UniverCity

BETTER LIVING ON BURNABY MOUNTAIN

Harvesting Solar Energy on Burnaby Mountain

A prospective report on photovoltaic electricity production at UniverCity

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1.0 INTRODUCTION

The Earth is showing us that our energy-use practices of the last one hundred and fifty years are unsustainable. Our society's reliance on fossil fuels to quench our ever-growing thirst for energy has resulted in a climatic shift that scientists are calling the first human influenced geological epoch; the Anthropocene. With the Earth's population at 7 Billion persons and growing the need to research, test, and implement alternative and renewable energy sources has never been higher. Wind, hydro, tidal, and solar power are energy sources that can, and are being, implemented to reduce fossil fuel dependence and to make the shift towards a sustainable energy economy. By adopting sustainable energy practices we can begin to arrest the environmental damage caused by fossil fuel consumption and preserve essential ecological systems.

This report examines the feasibility of installing photovoltaic arrays on the structures and the immediate grounds of the UniverCity residential and commercial community on Burnaby Mountain, BC. Offsetting the community's electrical consumption with photovoltaic arrays represents a unique opportunity to showcase the potential of large-scale photovoltaic arrays in urban settings; something that has not been done western Canada. The goals of this report are to examine potential photovoltaic array installation sites, outline how they would be operated and managed, and to estimate the installation costs and expected return on investment.

1.1 What is solar power?

Solar power is the conversion of the sun's radiated energy to electricity through photovoltaic cells. These cells consist of negative and positive silicon crystals that are "doped" with an element that gives them more or less electrons in their outer shell. In photovoltaic cells both negative and positive silicon crystals contact one another. When the cell absorbs the sun's radiation it pushes electrons across the junction between the crystal types producing a direct electrical current. The DC current must then pass through an AC/DC electrical inverter so that it can be used to meet our electrical needs. DC power is used for discrete batteries; AC for electrical distribution systems.

There are two means of using electricity generated from photovoltaic cells. First, a grid-tied system is designed to operate in parallel with a municipal electrical distribution grid. When electricity from the photovoltaic system is used and demand exceeds system capacity, electricity is then supplemented from the municipal distribution grid. The advantage of the grid-tied system is that excess photovoltaic electricity can be sold back to electrical utilities through programs such as BC Hydro's Net Metering program or an Independent Power Producer agreement. Additionally, a grid-tied system allows users to reduce their net electrical consumption by producing their own.

The second means is a fully independent system. An independent photovoltaic system is exactly what the name implies; it is a system completely isolated from the municipal electrical grid. Though an independent system requires battery banks for storing electricity, it has the advantage of allowing users to be completely free from electrical utilities and their associated costs and agreements. This type of system allows users to have electricity in remote areas where electrical grids do not exist.

1.2 Trends in Solar Power Production

In recent years photovoltaic technology has evolved from a niche technology to a significant electricity producer in several countries. The price of photovoltaic modules today is one hundred times cheaper than in 1977, and costs continue to decrease. If estimated projected cost reductions continue, electricity produced from photovoltaic systems will reach grid-parity in several countries within ten years.

Germany is leading the global push for the transition from fossil fuels to renewable energy sources. The primary cause of their high-profile success is environmental and economic government policy that supports renewable energy projects through grant programs and tax refunds. Further they discourage fossil fuel use with carbon taxes. Additionally, Germany understands that promoting sustainable energy production is only part of the solution; the other is learning how to use that energy efficiently. They promote energy efficiency through government several programs. In 2014 renewable energy accounted for 27.3% of Germany's gross power consumption; their aim is for 80% by 2050. The example set by Germany shows that with the right support renewable energy production is not only feasible but also favorable when compared to the rising environmental costs of oil.

Comparatively in Canada photovoltaic electricity production is currently generating 335 Gigawatt-hours of electricity per year or about 0.0000006% of Canada's annual gross power consumption. The majority of these installations are in Ontario, which makes up 91% of all photovoltaic installations in Canada. Most of Ontario's photovoltaic systems are grid-tied and ground-mounted. This allows unused land to be converted into power producing locations that can sell electricity at a close-to grid-parity rate. Ontario's Renewable Energy Standard Offer Program (RESOP) provides a guaranteed price for electricity for 20 years at $0.42/kWh. This opportunity provides small, privately owned photovoltaic systems a predictable return on investment timeline for recouping capital costs of installing the system; which in turn encourages financing by the open capital market. Ontario's leadership in renewable energy policy and sheer size is helping Canada make the transition towards adopting more renewable energy, but the rest of the Canadian provinces still have a long way to go to reach Ontario's scale.

Largely due to the province's heavy reliance on hydroelectric power British Columbia is just beginning to implement large-scale photovoltaic systems. Hydroelectric power as a renewable energy source is good but creating dams destroys sensitive ecosystems and in some cases has displaced First Nations groups. Photovoltaic systems also require large amounts of space but have lower environmental impacts. Recently, the largest photovoltaic project in western Canada came online in Kimberly, BC. Called SunMine, the project is situated on the former mine site that once supported the town's economy. As of July 27[t,] 2015 the 1.05 Megawatt project has demonstrated BC's sound potential for photovoltaic electricity production.

Following the path laid out by Germany on an international scale, Ontario on a national scale and Kimberly on a provincial scale, UniverCity can demonstrate the feasibility of a large-scale urban photovoltaic system in the lower mainland region. Installing photovoltaic arrays on the rooftops of existing UniverCity buildings and SFU grounds would help UniverCity meet its core mandate to sustainably develop SFU's endowment lands.

A photovoltaic project would provide the community and university with an environmentally conscious reputation, and practically reduce the net electrical consumption of the community. It is hoped that by installing a photovoltaic system in the community general public awareness of the possibility and performance of solar power will increase; which in turn could lead to policy reforms and opportunities beyond SFU akin to those in Ontario and Germany.

2.0 PHOTOVOLTAIC TECHNOLOGY

This section discusses the three most popular photovoltaic cell technologies currently available and the reasoning behind the choice of panel technology that would fit UniverCity's needs. Photovoltaic module technology is primarily dictated by two factors: unit production costs and efficiency of power generation.

In recent years the production costs of photovoltaic technology has decreased dramatically. Improved manufacturing techniques and an expanding photovoltaic market are driving production costs down. If these trends continue photovoltaic technology becomes increasingly favorable as a means to sustainably satisfy growing energy needs.

Production refinement combined with improved construction materials is increasing the net energy efficiency of photovoltaic cells. Currently the upper limits of cell efficiencies are reaching 20% compared to efficiencies limits of 10% 25 years ago. It is anticipated photovoltaic cell efficiency will continue to increase. Such a trend will reduce return on investment timelines and increase the appeal of adopting solar as an energy source.

The three most popular photovoltaic cell technologies currently being used are monocrystalline silicon, poly or multicrystalline silicon and amorphous silicon.

Monocrystalline silicon cells are constructed from a single crystal of silicon. This requires cost-intensive precision manufacturing processes but creates a highly efficient photovoltaic cell. Monocrystalline silicon photovoltaic cells are widely available and require little maintenance over their ample 25 years lifespan. Monocrystalline silicon photovoltaic cells are expensive but highly efficient; they are proven and readily available, and do not require maintenance beyond annual cleaning.

Multicrystalline silicon cells are constructed from a large number of silicon crystals, which reduces the cost, and complexity of the manufacturing process, and creating a less expensive but less efficient (3-5%) photovoltaic cell. Similarly, to monocrystalline cells, multicrystalline cells have a proven track record and require little maintenance. Their only explicit differences are a reduction in cost and efficiency. In practice, reduced efficiency results in cells requiring more surface area to produce the same amount of electricity as monocrystalline cells.

Amorphous silicon cells represent the leading edge in silicon-based photovoltaic cell technology. The term “amorphous” refers to the thin-film property of the silicon wafers that make up the cell. Amorphous cells consume fewer raw materials for manufacturing, resulting in higher production efficiency. These cells can be easily integrated onto buildings because of their lower space requirements. They are also highly resistant to overheating compared to mono and multicrystalline cells. Amorphous cell drawbacks include: the technology has not had enough time to demonstrate its long-term performance, the cell technology has not yet reached the same electrical production efficiency as mono and multicrystalline cells and they have a shorter projected performance lifespan. In sum, this newer photovoltaic cell technology is adaptable and easy to manufacture but has not yet reached the electrical production and durability found in older style cells.

After reviewing these currently available photovoltaic cell technologies and conferring with several industry consultants, multicrystalline cells with a 260w electrical production capacity are likely the most suitable cell for solar installations at UniverCity. These cells produce electricity at a reasonable installed cost; allowing the arrays to have a meaningful reduction of the electrical consumption of the community while staying within a realistic return on investment timeline. However they do require more installation space than monocrystalline cells and amorphous cells are not yet suitable for a “dedicated” installation of the SFU scale.

3.0 INSTALLATION SITES AND PV POTENTIAL

To assess the feasibility of installing photovoltaic arrays within the community each UniverCity building and five undedicated SFU grounds locations were examined. For the UniverCity building installation sites available roof surface area, interior GFA (Gross Floor Area), and EUI (Electrical Use Intensity) figures were collected and compared against the approximate number of photovoltaic modules that could be mounted, estimated electrical output (kWh per year), building electrical consumption reduction and capital investment costs to determine a return on investment timeline and overall feasibility.

Similarly for the SFU grounds locations available surface areas, approximate number of photovoltaic modules and estimated electrical output were used in combination with a BC Hydro IPP (Independent Power Producer) rates to calculate a return on investment timeline and feasibility.

Once an installation site has reached its ROI the photovoltaic arrays will be producing electricity for free (other than maintenance costs) and in doing so will reduce the net annual electrical consumption and cost to the community.

The following sections outline the site-specific information for the installation of photovoltaic arrays and their respective potential to produce electricity.

3.1 Building Adapted Photovoltaic Arrays

Fourteen development parcels in the UniverCity community were examined to determine the opportunities, challenges, and costs of installing photovoltaic arrays on building rooftops. Within these parcels forty-two buildings were examined. The building types range from three story townhomes, to low-rise condominiums, high-rise condominium towers and to mixed-use residential/commercial. Factors that determine a building's ability to accommodate photovoltaic panel installation were collected from (Zakaria, Zainuddin & Shaari 2013) and (Ordonez, Jadraque, Alegre & Martinez 2010). Those factors were used to calculate roof surface areas and the number of panels that be could installed. Figures were taken from the MURB Builder Insight, technical maintenance bulletin to calculate building EUI's.

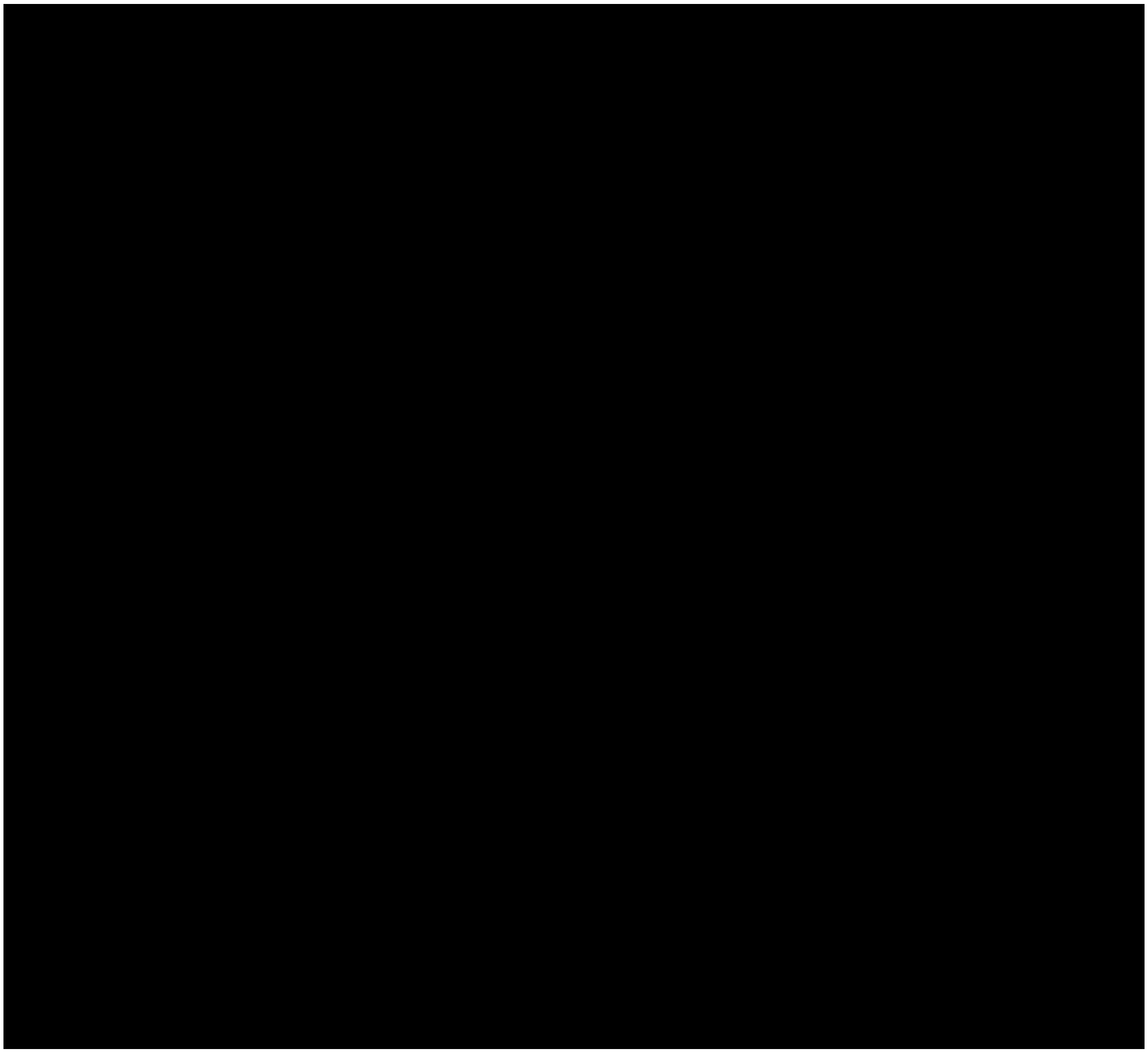

Figure 1.0 Building-Adapted Photovoltaic System Sites (Yellow)

Results:

Of the forty-two buildings examined, *Cornerstone*, *Hub*, *Origin* and *The Nest* showed the highest potential for building-adapted photovoltaic electricity production. These four buildings are south-facing, have low EUI’s due to geothermal or district heating, and have large flat roofs that can accommodate a sizeable number of panels.

Table 1.0 Building-Adapted PV Installation Sites

Site	Useable sqft	EUI (kWh per year)	Panel #'s	Electrical Output	Annual Output (kWh)	Electrical Consumption Reduction
Cornerstone	2474	716,746	142	37 kW	42,598	5.94%
Hub	1132	714,169	65	17 kW	19,457	2.72%
Origin	1433	430,922	82	21 kW	24,638	5.72%
Nest	1984	438,785	114	30 kW	34,194	7.79%

Opportunities:

With a combined potential photovoltaic electrical output of 120,887 kWh per year these four buildings are the best options currently available for installing building adapted photovoltaic arrays. By electing to install photovoltaic arrays on these buildings the trust is making an investment that will lower electricity rates for residents, reduce net electrical consumption and demonstrate UniverCity’s commitment to sustainable practices. Although these four buildings are the only currently feasible buildings, future developments may also prove to be viable, or designed specifically, for building adapted photovoltaic systems. If arrays were installed on these four buildings it is possible that future developments could be encouraged to incorporate photovoltaic arrays into building design; leading to more efficient arrays and further improving UniverCity’s reputation as a sustainable, environmentally conscious community.

Challenges:

The following factors outline why the other 38 buildings were not suitable for photovoltaic array installation. The ratio of building EUI and available roof surface area was the primary limiting factor. The high-rise condominium towers One University Crescent, Novo 1 & 2, Aurora, Altaire and Highland all have high electricity use intensities because of their high-density occupancy. Furthermore, the vertical orientation of these buildings means minimal roof surface area that could be dedicated to photovoltaic arrays and most roof areas are dedicated to mechanical units. For example the first tower of the Novo 1 development has 443 sqft of available roof surface area compared to Cornerstone's 2,474 sqft. This small photovoltaic array would not provide a significant reduction in electrical consumption hence, making the capital investment costs unjustifiable.

A second factor that limited photovoltaic feasibility was building spread. The Serenity and Verdant developments each have multiple detached buildings within their development parcels. Verdant's four buildings have an acceptable EUI to roof surface area ratio but skylights in the roofs and the spread of available roof surface area across four non-continuous surfaces reduces its potential electrical output and increases capital costs.

The Serenity development consists of 22 multi-unit townhomes with mixed shed and gabled roofs. The limiting factor of this development was roof type and sun exposure. Although photovoltaic modules could be installed on these roofs there is insufficient south-facing roof square-footage to produce electricity at a rate that would justify capital investment costs. Additionally the cost of 22 separate AC/DC inverters required to connect each of the 22 potential systems would unreasonably drive up installation costs.

Costs:

Capital costs were the driving force behind whether or not a building was deemed feasible for the installation of photovoltaic arrays. If it's not economical a photovoltaic system is not sustainable and no amount of positive public image is worth investing in a project that would take 50 years to pay off with only minimal returns. To understand the economic feasibility of installing photovoltaic arrays on each building the approximate capital investment costs were weighted against annual electrical cost savings to establish a return on investment timeline. This timeline, the time it would take for the arrays to producing electricity for free, determined whether or not the site made economic sense.

Table 2.0 Building-Adapted Photovoltaic System Costs

Sites	Annual Electrical Bill Savings	Capital Cost Estimate	AVG (Based on $4/watt)	ROI (Years)
Cornerstone	$3,406	$129,500-$185,000	$139,952	41
Hub	$1,554	$59,150-$84,500	$63,925	41
Origin	$1,972	$74,900-$107,000	$80,946	41
Nest	$2,734	$103,950-$148,500	$112,341	41

On average, the buildings examined had a return on investment timeline of 40 years, some were closer to 50. 40 years is a long time to wait for a capital benefit when compared to the 25-year performance warranty on 260w multicrystalline panels but panels being produced today are far exceeding projected performance declines. By the time the photovoltaic arrays are producing electricity for free, they will be doing so at a reduced but viable rate. For the total capital investment cost of $397,164 photovoltaic arrays could be installed on these four buildings with an expected total return on investment in approximately 40 years; at which point the arrays would produce electricity for free until they reach the end of their service life.

3.2 Ground-Mounted Photovoltaic Arrays

Three SFU grounds locations were analyzed to determine the opportunities, challenges and costs of installing ground-mounted photovoltaic arrays. They are all south-facing grass fields with the exception of Site 1, a leveled gravel lot. Each area was mapped to calculate its surface area. This information was used to estimate the number of photovoltaic panels that could be accommodated. The SFU Planning Department was consulted about these locations, but as this is a hypothetical analysis of solar electricity production potential, all sites were assumed to be undedicated and available for photovoltaic arrays.

Figure 2.0 Ground-Mounted Photovoltaic System Sites (Red)

Results:

The potential for photovoltaic electricity production at these sites is obviously extensive. Trees minimally obstruct each site, the topography is either flat or sloped to the south and their impact would only be aesthetic. Although each of these sites shows great electrical production potential Sites: 1 and 2 show the greatest potential. This is due to their large unobstructed surface areas, high solar exposure and location in unused areas of the SFU campus.

Table 3.0 Ground-Mounted Installation Sites

Sites	Useable Roof Surface Area	Panel #'s	Output (kW)	kWh Per year	Consumption Reduction
SFU 1	98,577	5,668	1,473	1,697,601	13.2%
SFU 2a	39,411	2,266	589	678,810	5.3%
SFU 2b	45,192	2,598	675	777,923	6.0%
SFU 3a	19,116	1,099	285	328,456	2.6%
SFU 3b	5,694	327	85	97,961	0.8%

Opportunities:

With a combined electrical output of 3.5 Megawatts (3,500,000 kW) these ground-mounted photovoltaic arrays could be one of the biggest solar power systems in British Columbia. Implementing ground-mounted photovoltaic arrays has the advantage of not being restricted by building design; this allows for more efficient array layouts and slightly lower installation costs when compared to building-adapted photovoltaic arrays. Dedicating these grounds locations to photovoltaic electricity production would benefit both the UniverCity community and the university. The large electrical production potential of these sites implies the community could see a significant reduction in their electrical rates and SFU would gain notoriety as a academic institution at the forefront of green living practices and sustainable development. In particular site 2 beside the Gaglardi Causeway would be one of the first things visitors and students see when they enter the campus; a strong visual statement of the university's and the trust commitment to using renewable energy.

Challenges:

The primary challenge to installing ground-mounted photovoltaic systems on these sites is securing the land. Approval of the project from the SFU Planning Committee and SFU Board of Directors would be required, further permits for multiple large-scale photovoltaic arrays would be needed from the City of Burnaby. There is potential for conflicting interests for the use of the proposed installation sites. Specifically the athletic facilities department has expressed interest in Site 1. These conflicting interests will require extensive consultation and success is not assured.

Photovoltaic arrays have a stark visual presence. This appearance has the potential to showcase SFU and UniverCity's commitment to renewable energy practices, but it could also be viewed as an eyesore that detracts from the intended master plan for the campus. Sites 2 and 3 are highly visible locations and will have a substantial aesthetic impact that will need to be assessed and possibly mediated.

Considering that the ground-mounted arrays will be in fields that are completely open to public access, security is also an issue. Vandalism or damage to the arrays could occur if fencing or another security measure is not provided.

Costs:

As with building-mounted photovoltaic arrays, capital cost is the primary limiting factor for the approval of ground-mounted arrays in these locations. In this scenario capital costs are higher but so are the returns. The return on investment timeline is shorter. Photovoltaic systems under 100 kW, like those proposed for the UniverCity buildings, are covered under BC Hydro's Net Metering program. However, the size of these ground-mounted arrays requires an IPP agreement with BC Hydro. This agreement is the mechanism that electricity produced by the arrays would then be sold to BC Hydro.

Table 4.0 Ground-Mounted Photovoltaic System Costs

Sites	IPP Profit	Capital Cost Estimate	AVG (Based on $4/watt)	ROI (Years)
SFU 1	$176,024	$5,941,603-$6,790,404	$6,366,003	36
SFU 2a	$70,405	$2,375,835-$2,715,240	$2,545,537	36
SFU 2b	$80,670	$2,722,730-$3,111,692	$2,917,211	36
SFU 3a	$34,010	$1,149,596-$1,313,824	$1,231,710	36
SFU 3b	$10,161	$342,863-$391,844	$367,353	36

Analysis reveals that with substantial annual returns generated through the IPP agreement, the ground-mounted sites would be able to begin generating electricity for only the cost of cleaning and maintenance after 36 years. This return on investment timeline is much nearer to the industry standard 25-year performance warranty of photovoltaic panels. Once capital investment has been repaid through IPP profits, the panels will still be operating at an acceptable level of efficiency with the potential to produce approximately $371,270 per year in revenue.

4.0 CONNECTING TO THE ELECTRICAL GRID

In order for a grid-tied photovoltaic system to connect to the municipal electrical grid the system has to enter into one of two agreements. These agreements ensure safe electrical production practices, provide a means of reducing electricity costs, or creating a profit for the proprietor, and would allow proper system monitoring. Currently in BC there are two programs that allow photovoltaic systems to be connected to the electrical grid: BC Hydro's Net Metering Program and BC Hydro's independent power producer electricity purchase agreement.

4.1 BC Hydro Net Metering Program

The program was created to support individuals who want to adopt renewable energy production while remaining connected to municipal electrical grids. Metering is done through the customers existing Smart Meter. The program operates such that electricity produced by either solar or wind is first used to offset the customer's consumption; then if the customer generates more electricity than they consume in one billing month, they receive a credit. At the end of the year if the customer has excess generation credits, BC Hydro makes a payout at a rate of 9.99 cents per kWh. To apply to the program customers need to complete an application providing: site information (location, service voltage), installer/contractor information, description of generator system (wind, solar, hydro) and specifications of the grid-tie inverter being used.

4.2 Independent Power Producer Electricity Purchase Agreement (IPP EPA)

BC Hydro created the IPP EPA program to meet electrical demand as the province's population and economy grows. It creates a diversified power supply network that supports innovative and sustainable energy generation projects. The agreement accomplishes this by providing an environment for independent power producers such as, private utilities, municipalities and private citizens, to sell clean and/or renewable energy without being exposed to market risks. BC Hydro eliminates these risks through the long-term price certainty of their standing-offer program.

Like the Net Metering program the Standing Offer program provides a means for clean and renewable energy projects to recoup their capital investment costs. However, the standing offer program operates on a profit for electricity and not on a reduced consumption/ generation credit basis. To apply a project must meet the following requirements:

- Producing clean or renewable energy.
- Located in British Columbia
- Larger than 0.1 MW and smaller than 15 MW.
- Target operation date within three years of signing the agreement.
- All material permits and approval of local land-use zoning.

Once all these requirements are met the project can be submitted and reviewed, and if approved an independent interconnection study must be undertaken before the EPA agreement is ratified.

An EPA agreement would allow the ground-mounted portion of the UniverCity solar project to become an IPP. Once plans for the arrays have been completed and approved, appropriate zoning and permits accepted, the project application would be sent to BC Hydro for approval. Upon approval the ground-mounted arrays would be connected to the municipal electrical grid and begin producing and selling electricity. Once the capital investment is repaid the array will produce a significant annual profit for the community.

5.0 OPERATION AND OWNERSHIP MODELS

Once the arrays are approved, and the funds to install them are secured, the question of who operates and owns the arrays arises. A definitive ownership and operations model is necessary to structure the responsibility for the arrays. A well-defined model will ensure adequate maintenance and that profits from the electricity produced are being used to benefit the community. This section details two potential operation and ownership models that could regulate the photovoltaic arrays installed on community buildings and university grounds.

5.1 An SFU/ UniverCity Operated Utility

In this model the SFU Community Trust would manage the installation and maintenance of the photovoltaic arrays. The model's mandate would be to ensure that the electricity produced by the arrays is used to offset the community's electrical consumption and electrical costs. The Trust would make the initial capital investment then pass service and maintenance costs onto residents. Once the investment is paid off residents will receive a reduction in their electricity bill via electricity sold to BC Hydro's Net Metering program and through an IPP agreement. As the procurement and installation mandate of the community Trust is completed, responsibility for the arrays would be transferred to the SFU Facilities Department. An SFU/ UniverCity operations and ownership model would create an institutionally based electrical utility, which over time and with potential expansion of the photovoltaic system, could receive a percentage of profits in the form of annual royalties.

The pros of this model are that all decisions are made "in-house", ensuring that the array operation will adhere to the mandate of benefitting the community and making UniverCity a more sustainable community. Additionally, profits made from the Net Metering program and IPP agreement would provide a new revenue stream for the university and the community. As an independent electrical utility SFU and the Trust would demonstrate their commitment to renewable energy and sustainable building practices, while generating a profit from electricity produced once the capital investment has been repaid.

The cons of this model are that the Trust and later on the SFU Facilities Department will have to accommodate the extra workload of maintaining and monitoring the photovoltaic arrays. Although the modules themselves do not require much maintenance beyond annual cleaning and adjustment a dedicated team of staff would still be required, requiring wages and training. This additional responsibility for the Trust/SFU takes away labour resources from other areas that may or may not impact the functioning of general SFU and UniverCity operations.

5.2 Privately Operated Utility

In this model a private utility company such as Corix would manage the installation and maintenance of the photovoltaic arrays. An agreement between the Trust and a private utility company would be signed that would stipulate: the utility's access to customers and publicity, contract length (20 years?), royalty percentage to the trust (3%?), and their revenue percentage (8%?). This model would be "selling the opportunity" to a private utility company. They get the benefits of long-term access to a stable customer base and a reputation as a company commitment to renewable energy.

The pros of this model are that it absolves the Trust and SFU of maintenance and operations responsibilities. Furthermore, the private utility company would be making the initial capital investment, which could speed up project timelines or make larger arrays more feasible. The Trust would effectively be selling the opportunity to be an IPP to a private utility company. In turn the Trust would receive an annual royalty percentage and community residents would have lower electricity rates. This model gives the Trust and the university the reputation of an environmentally conscious community and institution without the risk of investment and maintenance responsibilities.

The cons of this model are the Trust/ SFU will lose both decision-making power for the photovoltaic arrays and profits associated with their operation. The contract with the private utility will require a mandate to benefit the community but ultimately the company will make decisions based on their own bottom line and not the interests of the community. Additionally the royalty percentage gained from the private utility company will be significantly smaller than the possible revenue from directly owning and operating the arrays. In this model the Trust/SFU is trading profits for responsibility, less responsibility lower profits.

6.0 RECOMMENDATIONS

After reviewing relevant research, examining potential installation sites and consulting with solar industry experts the following recommendations emerged. These recommendations are not to be taken as exclusive or concrete and should be viewed as the first steps towards transforming UniverCity and SFU into a sustainable community powered by renewable energy.

6.1 Installation Sites

The research showed that of the current forty-two buildings in the UniverCity community only four were viable to accommodate photovoltaic array installations. Of those four only two are realistically feasible. The Cornerstone and Nest buildings are the best options for building adapted photovoltaic array installations currently available. Both buildings have large flat roofs capable of accommodating a large number of panels. Additionally both buildings do not use electrical baseboard heating, Cornerstone uses geothermal and The Nest uses the community's district heating. This drives down their respective EUI's and allows the electricity produced by the photovoltaic panels to have a significant impact on their overall electrical consumption. The other two viable buildings: The Hub and Origin, could both accommodate a reasonable amount of panels and have low EUI's, but they can not accommodate enough panels to produce electricity at a rate that would be worth the capital investment. The Cornerstone and Nest buildings are recommended for consideration for building-adapted photovoltaic array installation.

The research showed that of the three possible SFU grounds locations, the most feasible were Sites 1 and 2. Both of these locations have large, flat, south-facing surfaces that can readily accommodate a large number of photovoltaic panels. Out of all the locations and buildings examined for this report the SFU grounds Sites 1 and 2 are the best options for installing photovoltaic arrays on Burnaby Mountain. Sites 1 and 2 are strongly recommended for photovoltaic array installation. If approved these sites would have a significant impact on the electrical consumption of UniverCity and would be one of the largest photovoltaic systems in British Columbia; with the notable advantage of showcasing SFU's reputation as a sustainable, environmentally conscious institution and community.

6.2 Operations Model

As mentioned above both operations models have pros and cons. But the SFU/ Trust operated utility model offers a better return on the time and financial investment of installing photovoltaic arrays. Furthermore it presents a unique opportunity for the university and community to manage and monitor their own electrical production and consumption. It is recommend that the Trust/SFU operating and ownership model be adopted if photovoltaic arrays are approved for installation. The added maintenance responsibilities and financial risk are worth the benefits of controlling electrical production and consumption, and reaping the full amount of profits/electricity cost savings once the initial capital investment has been repaid. Additionally, the Trust/SFU operations and ownership model would keep decisions about the arrays "in-house" ensuring that any changes, updates or additions to the systems would always benefit the university and community. Though fully capable of taking on a photovoltaic array system, the private sector have less emphasis on achieving more esoteric community and climate change goals and objectives.

6.3 Next Steps

This report is hopefully the first step in powering UniverCity with renewable energy. There is a long road ahead before the community can truly benefit from producing their own electricity, but it will be worth the wait. The process of reducing electrical consumption from the municipal electrical grid is a gradual one, that will increase as more photovoltaic arrays are approved and installed within the community. Moving forward from this report, a list of logical next steps to help increase awareness and potential for solar power within the community is provided.

Currently UniverCity development phases 3 and 4 are under construction and because of this information on roof designs or their potential for photovoltaic electricity production was not available. It is recommend that this report be updated once all development parcels have been constructed so as to have a complete picture of UniverCity's potential for building-adapted photovoltaic arrays. There is a good chance that many yet-to-be-constructed buildings could have a high potential for accommodating photovoltaic arrays and could greatly increase the overall photovoltaic electrical production potential of the community.

In addition to re-examining the community's potential for photovoltaic electrical production it is recommend that developers be encouraged to incorporate photovoltaic arrays into building design; perhaps an incentive benefit could be negotiated. Roof structure plays a large role in determining a building's potential for solar so if developers are willing to design their buildings with solar in mind the potential for the community to produce solar electricity could increase.

The scope of this report was to examine UniverCity community buildings and SFU ground locations that could accommodate photovoltaic arrays. Examining SFU buildings for arrays was deemed unmanageable for the timeline of this project. It is recommend that south-facing SFU buildings like Convocation hall, the Maggie Benson building, Shrum Science building, and the Academic Quadrangle be examined for their capacity to install photovoltaic arrays. If approved SFU building-adapted photovoltaic arrays in combination with the installation sites highlighted in this report could produce a significant amount of electricity for both the institution and the surrounding community.

7.0 Closing Statement

This internship report was completed with the goal of providing the Trust with information about the feasibility and potential for photovoltaic arrays within the UniverCity community and to provide the writer with an opportunity to learn about the subject. As a student project, this report should not taken be as definitive. Any discrepancies in calculation or prediction are the result of the writer's recent familiarity with the subject. It is hoped that this report has illuminated Burnaby Mountain's potential for solar electricity production and that in the future the community and school will approve and invest in photovoltaic array projects. There is substantial potential for the university to demonstrate its commitment to sustainable development and green living practices. By adopting and installing photovoltaic arrays SFU could become one the foremost environmentally conscious universities in the country.

8.0 METHODOLOGY

This report was approached from a bottom-up perspective. Existing academic research was reviewed and solar industry consultants were contacted to establish a foundation for the challenges and opportunities of implementing photovoltaic arrays within the UniverCity community. The academic research illuminated global photovoltaic power production and technology trends, and local examples that situated the project; providing a realistic scope of what could be achieved and identify potential obstacles. Solar industry consultants filled gaps in the academic research. Their information proved invaluable to the creation of a comprehensive feasibility report.

Photovoltaic installation case studies of Australia's Queen's University, Portland State University and Kimberly's SunMine were examined to understand possible electrical outputs, consumption reduction percentages, operating models and expected returns on investments.

Once the foundation provided by the academic research, consultants, and case studies was established the building stock of the UniverCity community and SFU grounds locations were examined for their potential and cost of producing photovoltaic electricity. Each constructed development parcel in the UniverCity community had its Energy Use Intensity (EUI) calculated by taking the average kWh/ year of electricity used per square meter gained from the MURB Report and multiplying it against each building's Gross Floor Area to establish the number of kWh each building used per year. The available roof surface area of each building was calculated from their respective architectural drawings and the available area was used to estimate the number of 260W panels that could be mounted. The potential electrical output from the panels was calculated using PVlabs's calculation formula, factoring in weather and annual solar radiance. The potential electrical output of each building was compared to its annual electrical consumption and represented in a percentage annual electrical consumption reduction. For SFU grounds installation sites potential electrical output was compared to the total community load and represented in a percentage annual electrical consumption reduction. Lastly, the annual electrical bill savings for each building, and the whole community, was compared to the capital installation costs to determine a return on investment timeline.

From this research and these calculations the feasibility of the installation sites were assessed and recommendations of whether or not it makes sense to install photovoltaic arrays were made.

9.0 APPENDIX

Academic Articles:

- Critical factors affecting retrofitted roof-mounted PV arrays: Malaysian Case Study. (N.Z. Zakaria, H.Zainuddin, S. Shaari *Clean Energy and Technology 2013)*

- Analysis of the PV solar energy capacity of residential rooftops in Andalusia, Spain. (J. Ordonez, E. Jadraque, J. Alegre, G. Martinez 2010)

- Environmental payback time analysis of a roof-mounted BIPV system in Hong Kong. (L. Lu & H.X. Yang. 2010)

- Building-integrated photovoltaics in architectural design in China. (Changhai Peng, Ying Huang, Zhishen We 2011)

- Third generation photovoltaics. (Catchpole, K.R.; Green, M.A. 2002)

- Grid Connected Monocrystalline and Polycrystalline photovoltaic system: A comparative study on performance. (Z.M. Zain, M.I. Hussin, N.Y. Dahlan, L.A. Rimon 2013)

- Long-term Performance of Amorphous Photovoltaic Modules. (P. Vorasayan, T.R. Betts, R. Gottschalg, D.G. Infield 2006)

- First year performance monitoring of amorphous-silicon grid-connected PV system. (Hussin, Zain, Omar, Shaari 2013)
- Sector profile for solar photovoltaics in Canada. Canmet ENERGY. (2012) (Navigant Consulting)

- National Survey Report of PV power Applications in Canada (2013)

- International Energy Agency Annual Report on Photovoltaic Power Systems Program (2014)

- Energy Use in Mid to High-Rise Multi-use Residential Buildings (Builder Insight, technical maintenance bulletin)

Case Studies:

- T'sou-ke First Nation Reservation – Sooke, BC

- Central Park Strata Building – Victoria, BC

- St. Mary's Hospital – Sechelt, BC

- MINI Dealership – Richmond, BC

- SunMine – Kimberly, BC

- Queen's University – Brisbane, Australia

- Oregon State University

Industry Consultants: (Should they be included? Ask first?)

- HESPV – Victoria, BC

- Terratek – Lower Mainland