4831.6

GlobHor Horizontal Global Irradiation
T amb Ambient Temp
GlobInc Global incident Irradiance
GlobEff Effective Global Irradiance
EArray Effective energy at array output
E Load User Energy (Load)
E User Energy supplied to user
E Grid Energy exported to the grid

Table 26 – Kensington CC PV System Equity Payback model

'ear	Degra-dation	Energy (kWh)	¢/KWh	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	126,000	0.090	$11,340.00	$11,340.00	3.9%	3.9%	-$278,700.00	-96.1%
2	1.5%	124,110	0.094	$11,616.70	$22,956.70	4.0%	7.9%	-$268,163.31	-77.9%
3	0.5%	123,489	0.097	$12,020.96	$34,977.65	4.2%	12.1%	-$257,779.16	-60.0%
4	0.5%	122,872	0.101	$12,439.29	$47,416.94	4.3%	16.4%	-$247,545.33	-46.4%
5	0.5%	122,258	0.105	$12,872.17	$60,289.11	4.4%	20.8%	-$237,459.64	-36.2%
6	0.5%	121,646	0.109	$13,320.13	$73,609.24	4.6%	25.4%	-$227,519.96	-28.6%
7	0.5%	121,038	0.114	$13,783.67	$87,392.90	4.8%	30.2%	-$217,724.17	-22.8%
8	0.5%	120,433	0.118	$14,263.34	$101,656.24	4.9%	35.1%	-$208,070.18	-18.3%
9	0.5%	119,831	0.123	$14,759.70	$116,415.94	5.1%	40.2%	-$198,555.94	-14.7%
10	0.5%	119,232	0.128	$15,273.34	$131,689.28	5.3%	45.5%	-$189,179.44	-11.8%
11	0.5%	118,635	0.133	$15,804.85	$147,494.13	5.5%	50.9%	-$179,938.67	-9.4%
12	0.5%	118,042	0.139	$16,354.86	$163,848.99	5.6%	56.6%	-$170,831.67	-7.5%
13	0.5%	117,452	0.144	$16,924.01	$180,773.00	5.8%	62.4%	-$161,856.51	-5.8%
14	0.5%	116,865	0.150	$17,512.96	$198,285.96	6.0%	68.5%	-$153,011.27	-4.4%
15	0.5%	116,280	0.156	$18,122.42	$216,408.38	6.3%	74.8%	-$144,294.08	-3.2%
16	0.5%	115,699	0.162	$18,753.08	$235,161.46	6.5%	81.2%	-$135,703.08	-2.2%
17	0.5%	115,121	0.169	$19,405.68	$254,567.14	6.7%	87.9%	-$127,236.44	-1.3%
18	0.5%	114,545	0.175	$20,081.00	$274,648.14	6.9%	94.9%	-$118,892.37	-0.5%
19	0.5%	113,972	0.182	$20,779.82	$295,427.96	7.2%	102.0%	-$110,669.09	0.2%
20	0.5%	113,402	0.190	$21,502.96	$316,930.91	7.4%	109.5%	-$102,564.86	0.8%
21	0.5%	112,835	0.197	$22,251.26	$339,182.17	7.7%	117.2%	-$94,577.94	1.3%
22	0.5%	112,271	0.205	$23,025.60	$362,207.78	8.0%	125.1%	-$86,706.64	1.8%
23	0.5%	111,710	0.213	$23,826.89	$386,034.67	8.2%	133.3%	-$78,949.28	2.2%
24	0.5%	111,151	0.222	$24,656.07	$410,690.74	8.5%	141.9%	-$71,304.23	2.6%
25	0.5%	110,596	0.231	$25,514.10	$436,204.85	8.8%	150.7%	-$63,769.84	3.0%
26	0.5%	110,043	0.240	$26,401.99	$462,606.84	9.1%	159.8%	-$56,344.53	3.3%
27	0.5%	109,492	0.250	$27,320.78	$489,927.62	9.4%	169.2%	-$49,026.70	3.6%
28	0.5%	108,945	0.260	$28,271.55	$518,199.17	9.8%	179.0%	-$41,814.81	3.8%
29	0.5%	108,400	0.270	$29,255.39	$547,454.56	10.1%	189.1%	-$34,707.32	4.1%
30	0.5%	107,858	0.281	$30,273.48	$577,728.04	10.5%	199.6%	-$27,702.72	4.3%

9.9 Appendix I

This section includes PV input software parameters, outputs, and the payback for Renfrew Park CC.

Table 27 – Renfrew Park CC input parameters into PV SYST

Input Parameters
2 arrays
Inclination: 36 deg
Azimuth: -45 deg
Module Manufacturer: SunPower
Module Model: Mono-Si SPR-300NE-BLK-D
Number Modules: 168 x 2
Inverter Manufacturer: SMA
Inverter Model: Sunny Tripower 10000TLEE-JP-10
Number Inverters: 5 x 2
Array 1 configuration: 21 strings in parallel with 8 of modules in series
Array 2 configuration: 24 strings in parallel with 7 modules in series
Module area: 548m^2

Renfrew Variant 1

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E Load	E User	E_Grid
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh
January	25.2	2.80	36.8	35.2	3408	69884	3263	0.0
February	43.0	4.61	55.4	53.3	5111	63900	4935	0.0
March	87.9	6.50	105.4	102.0	9656	69899	9347	0.0
April	127.6	9.08	136.7	132.5	12269	68227	11880	0.0
May	173.8	12.56	172.7	167.3	15232	71476	14760	0.0
June	182.3	15.52	180.1	174.9	15587	68875	15092	0.0
July	197.5	18.22	198.7	193.1	17014	69341	16484	0.0
August	165.4	17.81	177.9	172.8	15297	52571	14531	293.4
September	112.3	14.56	132.4	128.6	11640	57881	11274	2.1
October	63.3	10.29	79.8	77.0	7159	69854	6923	0.0
November	29.8	6.22	41.4	39.6	3786	68414	3643	0.0
December	20.4	3.05	30.8	29.3	2839	68783	2701	0.0
Year	1228.5	10.13	1348.0	1305.7	118997	799106	114833	295.5

GlobHor Horizontal Global Irradiation
T amb Ambient Temp
GlobInc Global incident Irradiance
GlobEff Effective Global Irradiance

EArray Effective energy at array output
E Load User Energy (Load)
E User Energy supplied to user
E Grid Energy exported to the grid

Table 28 – Renfrew Park CC PV System Equity Payback model

Year	Degra-dation	Energy (kWh)	¢/KWh	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	119,000	0.090	$10,710.00	$10,710.00	3.7%	3.7%	-$279,300.00	-96.3%
2	1.5%	117,215	0.094	$10,971.32	$21,681.32	3.8%	7.5%	-$269,348.69	-78.6%
3	0.5%	116,629	0.097	$11,353.13	$33,034.45	3.9%	11.4%	-$259,541.43	-60.9%
4	0.5%	116,046	0.101	$11,748.21	$44,782.66	4.1%	15.5%	-$249,876.14	-47.3%
5	0.5%	115,466	0.105	$12,157.05	$56,939.72	4.2%	19.7%	-$240,350.77	-37.1%
6	0.5%	114,888	0.109	$12,580.12	$69,519.84	4.3%	24.0%	-$230,963.30	-29.5%
7	0.5%	114,314	0.114	$13,017.91	$82,537.74	4.5%	28.5%	-$221,711.71	-23.7%
8	0.5%	113,742	0.118	$13,470.93	$96,008.67	4.7%	33.2%	-$212,594.06	-19.1%
9	0.5%	113,174	0.123	$13,939.72	$109,948.39	4.8%	38.0%	-$203,608.39	-15.5%
10	0.5%	112,608	0.128	$14,424.82	$124,373.21	5.0%	43.0%	-$194,752.80	-12.5%
11	0.5%	112,045	0.133	$14,926.80	$139,300.01	5.2%	48.1%	-$186,025.41	-10.1%
12	0.5%	111,484	0.139	$15,446.26	$154,746.27	5.3%	53.5%	-$177,424.36	-8.1%
13	0.5%	110,927	0.144	$15,983.79	$170,730.06	5.5%	59.0%	-$168,947.81	-6.4%
14	0.5%	110,372	0.150	$16,540.02	$187,270.08	5.7%	64.7%	-$160,593.98	-5.0%
15	0.5%	109,820	0.156	$17,115.61	$204,385.69	5.9%	70.6%	-$152,361.08	-3.8%
16	0.5%	109,271	0.162	$17,711.24	$222,096.93	6.1%	76.7%	-$144,247.35	-2.7%
17	0.5%	108,725	0.169	$18,327.59	$240,424.52	6.3%	83.0%	-$136,251.09	-1.8%
18	0.5%	108,181	0.175	$18,965.39	$259,389.91	6.6%	89.6%	-$128,370.58	-1.0%
19	0.5%	107,640	0.182	$19,625.38	$279,015.29	6.8%	96.4%	-$120,604.14	-0.3%
20	0.5%	107,102	0.190	$20,308.35	$299,323.64	7.0%	103.4%	-$112,950.14	0.3%
21	0.5%	106,567	0.197	$21,015.08	$320,338.72	7.3%	110.7%	-$105,406.94	0.8%
22	0.5%	106,034	0.205	$21,746.40	$342,085.12	7.5%	118.2%	-$97,972.93	1.3%
23	0.5%	105,504	0.213	$22,503.18	$364,588.30	7.8%	125.9%	-$90,646.55	1.8%
24	0.5%	104,976	0.222	$23,286.29	$387,874.59	8.0%	134.0%	-$83,426.21	2.2%
25	0.5%	104,451	0.231	$24,096.65	$411,971.24	8.3%	142.3%	-$76,310.41	2.5%
26	0.5%	103,929	0.240	$24,935.22	$436,906.46	8.6%	150.9%	-$69,297.61	2.9%
27	0.5%	103,409	0.250	$25,802.96	$462,709.42	8.9%	159.8%	-$62,386.33	3.1%
28	0.5%	102,892	0.260	$26,700.90	$489,410.32	9.2%	169.1%	-$55,575.10	3.4%
29	0.5%	102,378	0.270	$27,630.10	$517,040.42	9.5%	178.6%	-$48,862.47	3.7%
30	0.5%	101,866	0.281	$28,591.62	$545,632.04	9.9%	188.5%	-$42,247.01	3.9%

9.10 Appendix J

This section includes PV input software parameters, outputs, and the payback for Kitsilano CC.

Table 29 – Kitsilano CC input parameters into PV SYST

Input Parameters
2 arrays
Inclination: 36 deg
Azimuth: 0 deg
Module Manufacturer: SunPower
Module Model: Mono-Si SPR-300NE-BLK-D
Number Modules: 168 x 2
Inverter Manufacturer: SMA
Inverter Model: Sunny Tripower 10000TLEE-JP-10
Number Inverters: 5 x 2
Array 1 configuration: 21 strings in parallel with 8 of modules in series
Array 2 configuration: 24 strings in parallel with 7 modules in series
Module area: $548m^2$

Kitsilano Variant 1
Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E Load kWh	E User kWh	E_Grid kWh
January	24.8	3.61	43.5	42.2	4044	36404	3680	203
February	42.2	5.04	62.8	60.9	5793	32028	5160	438
March	87.5	6.59	115.1	111.7	10484	33413	8598	1555
April	126.2	9.18	142.8	138.6	12739	31579	9928	2403
May	172.3	12.68	173.3	167.9	15167	35556	12158	2526
June	181.5	15.65	172.2	166.4	14891	40824	13177	1247
July	195.3	18.34	191.8	185.6	16374	43137	14575	1283
August	161.3	18.02	176.2	170.9	15124	38748	12863	1795
September	111.7	14.67	145.0	140.9	12648	36461	10579	1671
October	63.1	10.40	92.9	90.4	8375	37929	7449	656
November	29.6	6.42	50.8	49.3	4639	33070	4057	408
December	19.8	3.97	39.9	38.7	3716	31680	3171	389
Year	1215.3	10.41	1406.4	1363.6	123995	430827	105394	14574

GlobHor Horizontal Global Irradiation
T amb Ambient Temp
GlobInc Global incident Irradiance
GlobEff Effective Global Irradiance
EArray Effective energy at array output
E Load User Energy (Load)
E User Energy supplied to user
E Grid Energy exported to the grid

Table 30 –Kitsilano CC PV System Equity Payback model

Year	Degra-dation	Energy (kWh)	¢/KWh	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	124,000	0.090	$11,160.00	$11,160.00	3.9%	3.9%	-$278,871.43	-96.1%
2	1.5%	122,140	0.094	$11,432.30	$22,592.30	3.9%	7.8%	-$268,501.99	-78.1%
3	0.5%	121,529	0.097	$11,830.15	$34,422.45	4.1%	11.9%	-$258,282.67	-60.3%
4	0.5%	120,922	0.101	$12,241.84	$46,664.29	4.2%	16.1%	-$248,211.28	-46.6%
5	0.5%	120,317	0.105	$12,667.85	$59,332.14	4.4%	20.5%	-$238,285.68	-36.5%
6	0.5%	119,715	0.109	$13,108.69	$72,440.84	4.5%	25.0%	-$228,503.77	-28.9%
7	0.5%	119,117	0.114	$13,564.88	$86,005.71	4.7%	29.7%	-$218,863.47	-23.0%
8	0.5%	118,521	0.118	$14,036.93	$100,042.65	4.8%	34.6%	-$209,362.72	-18.5%
9	0.5%	117,929	0.123	$14,525.42	$114,568.07	5.0%	39.6%	-$199,999.50	-14.9%
10	0.5%	117,339	0.128	$15,030.90	$129,598.97	5.2%	44.8%	-$190,771.83	-12.0%
11	0.5%	116,752	0.133	$15,553.98	$145,152.95	5.4%	50.1%	-$181,677.74	-9.6%
12	0.5%	116,169	0.139	$16,095.26	$161,248.21	5.6%	55.7%	-$172,715.30	-7.6%
13	0.5%	115,588	0.144	$16,655.37	$177,903.59	5.8%	61.5%	-$163,882.60	-6.0%
14	0.5%	115,010	0.150	$17,234.98	$195,138.57	6.0%	67.4%	-$155,177.76	-4.6%
15	0.5%	114,435	0.156	$17,834.76	$212,973.33	6.2%	73.6%	-$146,598.94	-3.4%
16	0.5%	113,863	0.162	$18,455.41	$231,428.73	6.4%	79.9%	-$138,144.30	-2.3%
17	0.5%	113,293	0.169	$19,097.66	$250,526.39	6.6%	86.5%	-$129,812.06	-1.4%
18	0.5%	112,727	0.175	$19,762.25	$270,288.64	6.8%	93.4%	-$121,600.43	-0.7%
19	0.5%	112,163	0.182	$20,449.98	$290,738.63	7.1%	100.4%	-$113,507.68	0.0%
20	0.5%	111,602	0.190	$21,161.64	$311,900.27	7.3%	107.7%	-$105,532.08	0.6%
21	0.5%	111,044	0.197	$21,898.07	$333,798.33	7.6%	115.3%	-$97,671.94	1.2%
22	0.5%	110,489	0.205	$22,660.12	$356,458.45	7.8%	123.1%	-$89,925.58	1.7%
23	0.5%	109,937	0.213	$23,448.69	$379,907.14	8.1%	131.2%	-$82,291.36	2.1%
24	0.5%	109,387	0.222	$24,264.70	$404,171.84	8.4%	139.6%	-$74,767.65	2.5%
25	0.5%	108,840	0.231	$25,109.12	$429,280.96	8.7%	148.3%	-$67,352.86	2.8%
26	0.5%	108,296	0.240	$25,982.91	$455,263.87	9.0%	157.3%	-$60,045.41	3.2%
27	0.5%	107,754	0.250	$26,887.12	$482,150.99	9.3%	166.5%	-$52,843.74	3.5%
28	0.5%	107,216	0.260	$27,822.79	$509,973.78	9.6%	176.2%	-$45,746.32	3.7%
29	0.5%	106,680	0.270	$28,791.02	$538,764.81	9.9%	186.1%	-$38,751.65	4.0%
30	0.5%	106,146	0.281	$29,792.95	$568,557.76	10.3%	196.4%	-$31,858.23	4.2%

9.11 Appendix K

This section includes PV input software parameters, outputs, and the payback for the solar canopy at VanDusen Botanical Garden's VC.

Table 31 – VanDusen Botanical Garden's VC input parameters into PV SYST

Input Parameters
4 arrays
Inclination: 15 deg
Azimuth: 0 deg
Module Manufacturer: SunPower
Module Model: Mono-Si SPR-X20-250-BLK
AMPT 320W V41-92
Number Modules: 396 x 2/276/120
Inverter Manufacturer: SMA
Inverter Model: Sunny Boy SB 11000TLUS/ Sunny Boy 6000
Number Inverters: 8 x 2/5/4
Array 1 configuration: 33 strings in parallel with 12 of modules in series
Array 2 configuration: 33 strings in parallel with 12 modules in series
Array 2 configuration: 24 strings in parallel with 7 modules in series
Array 3 configuration: 23 strings in parallel with 12 modules in series
Array 4 configuration: 10 strings in parallel with 12 modules in series
Module area: 1478m^2

VanDusen Variant 1
Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E Load	E User	E_Grid
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	kWh	kWh
January	24.6	2.48	33.8	33.0	8893	47419	6856	1515
February	42.4	4.34	52.0	51.1	13179	38685	9784	2794
March	87.8	6.31	101.9	100.2	22884	47419	16292	5785
April	127.2	8.88	139.2	137.1	30410	44402	18406	11058
May	173.5	12.35	180.8	178.1	42277	47419	22570	18562
June	182.9	15.41	186.5	183.6	45601	44409	21999	22423
July	196.7	18.11	202.8	199.7	51328	47419	23730	26386
August	164.1	17.80	177.7	175.1	44780	47419	21523	22167
September	111.8	14.46	130.1	128.1	31266	44409	16727	13657
October	63.1	10.18	76.5	75.1	18423	47783	13673	4035
November	29.7	6.10	38.2	37.4	9496	52839	8028	909
December	19.9	2.62	27.1	26.3	7252	66886	6650	99
Year	1223.7	9.95	1346.7	1325.0	325789	576507	186240	129390

GlobHor Horizontal Global Irradiation
T amb Ambient Temp
GlobInc Global incident Irradiance
GlobEff Effective Global Irradiance

EArray Effective energy at array output
E Load User Energy (Load)
E User Energy supplied to user
E Grid Energy exported to the grid

Table 32 – VanDusen Botanical Garden's PV System Equity Payback model

Year	Degra-dation	Energy (kWh)	¢/KWh	Annual Energy Savings	Cummulative Benefit	Annual Cash Flow	Cumulative Cash Flow	NPV	IRR
1	0.0%	326,000	0.090	$29,340.00	$29,340.00	2.5%	2.5%	-$1,145,807.14	-97.5%
2	1.5%	321,110	0.094	$30,055.90	$59,395.90	2.6%	5.1%	-$1,118,545.56	-82.7%
3	0.5%	319,504	0.097	$31,101.84	$90,497.74	2.6%	7.7%	-$1,091,678.62	-66.4%
4	0.5%	317,907	0.101	$32,184.19	$122,681.92	2.7%	10.5%	-$1,065,200.61	-53.2%
5	0.5%	316,317	0.105	$33,304.19	$155,986.12	2.8%	13.3%	-$1,039,105.90	-43.0%
6	0.5%	314,736	0.109	$34,463.18	$190,449.30	2.9%	16.2%	-$1,013,388.95	-35.2%
7	0.5%	313,162	0.114	$35,662.50	$226,111.80	3.0%	19.3%	-$988,044.27	-29.2%
8	0.5%	311,596	0.118	$36,903.55	$263,015.35	3.1%	22.4%	-$963,066.50	-24.3%
9	0.5%	310,038	0.123	$38,187.80	$301,203.15	3.3%	25.7%	-$938,450.30	-20.5%
10	0.5%	308,488	0.128	$39,516.73	$340,719.88	3.4%	29.0%	-$914,190.45	-17.3%
11	0.5%	306,946	0.133	$40,891.92	$381,611.80	3.5%	32.5%	-$890,281.80	-14.7%
12	0.5%	305,411	0.139	$42,314.95	$423,926.75	3.6%	36.1%	-$866,719.25	-12.5%
13	0.5%	303,884	0.144	$43,787.52	$467,714.27	3.7%	39.8%	-$843,497.79	-10.6%
14	0.5%	302,364	0.150	$45,311.32	$513,025.59	3.9%	43.7%	-$820,612.50	-9.0%
15	0.5%	300,853	0.156	$46,888.15	$559,913.75	4.0%	47.7%	-$798,058.49	-7.6%
16	0.5%	299,348	0.162	$48,519.86	$608,433.61	4.1%	51.8%	-$775,830.98	-6.4%
17	0.5%	297,852	0.169	$50,208.35	$658,641.96	4.3%	56.1%	-$753,925.25	-5.4%
18	0.5%	296,362	0.175	$51,955.60	$710,597.57	4.4%	60.5%	-$732,336.62	-4.5%
19	0.5%	294,881	0.182	$53,763.66	$764,361.22	4.6%	65.1%	-$711,060.51	-3.6%
20	0.5%	293,406	0.190	$55,634.63	$819,995.86	4.7%	69.9%	-$690,092.41	-2.9%
21	0.5%	291,939	0.197	$57,570.72	$877,566.58	4.9%	74.8%	-$669,427.84	-2.3%
22	0.5%	290,479	0.205	$59,574.18	$937,140.76	5.1%	79.8%	-$649,062.41	-1.7%
23	0.5%	289,027	0.213	$61,647.36	$998,788.12	5.3%	85.1%	-$628,991.80	-1.2%
24	0.5%	287,582	0.222	$63,792.69	$1,062,580.81	5.4%	90.5%	-$609,211.73	-0.7%
25	0.5%	286,144	0.231	$66,012.68	$1,128,593.49	5.6%	96.2%	-$589,718.00	-0.3%
26	0.5%	284,713	0.240	$68,309.92	$1,196,903.41	5.8%	102.0%	-$570,506.47	0.1%
27	0.5%	283,290	0.250	$70,687.10	$1,267,590.51	6.0%	108.0%	-$551,573.05	0.5%
28	0.5%	281,873	0.260	$73,147.01	$1,340,737.52	6.2%	114.2%	-$532,913.71	0.8%
29	0.5%	280,464	0.270	$75,692.53	$1,416,430.05	6.4%	120.7%	-$514,524.49	1.1%
30	0.5%	279,062	0.281	$78,326.63	$1,494,756.68	6.7%	127.3%	-$496,401.48	1.4%

9.12 Appendix L

This section includes the raw data and calculated data used in the project.

Table 33 - Historical Park Board CO_2 Emissions

Year	Building (tonnes of CO_2)	Fleet (tonnes of CO_2)	Total (tonnes of CO_2)
2008	11,003	1,896	12,898
2009	10,190	1,800	11,990
2010	9,648	1,698	11,346
2011	11,077	1,622	12,700
2012	10,772	1,568	12,340
2013	10,146	1,600	11,747
2014	9,238	1,583	10,821
2015	8,735	1,456	10,191

Table 34 - 2015 Consumption and Emissions

Building	2015 Electricity Consumption (MWh)	2015 Gas Consumption (GJ)	2015 Water Consumption (m^3)	2015 Total Emissions (tonnes)
Hillcrest CC	6,034	25,450	68,881	1,337
Killarney CC	2,857	15,620	71,621	812
Renfrew Park CC	799	6,748	19,871	346
Kensington CC	577	5,004	23,147	257
Kitsilano CC	431	3,206	7,120	165
VanDusen Garden VC	586,858	N/A	N/A	N/A

Table 35 - 2015 Pool Attendance

Building	Enrollments	Scans	Drop-ins	ActiveNet	Annual Users	Daily Users[1]
Hillcrest CC	5,493	192,577	131,062	208,573	537,705	1,605
Kensington CC	2,185	36,005	2,783	26,650	67,623	185
Killarney CC	6,947	155,467	46,362	80,028	288,804	791
Renfrew Park CC	3,671	82,021	5,583	55,145	146,420	401
Kitsilano CC	--	--	--	--	18,250	50

[1] Daily usage calculated by dividing the annual value by 365 days.

Table 36A - 2015 Electricity consumption

	Kitsilano CC		**Killarney CC**		**Kensington CC**	
Month	kWh	KW	kWh	KW	kWh	KW
Jan	36,404	48.9	261,150	351.0	51,060	68.6
Feb	32,034	47.7	241,143	358.8	46,830	69.7
Mar	33,413	44.9	251,715	338.3	50,783	68.3
Apr	31,579	43.9	221,284	307.3	48,464	67.3
May	35,560	47.8	216,473	291.0	48,852	65.7
Jun	40,845	56.7	206,888	287.3	45,123	62.7
Jul	43,144	58.0	214,728	288.6	46,457	62.4
Aug	38,751	52.1	240,402	323.1	46,290	62.2
Sep	36,464	50.6	256,950	356.9	44,303	61.5
Oct	37,935	51.0	272,881	366.8	48,079	64.6
Nov	33,074	45.9	235,440	327.0	49,880	69.3
Dec	31,680	42.6	237,681	319.5	50,861	68.4

Table 36B - 2015 Electricity consumption

	Renfrew Park CC		**Hillcrest CC**		**VanDusen Gardens VC**	
Month	kWh	KW	kWh	KW	kwh	KW
Jan	69,887	93.9	523,025	703.0	47,419	63.7
Feb	63,905	95.1	475,051	706.9	42,830	57.6
Mar	69,903	94.0	473,942	637.0	47,419	63.7
Apr	68,023	94.5	427,763	594.1	45,889	61.7
May	71,476	96.1	483,364	649.7	47,419	63.7
Jun	68,876	95.7	497,700	691.3	45,889	61.7
Jul	69,353	93.2	519,720	698.5	47,419	63.7
Aug	52,576	70.7	540,143	726.0	47,419	63.7
Sep	57,886	80.4	525,158	729.4	45,889	61.7
Oct	69,858	93.9	531,780	714.8	47,783	64.2
Nov	68,421	95.0	513,000	712.5	54,600	73.4
Dec	68,790	92.5	523,009	703.0	66,886	89.9

Table 37 - 2015 Water consumption and calculated DHW usages and pool make-up water

	Hillcrest CC	Killarney CC	Kensington CC	Renfrew Park CC	Kitsilano CC
Annual Consumption (m^3)	68,881	71,621	23,147	19,871	7,120
Per day[1] (m^3)	188.72	196.22	63.42	54.44	19.51
Per day (gal)	49,853.24	51,836.34	16,752.85	14,381.81	5,153.16
DHW usage/day (gal)	9,970.65	5,702.00	4,188.21	2,876.36	1,545.95
DHW usage/day (L)	37,742.99	21,584.40	15,854.10	10,888.21	5,852.05
Pool Make-up/day (gal)	24,926.62	6,220.36	8,376.42	4,026.91	772.97
Pool Make-up/day (L)	94,357.47	23,546.61	31,708.20	15,243.50	2,926.03

Table 34 - Building Location

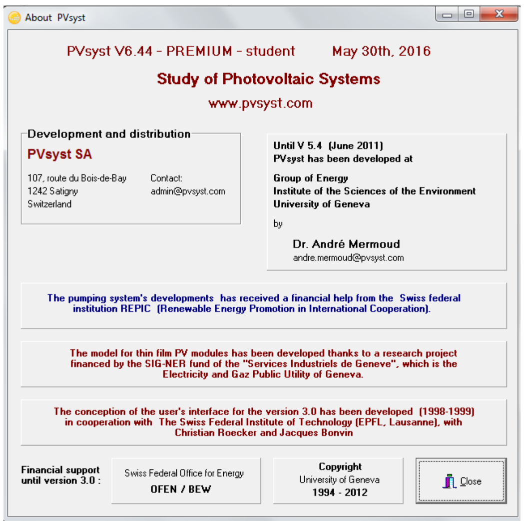
Building	**Latitude**	**Longitude**
Hillcrest CC	49.2437° N	-123.1072° W
Killarney CC	49.2273° N	-123.04441° W
Renfrew Park CC	49.2514° N	-123.0426° W
Kensington CC	49.2372° N	-123.0752° W
Kitsilano CC	49.2616° N	-123.162° W
VanDusen Botanical Gardens	49.238° N	-123.1293° W

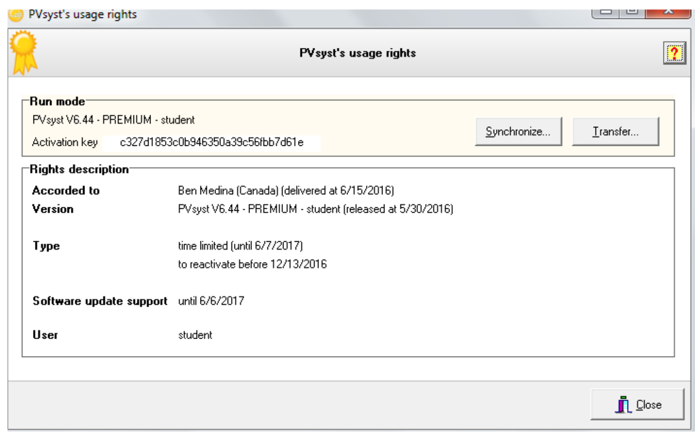
[1] Daily usage calculated by dividing the annual value by 365 days.

9.13 Appendix M

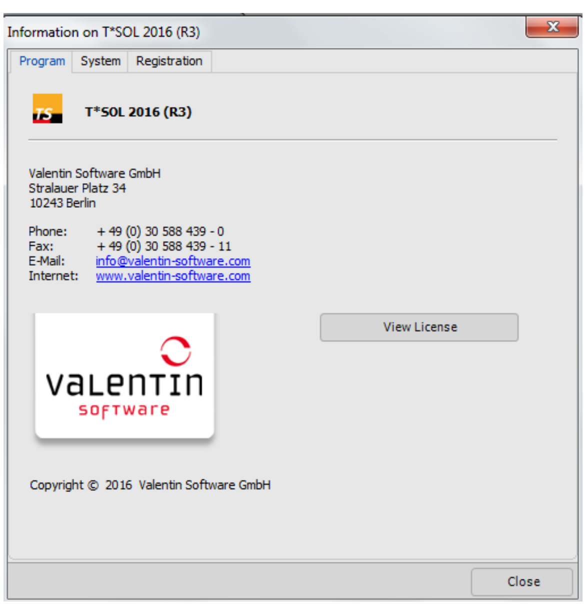
This section includes the versions of the software calculators used in the project.

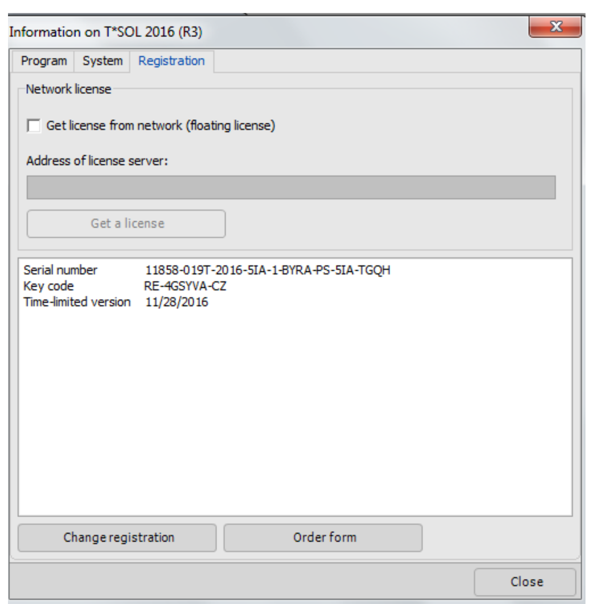
PVSYST version 6.44 (student). The Activation Key required to transfer the license to another computer. License valid until 6/7/2017.





TSOL version 2016 (R3). TSOL Serial # and keycode (required to transfer the license to another computer). License valid until 11/28/2016.





9.14 Appendix N

This section includes a few solar thermal and PV projects worth mentioning due to their capacity or creativity.

Drake Landing Solar Community (DLSC) project

The DLSC is a one-of-a-kind implementation in Okotoks, Alberta that uses seasonal solar thermal energy storage in its 52 home community. Solar thermal energy is collected in the summer, stored underground, and used by the homes as heat during the winter. It was estimated that each home will save 5 tonnes of CO_2/year for a total savings of 130 tonnes/year. More information on this project can be found here: http://www.dlsc.ca/.

De Bortoli Wines Solar Thermal project

This 200 KW system uses 3,000 evacuated tubes to preheat the condensing boilers to meet the demand in their De Bortoli's bottling line. This has been referred to as the largest solar thermal plant on a winery in Australasia. More information can be found here: http://www.apricus.com.au/2013/09/12/de-bortoli-winery-now-loving-the-sun

Bexar County Jail project

This project consists of 220 solar collectors installed on the Bexar County Jail complex in San Antonio, Texas. Equipped with a 6,000-gallon storage tank, this system supplies all of the water for the kitchen, showers, and bathroom facilities at the Jail. The expected monthly savings were calculated to be $30,000 to $60,000. A project overview can be found here: http://www.apricus.com/upload/userfiles/downloads/Apricus-Commercial-Project-Bexar-County-Jail.pdf

SolaRoad

The 2014 SolaRoad project in Krommenie, Holland was the world's first solar bike path. This 70m long bike path was priced at $3.7M and generates 3 MWh/year. More information can be found here: http://en.solaroad.nl/

Bike Lane in Korea

In 2015, a solar covered bike lane opened publicly in South Korea. This 32 km long bike lane in between a six lane highway connects Daejeon and Sejong. Project name, cost or generation capacity details were unavailable in the internet.

Oasis Project

In 2014, the British Columbia Institute of Technology (BCIT) inaugurated their Oasis 250 KW Solar Carport Project. This 4$.2M project is expected to generate 142 MWh/year and allows for 2 Electric Vehicle (EV) stations as power distribution to the BCIT micro-grid. Given this a pilot project, it serves as ongoing research for EV charging stations in Canada and the United States. More information on this pilot project can be found here: http://www.bcit.ca/microgrid/energyoasis/

Solar Compass

Thompson Rivers University in Kamloops is currently constructing the first solar roadway in Canada. This 9.6 KW project priced at $4.5/W is expected to generate 9.7 MWh/year, enough to power 40 computers eight hours a day for the entire year for an annual savings of $725. More information can be found here:
https://www.tru.ca/__shared/assets/The_Solar_Compass37675.pdf

9.15 Appendix O

This section includes a few innovative solar products in today's market.

Wattway

This is a PV road surface that harvests solar energy and produces electricity at 15% efficiency. Currently, it is only suited for asphalt surfaces but in a few years it will work on concrete. Only $10m^2$ and $50m^2$ sections are available at the moment and it is priced at 6€/W. More information can be found here: http://www.wattwaybycolas.com/en/

PV-thermal (PVT)

A PVT is a hybrid system that converts solar radiation into thermal energy and electricity. These systems combine a solar cell, which converts sunlight into electricity, with a solar thermal collector, which captures the remaining energy and removes waste heat from the PV module. The largest PVT system installed found has been in 2013 at the Inn at Schofield Barracks in Oahu, Hawaii. For more details on this profitable project, click here: http://www.prnewswire.com/news-releases/sundrum-system-exceeds-financial-expectations-of-largest-hybrid-pvt-system-in-us-214806591.html

Building Integrated PV (BIPV)

Traditionally, solar PV is mounted on a building's rooftop, however, architects have started to incorporate modules into the building envelope. BIPV not only generates electricity but it also reduces the solar gain inside the building which lowers the A/C costs. BIPV is still a niche market but gaining more and more popularity as business strive to be become sustainable. The following company was found to offer a diverse amount of BIPV solutions: http://www.onyxsolar.com/

Transparent Luminescent Solar Concentrator (TLSC)

A research team at Michigan State University has developed what they refer to as TLSC. The advantage of the TLSC over BIPV is its transparency. Currently, TLSC is at 1% efficiency but researchers believe that can be improved to 5%. An interview with Dr. Lunt, who leads this research, can be found here: http://www.digitaltrends.com/cool-tech/first-fully-transparent-solar-power-cell/

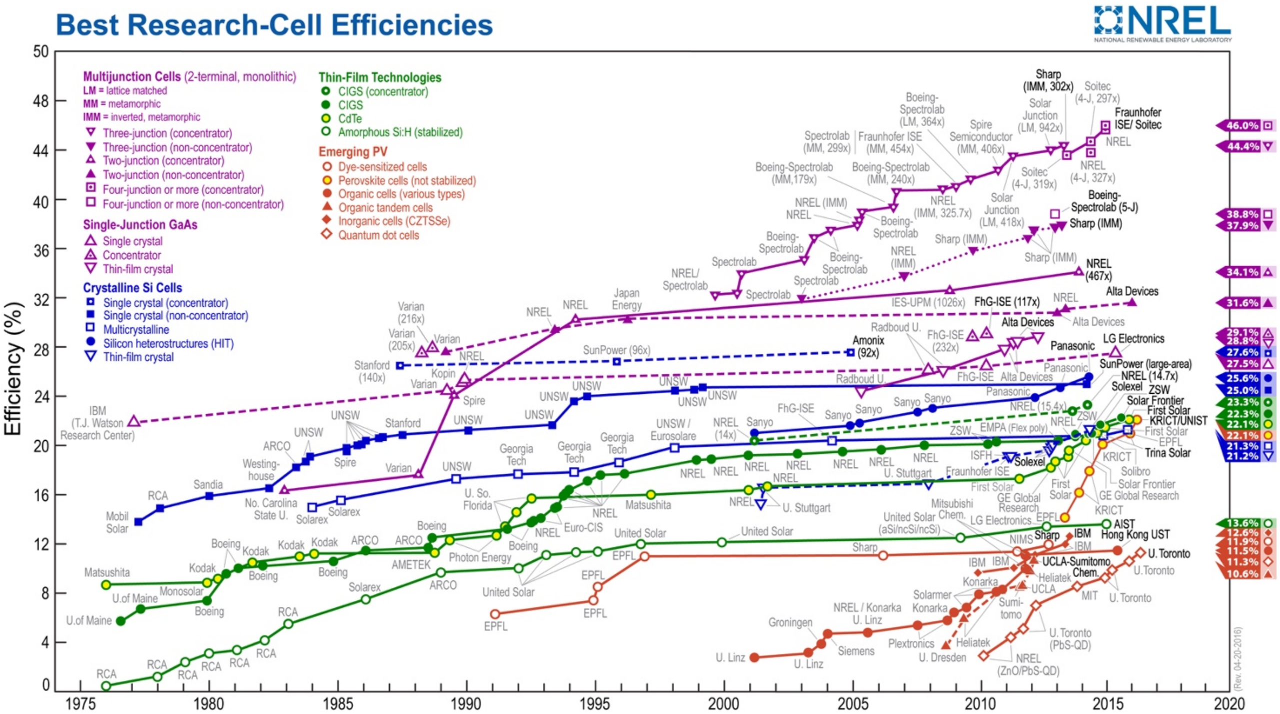
PV shingles

PV shingles are used in place of roof tiles and are more aesthetically pleasing than traditional PV modules. In general, the shingle efficiency lags first generation solar cell efficiency and are more expensive. The attractiveness is their easiness to install and their lifespan of 20 years.

9.16 Appendix P

This section includes a chart showing all the developments in solar cell efficiency from 1975 onwards. All the different technologies are included, from first generation cells (e.g., standard crystalline silicon) to second generation cells (e.g., thin-film) to third generation cells (e.g., gallium arsenide) which includes multi-junction, organic, dye-sensitized cells and more.

There is no doubt that much better results will be achieved and efficiency will scale up as more investments are granted to the renewable energy sector.



Source: http://www.nrel.gov/ncpv/images/efficiency_chart.jpg

9.17 Appendix Q

This section includes two estimates provided directly from the companies.

novo SOLAR SYSTEMS

For Budget purposes only

July 21, 2016

City of Vancouver - Park Board

RE: VanDusen Gardens Solar project

Attn: Ben Medina

300 kW solar energy system - 1200 panels mounted on carport structure • Includes inverters, Electrical wiring, installation and connection • Aluminum racking system installed on roof	$725,000.00
4 - Schletter 22' x 300' B1 Carports to mount arrays • Includes racking and installation.	$180,000.00
60 Concrete structures to mount carports • Includes installation.	$64,000.00
Structural engineering	$6,000.00
Sub total	$975,000.00
GST	$48,750.00
Total	$1,023,750.00

25 year warranty on Solar Modules, 12 year warranty on inverter, 2 year service warranty.

Sales Representative ____________________
Mark Tizya

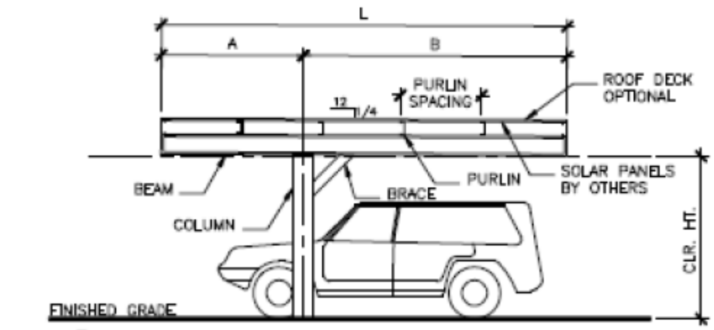
Client's signature ______________________ Date ________________

Table 39 – Quote from GAORFID for RFID system

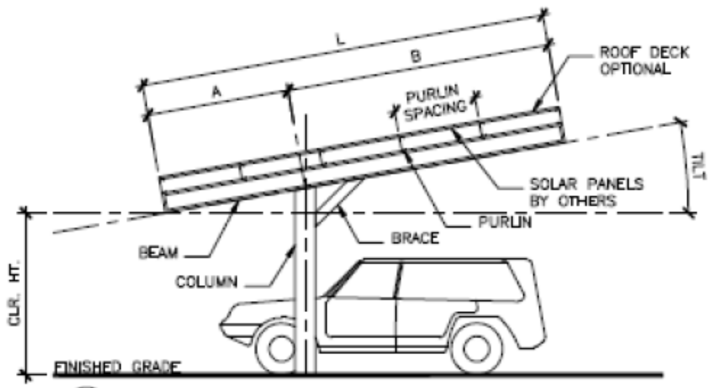
Quantity	**Item**	**Price**	**Total**
10,000	UHF 860-960 MHz Wristband RFID Tag, Model #116401	$2.99	$29,900
1	UHF 860-960 MHz RFID Reader/Writer (System logger), Model #236034	$449.00	$449
5	UHF 860-960 MHz RFID Reader/Writer w/ 4 Antenna Ports, Model #236015	$1,245.00	$6,225.00
5	UHF 900 MHz RFID Antenna Cable, Model #346001	$80.00	$400.00
5	UHF 900 MHz 7.5 dBi Reader Antenna, Model #3266005	$339.00	$1695.00
1	RFID Tracking Software System, Model #617002	$4,995.00	$4,995
			$43,664

9.18 Appendix R

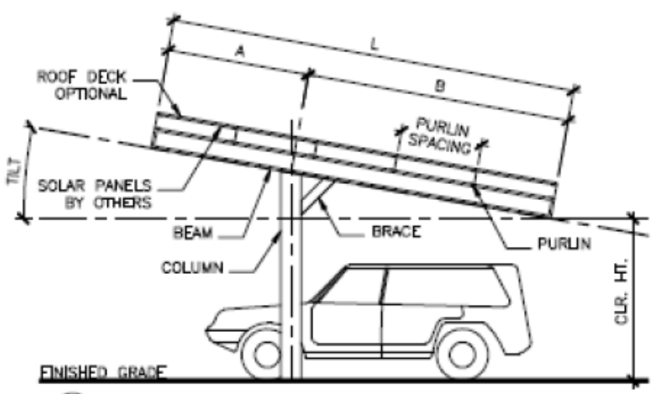
This section includes a solar canopy layout and designs.



1 — CROSS SECTION
BSP FLAT SLOPE N.T.S.



2 — CROSS SECTION
BSP UP SLOPE N.T.S.

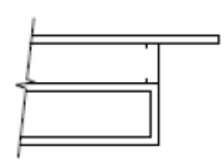


3 — CROSS SECTION
BSP DOWN SLOPE N.T.S.

SPECIFICATIONS

L = (MAX. 24')
B = (2/3L MAX.)
A = (L–B)
PURLIN SPACING =
TILT = (IN DEGREES)
MIN. CLEAR HIGH =
HIGH EAVE =   HIGH EAVE = CLR HT + 18" + LSW (TILT)
PANEL GAP (IF ANY) =
PORTRAIT: OR, LANDSCAPE: SOLAR PANEL
ROOF DECK (OPTIONAL) =
CANTILEVER (OPTIONAL) =
HANDICAP SPACE (OPTIONAL) =

NOTES

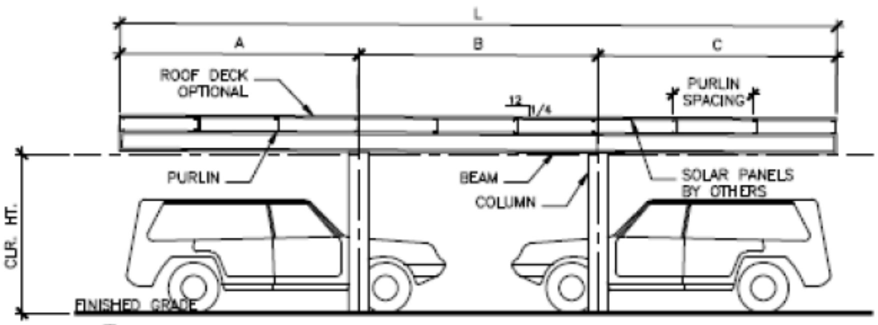


OPTIONAL SOLAR PANEL CANTILEVER
N.T.S.

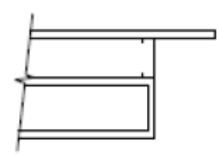
BAJA CONSTRUCTION CO., INC. 223 FOSTER ST., MARTINEZ CA 94553 1-800-366-9600 FAX: (925) 229-0161	**SOLAR SUPPORT SYSTEM** BRACED SINGLE POST		PROJ. NO.:
			SHEET: 1 OF 4

SPECIFICATIONS	
L = (MAX. 40')	
B = (2/3L MAX.)	
A = (L−B)	
PURLIN SPACING =	
TILT =	(IN DEGREES)
MIN. CLEAR HIGH =	
HIGH EAVE = HIGH EAVE = CLR HT + 18" + LSW (TILT)	
PANEL GAP (IF ANY) =	
PORTRAIT: SOLAR PANEL	OR, LANDSCAPE:
ROOF DECK (OPTIONAL) =	
CANTILEVER (OPTIONAL) =	
HANDICAP SPACE (OPTIONAL) =	

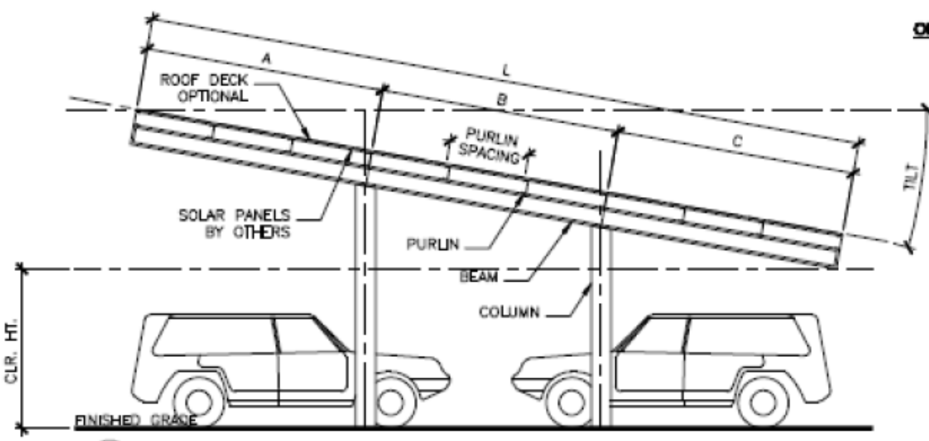
NOTES



1 CROSS SECTION
BSP BACK TO BACK FLAT SLOPE N.T.S.

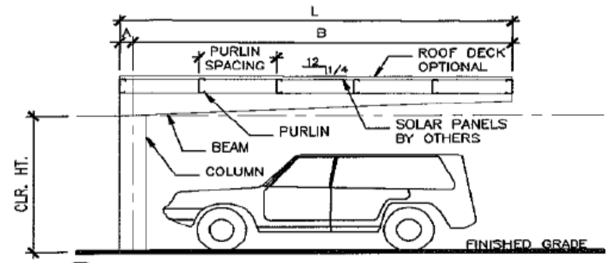


OPTIONAL SOLAR PANEL CANTILEVER
N.T.S.

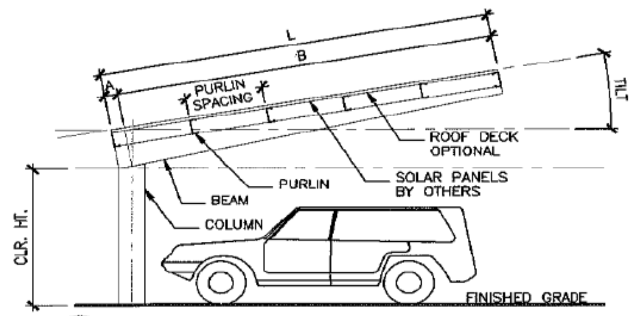


2 CROSS SECTION
BSP BACK TO BACK SLOPED N.T.S.

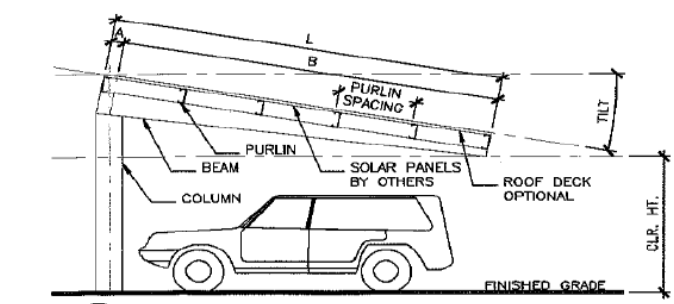
BAJA CONSTRUCTION CO., INC. 223 FOSTER ST., MARTINEZ CA 94553 1-800-366-9600 FAX: (925) 229-0161	**SOLAR SUPPORT SYSTEM** SINGLE POST BACK TO BACK		PROJ. NO.:
			SHEET: 2 OF 4



1 CROSS SECTION
FC FLAT SLOPE N.T.S.



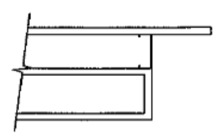
2 CROSS SECTION
FC UP SLOPE N.T.S.



3 CROSS SECTION
FC DOWN SLOPE N.T.S.

SPECIFICATIONS
L = (MAX. 20')
B = (2/3L MAX.)
A = (L–B)
PURLIN SPACING =
TILT = (IN DEGREES)
MIN. CLEAR HIGH =
HIGH EAVE =   HIGH EAVE = CLR HT + 18" + LSW (TILT)
PANEL GAP (IF ANY) =
PORTRAIT: OR, LANDSCAPE: SOLAR PANEL
ROOF DECK (OPTIONAL) =
CANTILEVER (OPTIONAL) =
HANDICAP SPACE (OPTIONAL) =

NOTES

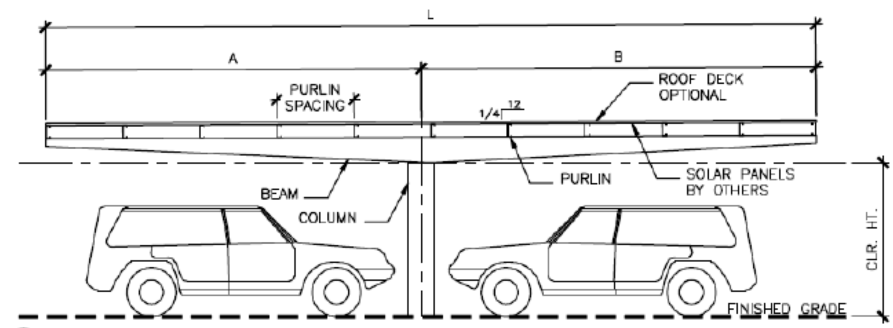


OPTIONAL SOLAR PANEL CANTILEVER
N.T.S.

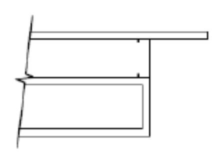
BAJA CONSTRUCTION CO., INC. 223 FOSTER ST., MARTINEZ CA 94553 1-800-366-9600 FAX: (925) 229-0161	**SOLAR SUPPORT SYSTEM** FULL CANTILEVER		PROJ. NO.:
			SHEET: 3 OF 4

SPECIFICATIONS
L = (MAX. 40')
B = (2/3L MAX.)
A = (L–B)
PURLIN SPACING =
TILT = (IN DEGREES)
MIN. CLEAR HIGH =
HIGH EAVE = HIGH EAVE = CLR HT + 18" + LSW (TILT)
PANEL GAP (IF ANY) =
PORTRAIT: OR, LANDSCAPE: SOLAR PANEL
ROOF DECK (OPTIONAL) =
CANTILEVER (OPTIONAL) =
HANDICAP SPACE (OPTIONAL) =

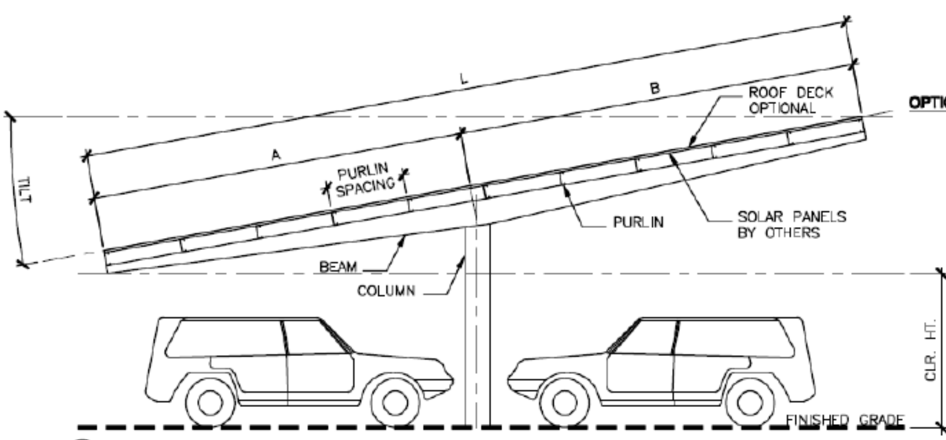
NOTES



1 CROSS SECTION
FC TEE FLAT SLOPE N.T.S.



OPTIONAL SOLAR PANEL CANTILEVER
N.T.S.



2 CROSS SECTION
FC TEE SLOPED N.T.S.

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SOLAR SUPPORT SYSTEM
FULL CANTILEVER TEE

PROJ. NO.:

SHEET: 4 OF 4

9.19 Appendix S

This section includes CO_2 facts.

- 50,000 hectares of trees = 250,000 tonnes of CO_2/year sequestered[1]
- One telephone pole sized 80 year old tree = 1 tonne of CO_2 sequestered[2]
- Driving 20,000 km in a small passenger vehicle emits 3.2 tonnes of CO_2[3]
- Including the food intake, the average Canadian produces 18 tonnes of CO_2 a year.
- A return flight from Vancouver to Toronto emits 1.4 tonnes of CO_2 per person.
- A return flight from Vancouver, Canada to London (UK) emits 3.5 tonnes of CO_2/ person.

[1] http://www.natureconservancy.ca/en/where-we-work/british-columbia/featured-projects/darkwoods/dw_carbon.html

[2] https://www.biv.com/article/2016/5/industrys-30-30-plan-targets-forestrys-co2-emissio/

[3] http://www.offsetters.ca/education/reducing-greenhouse-gases/