Green Energy Study for British Columbia
Phase 2: Mainland

Building Integrated Photovoltaic Solar and Small-Scale Wind

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1. Executive Summary

The solar energy resource in British Columbia is characterized by large variation between summer and winter. This characteristic of British Columbia weather makes grid-tie solar electric systems more efficient than off-grid systems since battery storage is not required and the energy generated by the system can be averaged over the entire year.

However, the low cost of utility electricity in British Columbia prevents grid-tied photovoltaic systems from being a viable economic choice unless other values can be obtained from the photovoltaic system. Using photovoltaic modules as building materials, Building Integrated Photovoltaics (BIPV) partially addresses this problem by reducing the overall cost of solar electricity and by providing other benefits such as:

- Acoustic insulation
- Thermal insulation
- Weather proofing
- Aesthetic building design
- Daylighting, shading and privacy

BIPV is a stepping-stone to broader acceptance of solar electricity since it provides other values besides energy generation. Aesthetic, social and environmental values are reflected in buildings that incorporate BIPV and the decision to use BIPV does not need to be justified on economics alone.

There are many methods of using BIPV in a building. BIPV roofing incorporates solar cells into conventional roofing products such as tiles or metal roofing. Glass based BIPV modules may be used in atria to replace overhead, semi-transparent glazing or in sunspaces, greenhouses and medium to large skylights. Curtain walls represent an even larger market for BIPV modules.

Promoting the use of BIPV systems in British Columbia requires the implementation of complementary programs. Foremost among these programs is net metering (or net billing), which allows consumer/generators to tie their system into the utility grid and sell the excess to the utility. Equally important is certification of equipment and the personnel that design and install photovoltaic systems. Finally, uptake by consumers of BIPV also requires education and marketing to promote the non-financial benefits of BIPV. Actual uptake will depend upon consumers' willingness to pay for non-financial benefits.

There are several non-financial benefits associated with BIPV and photovoltaic energy in general. Successful programs in the United States have shown that many residential customers are willing to pay a premium for their electricity if it is generated with environmentally sustainable technology. Customers benefit from the satisfaction they feel and the social status imparted by being a leader in their community.

BIPV is a highly visible indication of a company's commitment to social and environmental values. Commercial customers benefit from photovoltaic energy by associating their company or product with environmentally sustainable energy generation. BIPV also sets a commercial building apart visually, thus enhancing public exposure.

The environmental benefits of photovoltaic energy include green house gas reductions. A well-designed BIPV system in Vancouver will offset approximately 0.36 tonnes of CO_2 annually for every kW_{peak} of photovoltaic modules installed. This value assumes that the photovoltaic energy is displacing energy that would otherwise be generated from natural gas fired thermal plants.

The maximum potential generating capacity from residential BIPV on detached or semi-detached homes in British Columbia is estimated at 280 MW_{peak}. However, the economics of using solar electricity in BC are not favourable at the present time. The estimated levelized cost of generating photovoltaic energy in residential applications in BC is $0.92 to $1.09 per kWh assuming 0% inflation and a discount rate of 8%. Thus interest in residential BIPV will be limited to early adopters. A conservative estimate of uptake of 2.5% of consumers with suitable sites leads to a potential generating capacity of 7 MW_{peak}, which would produce approximately 7 GWh/year.

The maximum potential generating capacity from BIPV on commercial buildings in British Columbia is estimated at 160 MW_{peak}. The estimated levelized cost of generating photovoltaic energy in residential applications in BC is $0.44 to $0.68 per kWh assuming 0% inflation and a discount rate of 8%. A conservative estimate of actual potential again assumes an uptake of 2.5% of consumers and a small array of 2.5 kW_{peak}, which leads to a potential generating capacity of 4 MW_{peak}, which would produce approximately 2.6 GWh per year. The energy production relative to installed capacity of commercial systems is lower than for residential systems since commercial systems are assumed to be mounted vertically or horizontally rather than tilted for maximum energy collection.

Residential or small-scale wind power is much closer than photovoltaic power to being competitive with utility power in British Columbia, especially if suitable, high wind locations can be found. While it is difficult to predict the customer uptake of such systems, it is certain that the premium for producing this form of green energy will not deter customers who perceive social and environmental value in producing their own green energy. The potential for small-scale wind power production in BC has been estimated at 25 GWh/year based on 10kW installations at 1900 residential sites.

2. Introduction

The solar energy resource in British Columbia is characterized by large variation between summer and winter. This large variation is not a result of latitude but of the high degree of cloud cover in the winter. For example, in Vancouver, the average daily solar energy available in July is four times that of January.

This characteristic of British Columbia weather makes grid-tie solar electric systems more efficient than off-grid systems. Year-round, off-grid solar electric systems in British Columbia are difficult to design since it is not possible to store energy in batteries for more than a month or two and such systems often rely on fossil fuel generators for winter back up. Grid-tie solar electric systems, on the other hand, are not affected by this design constraint. The utility grid takes over the role of energy storage and effectively provides seasonal energy storage.

Although the high degree of winter cloud cover means Vancouver receives about one third less solar energy than, for example, San Diego, California, it is the low cost of utility electricity that that makes solar electricity so unattractive by comparison. A new application of photovoltaics called Building Integrated Photovoltaics (BIPV) partially addresses this problem by reducing the overall cost of solar electricity and by providing other benefits in addition to energy production.

BIPV is an excellent technology for on-site power generation and is an excellent way to increase the deployment of photovoltaic energy generation. BIPV incorporates photovoltaic modules directly into a building by replacing building materials such as roof tiles, curtain walls and rain screens with photovoltaic modules. BIPV makes solar electricity more attractive since part of the cost of the photovoltaic system is offset by the cost of the building material replaced by solar modules.

BIPV is a stepping-stone to broader acceptance of solar electricity since it provides other values besides energy generation. Aesthetic, social and environmental values are reflected in buildings that incorporate BIPV.

3. Opportunities for Solar Electric Energy in BC

3.1. Solar Photovoltaic Technology

Solar photovoltaic (PV) technology is the direct conversion of sunlight into electricity by solid-state semi-conductor diodes called photovoltaic cells. Silicon is the most common semi-conducting material used to make photovoltaic cells.

A single photovoltaic cell produces only a few watts, so solar photovoltaic modules are comprised of several photovoltaic cells laminated into a single unit. The voltage of the photovoltaic module depends on the number of cells connected in series, and the current is proportional to the surface area of the photovoltaic cells.

The most common solar module technology uses 200 to 300 μm thick wafers of crystalline silicon (c-Si) or multi-crystalline silicon (mc-Si), similar to the wafers used to manufacture integrated circuits. The manufacturing process for crystalline silicon solar modules consists of several steps including manufacture and testing of the cells, electrical interconnection of the cells and laminating them into a complete module.

Amorphous silicon (a-Si) is another photovoltaic technology that is gaining broad acceptance. Amorphous silicon is less efficient than crystalline technologies, but it has the advantage of using much less silicon. Amorphous silicon cells are deposited on a substrate such as glass or steel and are only 2 or 3 μm thick. Thin film technologies such as amorphous silicon hold the potential for low cost mass-produced solar modules.

Other thin film technologies have been commercialized for outdoor terrestrial applications in the past few years. These photovoltaic modules use semi-conductors such as Cadmium Telluride (CdTe), Cadmium Sulfide (CdS) and Copper Indium Diselenide (CIS). These technologies promise greater efficiencies than amorphous silicon but are still in the early stages of commercialization. [1]

Industry practice is to rate photovoltaic modules at Standard Test Conditions (STC). The power rating obtained at STC, is often referred to as the peak power of the module and is measured in peak watts (W_{peak}). This rating is useful for comparing one module to another, but does not reflect the actual performance of a photovoltaic module in the field.

3.2. Photovoltaic Market

Solar photovoltaic systems represent a $42 million industry in Canada. [2] Although the PV market in Canada is a small fraction of the worldwide $1.6 billion market, growth in Canada has kept pace with the rest of the world and module sales have increased, on average, by more than 20% per year for the past ten years. [2]

In 2000, 1.5 MW worth of modules were sold in Canada and of that, 2% of the modules were installed in grid-tie applications. Compared to the world market where grid-tie applications account for 31% of photovoltaic module sales, Canada’s photovoltaic market is still dominated by remote applications where photovoltaic energy is more cost effective than operating diesel generators or extending the utility grid [2,3].

Government programs that support greater use of photovoltaics helped increase the world market share for grid-tie applications to 31% from only 4.2% of sales in 1990.

These programs are designed to accelerate cost reductions in PV technology, reduce green house gas emissions and improve the position of the countries' domestic industries in the photovoltaic market.

The large number of government programs in other countries that support photovoltaic development has led to rapid growth of photovoltaic module sales of 30% per year in 2000. This trend is expected to continue for at least the next two to three years. [13]

3.3. Government Support for Photovoltaics

There are no Canadian government programs that specifically support BIPV at the present time. Two programs, the C2000 Commercial Building Program sponsored by Natural Resources Canada and the Commercial Building Incentive Program (CBIP) could be used to improve the return on investment for BIPV. So far no buildings have used photovoltaic systems under these programs.

The Canadian government recently launched a program that supports up to 25% of the equipment and installation costs of PV systems on government buildings. The program is part of the Renewable Energy Deployment Initiative (REDI), but it is restricted to Federal Facilities. Commercial photovoltaic systems are excluded from REDI because they can receive an accelerated capital cost allowance under Class 43.1 of the Income Tax Act. Class 43.1 allows taxpayers to deduct the cost of eligible equipment at up to 30 % per year on a declining balance basis. [19]

The CANMET Energy Technology Branch (CETB), a research and development arm of Natural Resources Canada, has programs that support renewable energy development in Canada. The Renewable Energy and Hybrid Systems Program, Renewable Energy for Remote Communities (RERC) Program and the Buildings and Renewables Program all support deployment of photovoltaic technologies.

Individual Provinces and Territories in Canada provide various types of support for photovoltaic technology. For example, the Renewable Energy Technology Conversion Assistance Program (RETCAP) provides financial assistance to residents of the Northwest Territories who want to install renewable energy systems. RETCAP is designed to support projects that do not qualify for REDI.

In British Columbia, the Social Service Tax Act provides an exemption for alternative energy generating material and equipment, including solar modules and other components of PV systems. [20] The British Columbia Government recently cancelled the BC Renewable Energy Technology Program, which supported demonstration projects of photovoltaic technology. [21]

3.4. Economic factors

3.4.1. BIPV

A rapidly growing opportunity for photovoltaic applications lies in using photovoltaic modules in place of conventional building materials. Part of the cost of the photovoltaic system is offset by the cost of the material replaced. BIPV products are high quality construction materials with warranties that match the lifespan of the solar cells. This must be kept in mind when comparing BIPV products with conventional building products.

BIPV Roofing is often a variation on the most durable roofing products such as metal roofing or fibre cement tiles. Table 1 shows typical costs of conventional roofing products that may be displaced by BIPV Roofing.

Table 1 – Roofing Material cost analysis

Roofing Material	Cost ($/m^2)
Asphalt	$2 to $10
Fibreglass	$10 to $15
Metal	$20 to $30
Slate	$45 to $60

In commercial buildings, the choice of exterior finishing materials is based on appearance. There is no payback or return on investment with these conventional building materials. BIPV curtain walls and exterior cladding perform the same functions as conventional materials and often have an architecturally appealing appearance.

The choice to use BIPV on a building should not rest solely on the expected payback; other architectural functions must be considered. Many high quality architectural finishing materials such as polished stone are more expensive than BIPV modules. However, these materials have different characteristics from glass and may not be directly replaceable with BIPV. Table 2 shows typical costs of conventional Curtain Wall infill materials that are similar to BIPV modules.

Table 2 – Curtain Wall Material cost analysis

Curtain Wall Material	Cost ($/m^2)
Clear Float Glass	$60
Laminated Glass	$95
Laminated/fritted Glass	$205

The low cost of utility electricity in British Columbia prevents grid-tied photovoltaic systems from being a viable economic choice unless other values can be obtained from the photovoltaic system. BIPV address this by using photovoltaic modules as building materials. Therefore, BIPV design allows solar modules to be used for:

- Acoustic insulation
- Thermal insulation
- Weather proofing
- Aesthetic building design
- Daylighting, shading and privacy
- Energy production

3.4.2. Grid-tie

Grid-tie systems are less expensive if the grid is used as storage instead of batteries. Batteries represent up to 20% of the cost of off-grid PV systems. If back-up power is not required in the event of a utility failure, a grid-tie system does not need batteries and excess energy generated by the system is exported to the utility grid.

Grid-tie photovoltaic systems operate more efficiently. All the energy produced by the solar modules is either used within the building or is exported to the grid for others to use. Off-grid systems on the other hand, must turn off the photovoltaic array if energy production exceeds demand and the batteries are full, thus reducing the total amount of energy produced by the system. Also, energy storage in batteries is only around 80% efficient, whereas a grid-tie system does not store energy and thus gains up to 20% in overall efficiency.

3.4.3. Net metering

Net metering is one method of allowing utility customers to use on-site power generation, such as BIPV, to reduce their energy consumption. Under net metering, a single, conventional meter is allowed to spin backwards when the customer's system produces excess power, and spin forward when the grid supplies supplemental power. Customers pay for their net consumption for a billing period and are charged for that consumption at retail rates. If energy production exceeds consumption, utilities may choose to carry a credit forward to the next billing period, refund the customer at wholesale rates or ignore any excess and zero the customer's account. The simplest interconnection arrangement for a grid-tie photovoltaic system is one that uses the existing bi-directional meters installed on most residences for net metering. Net metering makes PV generated electricity more valuable to customers, especially in residential applications where the peak load does not coincide with the peak energy production. The costs of implementing and administering net metering are much less than other metering options thus reducing the cost to the utility or the customer since no additional meters are required. Meter reading is performed in the same manner and a single account is maintained.

An alternative to net metering is net billing. Under net billing, two meters are used – one to measure the customer's gross consumption and the other to measure gross electricity production. The former is billed at current retail rates. The latter is credited at the utility's avoided cost, which is typically lower than bundled retail rates. Net billing is intended to provide a more realistic signal of the costs and benefits of renewable energy.

3.4.4. Cost of electricity

The equipment and installation costs for a PV system depend on the size or peak power rating of the system. Typical installed costs for a grid-tie system in British Columbia are about

\$10 000 per kW_{peak}. [4] A material credit for using BIPV modules can be used to reduce this cost depending on the building material being displaced. In some cases the cost of the BIPV modules is the same as the displaced material.

The cost of photovoltaic generated electricity is much greater than utility supplied electricity in British Columbia. In Vancouver, a 1 kW_{peak} system will produce about 900 kWh of electricity annually at a cost of \$0.44 to \$1.05 per kWh when financed over a period of twenty years. If a photovoltaic system is considered instead as an investment, the savings from annual electricity generation is equivalent to a non-taxable 0.5% to 2.0% annual return on investment.

In cases where commercial customers have a demand meter and are paying for peak demand, grid-tie PV systems can reduce the peak demand of the building. For example, a building with a properly designed PV array should produce at least 10% of its peak power rating during cloudy weather. This represents the worst-case condition where the peak demand coincides with cloudy weather. [5]

Thus, in addition to the kWh value of photovoltaic generated electricity, a building with a peak demand that occurs during the day will save at least \$3.32 to \$6.37 per month in demand charges for every 10 kW_{peak} of BIPV installed, depending on the maximum demand for the month. [6]

3.5. Social factors

There are several non-financial benefits associated with BIPV and photovoltaic energy in general. Experience in Sacramento, California with the PV Pioneers Program has shown that many residential customers are willing to pay a premium for their electricity if it is generated with environmentally sustainable technology. Customers benefit from the satisfaction they feel and the social status imparted by being a leader in their community.

There is a growing recognition that socially responsible companies provide a better return on investment, thanks to indices such as the Dow Jones Sustainability Index. Also, demand from investors for environmental and social reporting, as indicated by the rapid growth of environmental and ethical mutual funds, has pushed the issue of Corporate Social Responsibility (CSR) into corporate boardrooms. CSR as a business objective lends itself to BIPV. Not only can BIPV fit the requirements of a CSR program, it is a highly visible indication of a company's commitment to social and environmental values.

Commercial customers benefit from photovoltaic energy by associating their company or product with an environmentally sustainable energy generation. BIPV also sets a commercial building apart visually, thus enhancing public exposure. BIPV can be a feature of distinctive building design and fits in well with other green building features such as daylighting and energy conservation.

The Pembina Institute, in their 1998 report for Environment Canada, estimates that 14 Full Time Equivalent (FTE) jobs are created per million dollars invested in solar electricity generation. Thus, approximately 140 jobs are created for each MW_{peak} of solar photovoltaic systems installed.

There is no guarantee that the jobs created will only benefit British Columbians. Some of the jobs will be in research and development, manufacturing and distribution. However, system design, sales, installation and maintenance will create local jobs. [7]

3.6. Environmental factors

If the electricity produced by a BIPV system is assumed to offset new electricity generation from natural gas, 400 tonnes of CO_2 is offset for every GWh of electricity generated. [7] A well-designed BIPV system in Vancouver will offset approximately 0.36 tonnes of CO_2 annually for every kW_{peak} of photovoltaic modules installed.

The energy produced by a photovoltaic module depends on how it is used and where it is located. If good system design is assumed, photovoltaic modules recover the energy used in their production in two to four years and continue to produce clean, renewable energy for 20 to 30 years afterwards. [8]

BIPV modules generally have a better energy payback profile because most BIPV modules do not have aluminium frames. The aluminium frame accounts for about 6% of the energy content of a 75 watt (W) c-Si photovoltaic module and as much as 20% of a 40 W CIS module. [8]

There are toxic materials used in the manufacture of photovoltaic modules. For example, the solvents and etchants used to manufacture c-Si and mc-Si photovoltaic modules are the same as those used in the fabrication of micro-electronic devices. Recycling or reclamation mitigates the environmental impact of these materials. In addition, less toxic techniques and materials for cleaning and preparing solar cells can be adopted.

4. Solar Energy Resource in BC

Solar energy is a variable resource that depends on geographic location, season, time of day and weather patterns. The radiant energy per unit area, or insolation, expresses the solar energy available for conversion to electricity. Average insolation values, based on several years of weather records, are usually used to predict the output from a solar array.

Generally, the available solar resource is expressed in Peak Sun Hours. One peak sun hour is equivalent to $1kWh/m^2$ or $3.6\ MJ/m^2$ of solar energy striking the plane of a solar array. Environment Canada publishes average daily peak sun hour data for several locations. Monthly and annual averages are available.

The tilt of a photovoltaic array and its azimuth with respect to true south has an impact on the total energy collected by the array. In British Columbia, a solar array oriented due south with a tilt angle of 30° to 40° will receive maximum insolation. Charts showing the relationship between tilt and azimuth are given for two British Columbia cities.

4.1. Vancouver

The Annual Average Insolation in Vancouver for a surface tilted at 30° and oriented due south is 1380 Peak Sun Hours. [17] This value, along with Table 3, can be used to predict the electricity produced by a BIPV system with a fixed tilt and azimuth.

Table 3 – Relative Insolation values for Vancouver.

Azimuth	**Tilt Angle of Photovoltaic Array from Horizontal**			
	0°	**30°**	**60°**	**90°**
East	87%	80%	68%	53%
South East	87%	93%	85%	65%
South	87%	**100%**	94%	69%
South West	87%	97%	91%	70%
West	87%	85%	75%	59%

4.2. Prince George

The Annual Average Insolation in Prince George for a surface tilted at 30° and oriented due south is 1330 Peak Sun Hours. [17] Table 4 shows the effect of array orientation on potential energy production for a BIPV system in Prince George.

Table 4 – Relative Insolation values for Prince George.

Azimuth	Tilt Angle of Photovoltaic Array from Horizontal			
	0°	**30°**	**60°**	**90°**
East	84%	81%	74%	60%
South East	84%	95%	92%	74%
South	84%	**100%**	97%	77%
South West	84%	94%	90%	72%
West	84%	80%	72%	58%

4.3. Energy Production

Insolation varies throughout the year and Table 5 and Table 6 show the average daily insolation for each month in both Vancouver and Prince George. The tables show data for a PV array facing south at a tilt angle of 30°. Although this is the optimum orientation for maximum year round energy production, other tilt angles will increase energy production at certain times of the year, while decreasing it at other times.

For example, a vertical array of solar modules produces more of its total annual energy production in the winter than an optimally tilted array, but at the expense of producing less energy during the summer. Thus energy production can be maximized for particular times of the year. Additionally, if the orientation of the array is shifted to the east or west, energy production can be optimized for particular times of the day. Utilities with a summer afternoon peak load, such as the Sacramento Municipal Utility District often encourage west facing PV arrays to offset their peak demand.

Table 5 – Monthly average daily insolation for Vancouver [kWh/m^2]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1.3	2.4	3.5	4.7	5.7	5.7	6.3	5.5	4.8	2.8	1.6	1.1	3.8

Table 6 – Monthly average daily insolation for Prince George [kWh/m^2]

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1.6	2.6	3.7	4.9	5.4	5.6	5.8	5.2	3.8	2.6	1.5	1.2	3.6

5. BIPV Technology

BIPV technology is a relatively new application of PV and many companies are involved in research and development to create products that are compatible with existing building materials and techniques.

Solar modules and cells are usually priced in dollars per peak watt ($\$/W_{peak}$). Cost per square meter ($\$/m^2$) is a more useful measure for BIPV products therefore the price ranges shown in Table 7 show both values. The cost per square meter depends on the cell packing density, relative transparency and the cell efficiency of various modules.

This report distinguishes between residential BIPV applications and commercial applications. Aside from building size limitations that limit residential BIPV to less than 10 kilowatts, BIPV systems on private residences are usually installed on the roof, since overhead glazing and curtain walls are not a typical feature of these buildings. Inverter choice is also constrained by the building type. The electrical service to a residence is usually 120/240 V single phase versus the three phase systems in commercial buildings.

5.1. Roofing Materials

Residential BIPV products are limited mainly to roofing materials as the roof presents the greatest surface area on most residential buildings suitable for PV. PV is often installed over an existing roof in residential applications, but the use of BIPV materials offers the opportunity for cost savings. [14]

Historically, the roof is the preferred location for solar photovoltaic modules in residential applications. The conventional procedure is to mount standard modules on racks a few inches above the conventional roofing material. The cost of installing a stand-off, rack mounted photovoltaic array is comparable with that of a roof integrated photovoltaic array. However, the roofing material displaced by an integrated array makes the integrated array less expensive. [14]

The most popular approach to BIPV roofing incorporates solar cells into conventional roofing products such as tiles or metal roofing.

- Atlantis Energy Systems Inc. manufactures, Sunslates®, one of the best-known solar roofing products. Sunslates® are a fibre-cement roof tile, manufactured by Eternit, with six solar cells laminated behind a hardened glass cover. Each tile is rated at 17 W. The newest Sunslates® are anti-glare with dark c-Si cells that make them look like grey slate. A 6 KW_{peak} Sunslates® roof installed by an experienced contractor requires 72 person hours. [15]
- Four BIPV roofing products that use United Solar Systems Corp. triple junction a-Si technology are available in North America. Bekaert ECD, a joint venture between N.V. Bekaert S.A. and United Solar, manufactures the SHR 17 solar shingle, a 17-W flexible BIPV module that integrates with asphalt shingles or slates. They also manufacture two variants of BIPV Standing Seam Roofing (SSR) panels and a field applied BIPV roofing laminate that is applied to conventional standing seam roofing panels. These products are available as 64 W and 128 W BIPV modules. Installation is the same as regular roofing with all the electrical connections made inside the building.

- PowerLight Corporation manufactures PowerGuard® tiles. The tiles incorporate PV cells backed with insulating polystyrene foam. The BIPV modules produce electricity in addition to increasing building thermal insulation and extending roof life. No roof penetrations are required and they can be applied to new roofs or as a retrofit over existing roofs.

5.2. Glazing and Facades

Glass based photovoltaic modules are readily integrated into new or existing buildings. The only difference is the electrical wiring that must be accommodated in the glass framing. BIPV modules used to replace glazing are very similar to laminated glass. Two layers of glass are used to encapsulate the PV cells. In this configuration, where there is no frame surrounding the module, the BIPV modules are referred to as laminates.

BIPV modules may be used in atria to replace overhead, semi-transparent glazing or in sunspaces, greenhouses and medium to large skylights. Atrium systems potentially provide the best value of all BIPV systems. Such systems benefit from:

- Potentially optimal orientation of the PV array.
- No additional costs for mounting structure or installation as the PV modules directly replace the laminated glass.
- A high material credit for replacing laminated glazing.

Diffuse daylighting is desirable in overhead glazing installations and many off-the-shelf photovoltaic modules are suitable for this type of installation. [5]

Curtain walls represent an even larger market for BIPV modules. Curtain walls often have opaque surfaces (spandrel area) where opaque PV modules may be used. Most PV modules are opaque and there is, therefore, a wide range of products that may be used in spandrel areas. Although there are no PV modules that can be used in vision areas of a curtain wall, semitransparent modules may be used to replace some of the glazing in the vision areas of a curtain wall to reduce heat gain and glare or to enhance privacy.

Laminates and conventional framed PV modules are also used in rainscreen cladding systems. Rainscreens normally consist of panels made from various opaque materials set slightly off from the building on rails to allow for drainage and ventilation. The rainscreen cladding does not provide the primary weather barrier and does not need to be sealed as with curtain walls. The ventilation gap behind the rainscreen makes this type of system ideal for photovoltaic applications as it provides room for wiring and reduces the temperature of the PV modules. [18]

Manufacturers of architectural glass and glass products have demonstrated the best ability to produce BIPV modules that meet the structural requirements of BIPV construction. These manufacturers use either multi-crystalline or mono-crystalline cells from various manufacturers:

- OPTISOL® from Flabeg is a double glazed structure with integrated solar cells. The elements can be combined with all regular glass structures and can be used for a variety of applications such as curtain wall cold facades, warm facades, insulating and shading glazing, in roofs, winter gardens and facades or as complex/costly structural glazing construction.

OPTISOL® elements are available from 200 mm x 200 mm to 2000 mm x 3000 mm, the adjustable light permeability (varying cell spacing) as well as the possibility of using solar cells from different manufacturers allow for a variety of photovoltaic applications in facades and roofs.

- PROSOL® from Saint-Gobain Glass solar is a glass product that consists of two pieces of heat-reinforced glass. The exterior pane is normally low iron glass, in order to obtain the highest possible transmission of energy. The maximum dimensions are 2000 mm x 3210 mm. SGG PROSOL® can be installed on roofs and facades. Insulating glass can be installed behind the solar glass allowing light to enter the building.

Manufacturers of conventional modules have also entered the BIPV glazing market.

- BP Solar produces two versions of their Power Wall which is based on the Kawneer 1600 curtain wall system. The glazing used in the Power Wall is either an unframed laminate version of their Mega® multi-cyrstalline module series, or laminate versions of their a-Si Millenia® module series. Module sizes are more restricted since these products are based on standard modules.
- Terra Solar is a US manufacturer of a-Si PV laminates developed by EPV. These are tandem junction a-Si modules. The modules come in limited sizes, but more than one a-Si laminate can be incorporated in a glazed unit.

5.3. Glazed roofs

Several manufacturers in Europe, Japan and Australia produce framing systems for integrating photovoltaic module laminates into roofs. Most of these types of systems use aluminium extrusions to hold the photovoltaic laminates in place. The extrusions are similar to those used in sloped glazing for atria or sunspaces, but they are usually designed to attach directly to the roof structure and are not intended to span large areas.

These framing systems either provide a waterproof barrier that attaches directly to the roof with the PV modules installed above, or the modules and frames are sealed into a single unit that acts as the weather barrier. The systems with a separate waterproof barrier have the advantage of allowing ventilation behind the modules. [13]

5.4. Inverters

Residential buildings generally have split phase 120/240 V service and there are several grid-tie inverters capable of interconnecting at this voltage. There are five manufacturers supplying the North American market with inverters suitable for residential applications.

Many commercial buildings have three phase 120/208 V service. This means smaller commercial systems can use inverters designed for 120 V single-phase residential service. However, there is a choice of inverters manufactured by Xantrex Technologies, Inc. designed for larger PV arrays that produce three-phase 208 VAC power.

Table 8 summarizes the inverters that are presently available in North America. The range of prices reflects wholesale and retail prices.

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5.5. BIPV Product Summary

Table 7 – BIPV modules available in North America

Roofing products	Unit Size	Cost ($/$W_{peak}$)	Cost ($/$m^2$)
UniSolar® SSR Panels	64 and 128 W	$8 to $12	$450 to $600
UniSolar® SHR shingles	17 W	$13 to $16	$600 to $750
PowerGuard® ballast roofing	variable	N/A	N/A
Atlantis SunSlates® tiles	17 W	$7 to $10	$1300
Glazing elements			
Saint-Gobain c-Si and mc-Si	variable	$8 to $12	$800 to $1200
Flabeg Solar c-Si and mc-Si	variable	$8 to $12	$800 to $1200
Terra Solar a-Si	40 W	$4 to $7	$360 to $500
BP Solar MSX laminates	variable	$6 to $10	$600 to $800
BP Solar Millenia a-Si	43 W	$5 to $9	$400 to $660

Note: Module prices vary depending on quantity ordered, exchange rate and supplier.

Table 8 – Grid-tie Inverters available in North America

120/240 V split phase service	Unit Size	Cost ($/kW)
Xantrex SW Series	4 kW and 5.5 kW	$990 to $1400
Xantrex SunTie	1 kW to 2.5 kW	$1270 to $3000
Vanner RE24-4500DGT (SunLynx)	4.5 kW	$1330 to $1550
SMA Sunny Boy 2500	2.2 kW	$1440 to $1800
Advanced Energy GC-1000	1 kW	$2400 to $2830
Advanced Energy Multimode PCS	3 kW and 5 kW	$1700 to $3100
Omnion Series 2400	4 kW and 6 kW	$1400 to $2260
120/208 V three phase service		
Xantrex PV series	10 kW to 500 kW	$580 to $1350
Xantrex SW Series Three Phase	12 kW and 16.5kW	$1400 to $2050

Note: Some inverters require additional isolation transformers and switchgear.

5.6. The Future of BIPV

5.6.1. BIPV Modules

There are many other BIPV roofing products available in Europe. These products have not reached the North American market, but as demand increases manufacturers are certain to introduce them here. Some roof-tile manufacturers produce versions of their roof tiles that allow specially designed solar modules to be snapped in place after the roof is assembled. This allows flexibility in choosing the size of a photovoltaic array, since more modules may be added to the roof later. In other cases, photovoltaic module manufacturers are assembling modules that are the same size and shape as an existing roof tile so that the modules completely replace the original roof tiles. [15]

Several curtain wall manufacturers are working with photovoltaic module manufacturers to develop fully integrated BIPV curtain walls, with pre-wired framing. Once these products enter the market it will be possible for architects to specify a curtain wall that can accept either BIPV laminates or conventional glass. Additionally, it will allow developers to specify a curtain wall without BIPV, yet upgrade the wall to BIPV later if it is desired.

5.6.2. Grid-tie inverters

Micro-inverters are a type of grid-tie inverter with limited market penetration in North America. These inverters are small, usually less than 500 W, and are mounted directly on a solar module or in close proximity to it. This type of inverter reduces the amount of DC wiring and protective equipment used in a photovoltaic installation. Shott/Applied Power distributes a 300 W AC module called the SunSine AC.

Inverter manufacturers are developing new products to compete in the rapidly growing North American grid-tie photovoltaic market. Omnion has UL certification pending for two new residential inverters for photovoltaic applications. The Series 2500 Inverter from Omnion will be available as a 1kW or 2kW single-phase 120VAC inverter. Omnion also has new 50 kW and 100 kW industrial photovoltaic power converters designed for 480VAC three-phase service.

5.6.3. Costs

The trend in photovoltaic technology for the past 20 years has been for the price of modules to decrease by 20% for each doubling of total sales. If this trend continues and annual production continues to increase by 20%, photovoltaic technology prices will decrease by 50% within a decade. The break-even point for current PV technology to compete with conventional electricity generation at existing price levels is expected to occur between 2020 and 2030. [13]

6. Development Plan for BC

6.1. Programs in other jurisdictions

Many jurisdictions in the United States and Canada have implemented programs to support the deployment of renewable energy technology. These programs have been implemented both by utilities and by various levels of government. Examples of programs implemented or supported by utilities are outlined below.

6.1.1. Net Metering Programs

As discussed earlier, net metering allows for the flow of electricity both to and from the customer through a single, bi-directional meter. The customer uses excess generation to offset electricity that would have been purchased at the retail rate. This may be thought of as analogous to installing energy efficiency devices that reduce electricity consumption.

Toronto Hydro Energy Services Net Billing

Through this program, a customer can install solar/wind power on their property and receive credit for any excess power produced. Excess energy reduces the overall energy bill by running the meter backwards to a maximum of reducing the bill to zero.

Toronto Hydro Energy Services Inc.
777 Bay Street, Suite 423
Toronto, Ontario M5G 2C8
Tel: (416) 542-3200
Email: custmail@torontohydro.com

Los Angeles Department of Water and Power Net Metering

The Los Angeles Department of Water and Power (LADWP), offers net metering to residential and commercial customers generating less than 10 kW.

Walter Zeisl
Los Angeles Department of Water & Power
111 North Hope Street
Los Angeles, CA 90051
Tel: (213) 367-1342
Email: info@greenla.com
Website: www.greenla.com

6.1.2. Contractor Licensing, Certification and Accreditation

Many jurisdictions have rules regarding the licensing of renewable energy contractors to ensure that contractors have the necessary experience and knowledge to properly install systems. Some are developing programs that can be accredited through the Institute for Sustainable Power (ISP). ISP has been working on a global accreditation program for PV training programs since 1996. The program for North America is administered by the North American Board of Certified Energy Practitioners (NABCEP), which was created by ISP, the Interstate Renewable Energy Council, and the Florida Solar Energy Center.

To further extend the acceptance of the accreditation program, ISP is also working with the National Joint Apprenticeship and Training Committee (NJATC)

Institute for Sustainable Power
P.O. Box 260145
Highlands Ranch, CO 80163-0145
Website: www.ispq.org

Interstate Renewable Energy Council
POB 1156
Latham, New York, 12110-1156
Tel: (518) 458-6059
Email: info@irecusa.org

New York Solar Practitioner Certification & Accreditation

A 3-day photovoltaics course covers the essential elements of system design, site assessment, wiring DC circuits, inverter selection, and interconnection.

Joel Gordes
New York Solar Energy Industries Association
PO Box 101
Riverton, CT 06065
Tel: (860) 379-2430
Email: jgordes@earthlink.net

California Solar Contractor Licensing

The California Contractors State License Board administers the Solar Contractor license (C-46). Requirements include four years experience and the passing of both trade and law exams. Independent license schools offer courses to prepare for license exams.

Les Nelson
California Solar Energy Industries Association
Southern California Office
23120 Alicia Parkway, Suite 107
Mission Viejo, CA 92692
Tel: (714) 586-2470
Fax: (714) 586-2357
Email: lnelson@westernrenewables.com

6.1.3. Equipment Certification

Statutes requiring renewable energy equipment to meet certain standards are generally seen as a tool for reducing the chance that consumers will be sold inferior equipment.

Beyond being a consumer protection measure, equipment certification benefits renewables by reducing the number of problem systems and the resulting bad publicity.

California Equipment Certification

The California Emerging Renewables Buy-Down Program requires the entire solar energy system and installation to be certified as eligible. The Energy Commission maintains a list of components and systems that meet the required standards of the program. The system must come with a minimum five year parts and labour warranty against breakdown or unusual degradation.

Marwan Masri
California Energy Commission
Renewable Energy Program
1516 9th Street
Sacramento, CA 95814
Tel: (916) 654-4531
Fax: (916) 654-8251
Email: mmasri@energy.state.ca.us
Website: www.energy.ca.gov/greengrid/equipment.html

6.1.4. Green Pricing Programs

Green Pricing allows retail electricity customers to purchase electricity generated with environmentally sustainable technology. Existing programs in Canada use wind power as the generating source, but other technologies are under development. Potentially, green pricing programs allow customer/generators to receive a premium for electricity generated from renewable sources.

ENMAX Greenmax program

ENMAX provides an alternative to customers called Greenmax. The voluntary program allows customers to choose a monthly premium of $5, $10 or $15 to support wind-generated power for as much as 45 per cent of an average home's monthly energy consumption.

ENMAX Corporation
2808 Spiller Road S.E.
Calgary, AB T2G 4H3
Tel: (403) 310-2010
Fax: (403) 514-2165

BRITISH COLUMBIA
INSTITUTE OF TECHNOLOGY
A POLYTECHNIC INSTITUTION

Los Angeles - Green Power for a Green LA

Green Power for a Green LA, initiated by the Los Angeles Department of Water and Power (LADWP) in 1999, is the United States' largest effort of its kind by a local utility. The program has more than 75,000 customers.

The Green Power program allows all LADWP customers to participate and offers 100% renewable energy with 20% coming from new sources. The premium for green power is 6% with the average residential customer paying approximately $3 a month. LADWP helps homeowners offset the increased cost of green power by providing two free compact fluorescent light bulbs and a free home energy audit.

Walter Zeisl
Los Angeles Department of Water & Power
111 North Hope Street
Los Angeles, CA 90051
Tel: (213) 367-1342
Email: info@greenla.com
Website: www.greenla.com

6.1.5. Rebate Programs

Rebate programs are offered at the state, local, and utility levels to promote the installation of renewable energy equipment. The majority of the programs are available from state agencies and municipally owned utilities and support solar water heating and/or photovoltaic systems. Eligible sectors usually include residents and businesses, although some programs are available to industry, institutions, and government agencies as well. In some cases, rebate programs are combined with low or no-interest loans.

Glendale Solar Electric Rebate

Glendale Water & Power (GWP) is a municipally owned utility that provides residential electric customers a rebate for photovoltaic (PV) installations. The one-time rebate is $3 per W up to 10,000 Ws. Funding for this rebate is $150,000, which comes from a portion of the 2.85 % surcharge residents pay on their monthly utility bills.

Customer Service – GWP
Glendale Water and Power
141 North Glendale Avenue, CA
Tel: (818) 548-3300
Fax: (818) 240-9418
Web: www.ci.glendale.ca.us/government/gwp_efficiency/gwp_programs.html

Los Angeles - Residential and Commercial PV Buydown Program

The program began September 1, 2000 and will continue for 5 years. LADWP has earmarked $6 million for the program's first year. Each of the following four years has funds reserved at a minimum of $8 million. LADWP's goal is to have 100,000 systems on rooftops in LA City by the year 2010.

The financial incentives include a maximum of $3/W for systems manufactured outside the City of Los Angeles, and a maximum of $5/W for those manufactured within the City. The maximum payment per site is $50,000 for residential and $1 million for commercial customers.

Solar Program Information
Los Angeles Department of Water & Power
111 North Hope Street
Los Angeles, CA 90051
Tel: (800) 473-3652
Email: info@greenla.com
Website: www.greenla.com/solar/incentives

Tucson Electric Power (TEP) SunShare PV Buy-down

Customers may either purchase a qualifying system of 1 kW or larger from a third party or may purchase a 1 kW or 5 kW system kit from TEP. Under the third party option, TEP will pay the customer $2,000 per AC kW of installed solar generating capacity. Under the TEP kit option, TEP will pay the customer $2,000 for the 1 kW system and $10,000 for the 5 kW system. The kit includes panels, inverter, supports, meter, and meter socket.

Chuck DeCorse
Tucson Electric Power
SunShare
P.O. Box 711
Mailstop RC116
Tucson, AZ 85702
Tel: (520) 745-3251
Fax: (520) 571-4014
Email: cdecorse@tucsonelectric.com
Web site: www.greenwatts.com

6.1.6. Equipment Sales and Leasing

A few utilities sell renewable energy equipment to their customers as part of a buy-down, low-income assistance, lease, or remote power program. Utility leasing programs target remote power customers for which line extension would be very costly. The customers can lease the technology, from the utility, and in some cases, the customer can opt to purchase the system after a specified number of years.

Sacramento - PV Pioneer II

The Sacramento Municipal Utility District (SMUD) offers a buy-down program to encourage customers to purchase their own PV systems. This program allows customers to purchase installed roof-mounted PV systems from the utility for less than $5,000. SMUD buys down about half the cost of the system, and then provides a financed loan to cover the balance. The loan is repaid over a period of ten years. Both traditional PV modules and building-integrated PV "roof shingles" are available under the program. Customers receive net metering.

Don Osborn
SMUD Solar Program
Sacramento Municipal Utility District
PO Box 15830, MS-A401
Sacramento, CA 95852-1830
Tel: (916) 732-6679
Fax: (916) 732-6423
Email: Dosborn@smud.org
Website: www.smud.org

Plumas-Sierra REC - Geothermal and Photovoltaic Leasing Program

Plumas-Sierra Rural Electric Cooperative offers a two-part leasing program. The first part of the program leases heat pumps to customers for a 30 year period at no interest. The second part of the program leases PV equipment to residential customers. Participants pay a monthly charge for operation and maintenance costs. The lease period is 15 to 20 years.

Nell Thomas
Plumas-Sierra Rural Electric Cooperative
73233 Highway 70
Portola, CA 96122
Tel: (530) 832-4261
Fax: (530) 832-5761
Website: www.psrec.org

6.1.7. Renewables Portfolio Standards/Set Asides

Renewables Portfolio Standards (RPS) require a certain percentage of a utility's overall or new generating capacity or energy sales to be derived from renewable resources. Portfolio Standards most commonly refer to electric sales measured in MWh, as opposed to electric capacity measured in MW. The term "set asides" is frequently used to refer to programs where a utility is required to include a certain amount of renewables capacity in new installations.

Ontario Power Generation Evergreen Energy program

OPG created a new operating unit, OPG - Evergreen Energy, to develop its renewable energy portfolio. By 2005 OPG will invest $50 million in renewable energy technologies to increase its green power capacity to 500MW.

Pat Anderson
Ontario Power Generation
700 University Avenue
Toronto, Ontario M5G 1X6
Tel: (416) 592-2555 or 1-877-592-2555
Email: pat.anderson@opg.com

6.1.8. Generation Disclosure

"Disclosure" typically refers to the requirement that utilities provide their customers with additional information about the energy they are supplying. This information often includes fuel mix percentages and emissions statistics. Fuel mix information, for example, can be presented as a pie chart on customers' monthly bills.

Ontario Electricity Facts Label

The Ontario government introduced the Electricity Facts Label as a tool to help consumers better understand the environmental factors that figure into their electricity supply. All companies that deliver electricity in Ontario must provide customers with an Electricity Facts Label showing Ontario's average electricity generation mix. A retailer offering environmentally friendly electricity must provide this label, along with the proportions of their power sources, so that consumers can compare their mix to Ontario's average generation mix.

6.1.9. Loan Programs

Loan programs offer financing for the purchase of renewable energy equipment. Low-interest or no-interest loans for energy efficiency are a very common strategy for demand-side management by utilities. Some governments also offer loans to assist in the purchase of renewable energy equipment.

6.1.10. Government Programs

Construction and Design Policies

Construction and design policies include state construction policies, green building programs, and energy codes. State construction policies are typically legislative mandates requiring an evaluation of the cost and performance benefits of incorporating renewable energy technologies into state construction projects such as schools and office buildings. Local energy codes are used to achieve energy efficiency in new construction and renovations by requiring that certain building projects surpass state requirements for resource conservation. Incorporating renewables is one way to meet code requirements.

Tax Incentives

Corporate tax incentives allow corporations to receive credits or deductions against the cost of equipment or installation to promote renewable energy equipment. In some cases, the incentive decreases over time. Some governments allow the tax credit only if a corporation has invested a certain dollar amount into a given renewable energy project. In most cases, there is no maximum limit imposed on the amount of the deductible or credit.

Many states offer personal income tax credits or deductions to cover the expense of purchasing and installing renewable energy equipment. Some states offer personal income tax credits up to a certain percentage or predetermined dollar amount for the cost or installation or renewable energy equipment. Credits may be limited to a certain number of years following the purchase or installation of renewable energy equipment.

Property Tax Incentives

The majority of the property tax provisions for renewable energy follow a simple model where the added value of the renewable energy equipment is not included in the valuation of the property for taxation purposes.

Sales Tax Incentives

Sales tax incentives typically provide an exemption from the state sales tax for the cost of renewable energy equipment. British Columbia already exempts renewable energy equipment from Provincial Sales Tax. [20]

6.2. Programs for BC

6.2.1. Net Metering

Net metering or net billing is an essential first step for the development of grid-tied renewable energy. Net metering programs reduce the cost of implementing grid-tied renewable energy systems, improve the return on investment and indicate support from the utility for such systems. Furthermore, net metering programs can reduce the time and administrative costs of connecting renewable energy systems to the utility grid.

Net metering is a customer-driven mechanism for supporting renewable energy deployment. Most of the costs associated with generating renewable energy are borne by the customer and it is up to the customer to weigh the social, environmental, and marketing benefits of installing a renewable energy system.

6.2.2. Contractor certification

Certification is intended to ensure quality design and installation of renewable energy systems and to assure consumers that the installer has the knowledge and skills to install a safe and reliable renewable energy system. Any program to promote the use of renewable energy should include some means of ensuring quality design and installation.

Although there is a perception of certification as unnecessary regulation and bureaucracy, experience in the United States has shown that both a photovoltaic designer and an electrician are required for the installation of safe, reliable systems. [23] Licensed electrical contractors in British Columbia are considered qualified to install solar electric systems. However, many contractors are not familiar with the DC portions of the electrical code and these systems may fail to conform to the electrical code when installed by untrained contractors. Furthermore, few electricians have the experience or training to design or evaluate a photovoltaic system and the performance and reliability of such systems may be compromised if a competent designer is not involved. [23]

The Canadian solar industry is considering whether to adopt the voluntary certification program put forward by the North American Board of Certified Energy Practitioners (NABCEP). NABCEP offers three distinct levels of certification: system designer, system installer, and code official/inspector. The first phase is focused on certification for grid-tie photovoltaic systems and the goal is for the certification to be used by public administrators and regulatory officials as the basis for licensing requirements. [22] Alternatives to NABCEP include industry certification by manufacturers or the development of local certification or licensing programs.

6.2.3. Equipment certification

Equipment certification programs streamline the process of choosing and getting approval for a grid-tie renewable energy system. In its simplest form, equipment certification is a list of pre-approved equipment that a utility will allow to be connected to its distribution system. Provisions for certification of systems, such as requiring warranties and even performance guarantees, are a means of ensuring that the objectives of a program to promote the deployment of renewable energy systems are met and that consumers are satisfied with their systems.

6.2.4. Renewable Portfolio Standards

BC Hydro has already made a commitment to producing 10% of its new electricity generation from renewables.

6.2.5. Education

Education and marketing play an important part in establishing a high rate of participation in renewable energy programs. The Sacramento Municipal Utility District (SMUD) PV Pioneers program has been very successful due to an approach that incorporates several of the programs discussed here, not least of which is a very aggressive marketing and education campaign. [http://www.smud.org/pv/]

An initiative by BC Hydro to promote distributed generation with BIPV could draw upon experience from the existing BC Hydro Power Smart program.

6.2.6. Green Pricing

Green Pricing is already used in some jurisdictions in Canada for the retail sale of electricity generated by renewable technology. In theory, generators of renewable energy could receive a portion of the premium paid by green energy consumers. This would be a greater incentive than net metering, however, it would be technically more difficult to implement. Alternatively, some jurisdictions offer a premium for energy that is generated with renewable energy. Recently the government of Canada announced an incentive for wind power, whereby wind energy generators will receive an additional $0.012/kWh for energy generated from wind power.

6.2.7. Other Programs

It is possible other programs such as rebate programs, financing programs or equipment sales and leasing programs could be implemented in British Columbia. However these types of programs would require a greater financial commitment either from the utility or government and such incentives would also require careful analysis of both the short term impact on the renewable energy market as well as the long term impact when the subsidies and rebates are removed.

6.3. BIPV potential in BC

6.3.1. Residential BIPV

The potential for BIPV on residential buildings is not limited to new home construction, although new construction offers the best economics for BIPV. Re-roofing of existing homes and additions such as atriums or covered sun decks are potential applications for BIPV on residences. This report considers residential BIPV applications for single family, detached or semi-detached homes. Although apartment buildings represent 32% of private dwellings in British Columbia [9], the high percentage of renters living in apartment buildings and joint ownership of strata title buildings, presents financial and social barriers to implementing BIPV. BIPV systems on these buildings would be more suited to commercial BIPV products and BIPV on apartment buildings is better treated as a commercial application. Nonetheless, multi-unit residential buildings are not included in this study.

There are approximately 1.4 million households in BC. Of that total, 839 940 are detached or semi-detached houses. [9] The fraction of these dwellings that have adequate solar access for BIPV is difficult to determine and varies from region to region.

Assumptions:

- One third of the buildings surrounding an obstruction are considered to have reasonable solar exposure [7]. Therefore there are about 280 000 potential residential BIPV locations in British Columbia.
- Residential BIPV systems typically go up to 10 kW_{peak}. In jurisdictions with programs that support grid-tied photovoltaics or BIPV, residential customers are installing 1 kW_{peak} to 4 kW_{peak} photovoltaic arrays [10,11,12]. Grid-tie photovoltaic systems can be as small as 100 Ws, but it is unlikely that such a small system would be building integrated. 1 kW_{peak} is assumed to be the minimum size for residential BIPV systems.
- The classical categories of innovation adopters is used to determine that up to 2.5% of dwellings will be pioneers or early adopters of residential BIPV systems. This assumes that there are programs initiated to promote residential BIPV. [13]

Therefore, 7000 detached or semi-detached residences represent the short-term potential for residential BIPV in British Columbia.

- 0% inflation, 8% discount rate and all capital costs are incurred in the first year.
- Interconnection costs include an on-site acceptance check, estimated at $200 (BC Hydro).
- No transmission costs.

The estimated potential generating capacity from residential BIPV is thus 7 MW_{peak} from a total potential of 280 MW_{peak}, as shown in Table 9. Table 9 summarizes the results of the analysis shown in the Appendix in Tables 11 and 12. Obviously the 280 MW value is extremely unlikely.

Table 9 – Residential BIPV potential for British Columbia

Measure	Unit	Estimate
Total potential generating capacity	MW_{peak}	7 to 280
Dependable Capacity	MW	0
Availability	%	11.4%
Total Average Energy production	GWh/year	7 to 284
Levelized Cost (see Tables 11,12)	$/kWh	$0.92 to $1.09

Tables 11 and 12 are a cash flow analysis of example residential BIPV systems in Vancouver and Prince George. Table 11 for Vancouver, assumes a south facing 30° tilted, standing seam metal BIPV roof of 3 kW_{peak} capacity. No material credit is used for the roofing material displaced by the BIPV roof to obtain the "worst case" generating cost.

Table 12 assumes a south facing, 30° tilted BIPV roof in Prince George. In this example, a material credit for a slate roof is assumed. This is a "best case" scenario.

6.3.2. Commercial BIPV

It is most economic to integrate PV into a building at the time of construction. However, retrofitting an existing commercial building is an option either in the form of sunshades, during re-roofing, or during a major upgrade or repair when a new curtain wall or rain screen is installed.

There are an estimated 160 000 commercial buildings in BC. These buildings are generally taller and have fewer obstructions around them than residential homes; therefore a greater percentage of those buildings will have suitable solar exposure. [7]

Assumptions:

- 40% of commercial buildings are considered suitable - there are 64 000 potential commercial BIPV systems in BC [7].
- Commercial BIPV system is a vertical south facing solar array.
- The average size of a commercial BIPV is also highly variable. This report uses an array size of 2.5 kW_{peak} to estimate BIPV potential and achieve a low cost per W_{peak} with the currently available inverters.
- The same percentage of early adopters, 2.5%, is assumed for commercial BIPV systems as for residential systems.
- 0% inflation, 8% discount rate and all capital costs are incurred in the first year.
- Interconnection costs are estimated at $1000 for commercial locations and assume single phase application with requirement for a separate transformer (BC Hydro).
- No transmission costs.

Commercial buildings represent a potential generating capacity that ranges from 4 MW_{peak} to 160 MW_{peak}. Table 10 summarizes the results of the analysis shown in the Appendix in Tables 13 and 14. The 160 MW figure is again the maximum potential and highly unlikely. The availability for Commercial BIPV systems is lower than for residential systems since vertical curtain walls receive less insolation than sloped roofs.

Table 10 – Commercial BIPV potential for British Columbia

Measure	Unit	Estimate
Total potential generating capacity	MW_{peak}	4 to 160
Dependable Capacity	MW	0
Availability	%	7.6%
Total Average Energy production	GWh/year	2.6 to 104
Levelized Cost (see Tables 13,14)	$/kWh	0.44 to 0.68

Tables 13 and 14 are a cash flow analysis of two example BIPV systems on commercial buildings in Vancouver and Prince George. Both systems assume a vertical BIPV curtain wall. Table 13 for Vancouver uses standard PV modules and Table 14 for Prince George assumes the use of more expensive custom BIPV modules. In each case, the material credit is the same.

7. Conclusion

Solar electricity is a relatively expensive means of producing electricity. BIPV partially addresses this problem by reducing the overall cost of solar electricity and by providing benefits in addition to energy production. To promote the use of solar electricity in British Columbia the non-financial benefits of BIPV systems must be emphasised since the low cost of utility electricity in British Columbia prevents grid-tie photovoltaic systems from being economically practical.

Rapid growth in the photovoltaic industry is reducing the cost of solar electricity and British Columbia can contribute to this growth by promoting the use of photovoltaic technology. If present trends in the photovoltaic industry continue, it is estimated that photovoltaic technology prices will decrease by 50% within a decade. The break-even point for current PV technology to compete with conventional electricity generation is expected to occur between 2020 and 2030. [13]

Promoting the use of BIPV systems in British Columbia requires the implementation of complementary programs. Foremost among these programs is net metering or net billing, which allow consumer/generators to tie their system into the utility grid and sell the excess to the utility . Equally important is certification of equipment and the personnel that design and install photovoltaic systems. Finally, uptake by consumers of BIPV also requires education and marketing to promote the non-financial benefits of BIPV.

The total potential generating capacity from residential BIPV on detached or semi-detached homes in British Columbia is estimated at 280 MW_{peak}. However, due to the unfavourable economics of using solar electricity in BC, an assumed uptake of 2.5% of consumers with suitable sites leads to a potential generating capacity of 7 MW_{peak}, which would produce approximately 7 GWh/year.

The maximum potential generating capacity from BIPV on commercial buildings in British Columbia is estimated at 160 MW_{peak}. A conservative estimate of actual potential assumes an uptake of 2.5% and a system size of 2.5 kW_{peak} which leads to a potential generating capacity of 4 MW_{peak}, which would produce approximately 2.6 GWh/year.

This level of uptake can only occur if there are programs in place to facilitate the implementation of BIPV and educate consumers about its potential. Actual uptake will depend upon consumers' understanding and willingness to pay for non-financial benefits.

A number of strategies can be used to facilitate grid connected BIPV systems. Grid connected renewable energy systems in general benefit from net metering, which simplifies the interconnection of these systems to the utility grid, and lends credibility to these systems by signalling utility support. Certification of equipment and the contractors installing the equipment assures customers of the quality of the PV systems they purchase.

No matter what strategies are chosen, an education and marketing campaign is required to introduce the new technologies and overcome misconceptions. Education has proven to be a key strategy in other jurisdictions with successful renewable energy programs.

8. BIPV Contacts

BIPV Roofing Products

Powerlight Corporation
2954 San Pablo Avenue
Berkeley, CA 94702
Tel: (510) 540.0550
Fax: (510) 540.0552
Email: mail@powerlight.com

Atlantis Energy Systems Inc.
4610 Northgate Blvd., Suite 150
Sacramento, CA 95834
Tel: (916) 920.9500
Fax: (916) 927.1697

Bekaert ECD Solar Systems LLC and
United Solar Systems Corp
1100 West Maple Road
Troy, Michigan 48084
Tel: (248) 362-4170 or 1-800-843-3892
Fax: (248) 362-4442
Email: info@uni-solar.com

BIPV Glazing

Saint-Gobain Glass Solar
Julicher Strasse 495
D-52070 Aachen
Germany
Tel: +49 (0) 2 41 / 96 67-2 40
Fax: +49 (0) 2 41 / 96 67-2 41

FLABEG Solar International GmbH
Mühlengasse 7
50667 Köln
Germany
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Fax: + 49 (0) 221 258 1117

Energy Photovoltaics, Inc
P.O. Box 7456
Princeton, NJ 08543
Tel: (609) 587-3000
Fax: (609)587-5355
Email: info@epv.net

TerraSolar USA
44 Court Street, Tower B
Brooklyn, NY 11201
Tel: (718) 422-0100
Fax: (718) 422-0300
Email: info@terrasolar.com

BP Solar
989 Corporate Drive
Linthicum, MD 21090

Grid-Tie Inverters

Vanner, Incorporated
4282 Reynolds Drive
Hilliard, OH 43026
Tel: (614) 771-2718

1-800-AC POWER
Fax: (614) 771-4904
Email: Info@Vanner.com

Omnion
S&C Power Electronics Division
2010 Energy Drive
P.O. Box 879
East Troy, WI 53120
Tel: (262) 642-7200
Fax: (262) 642-7760

Xantrex Technology Inc.
8999 Nelson Way
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9. Opportunities for residential wind power in BC

Wind energy is a form of solar energy produced by uneven heating of the Earth's surface. Wind resources are typically best along coastlines, on top of exposed hills, and in areas that are not heavily forested.

The greatest wind energy potential in British Columbia is located on the coast, South Central Interior, and in the Northeast. Average wind speed in these regions varies from about 10 km/h to 25 km/h (3 to 7 m/s). Interior regions of British Columbia in the Cariboo and South Okanogan represent a good market for small grid-tie wind turbines since these types of systems are well suited to the agricultural land common in these regions. [7]

Wind turbine installations are not practical in urban areas and a minimum of one acre is usually recommended for a small wind turbine installation. [24,25]This report focuses on small wind turbine installations that range in size from 1 kW to 50 kW. This type of wind turbine is considered suitable for residential, small business or farm applications and is popular in jurisdictions that allow interconnection with the utility of small-scale renewable energy systems.

9.1. Small Wind Turbine Technology

Modern wind turbines are technically advanced and reliable. Most small wind turbines use three blades, which run smoother than two blade turbines. The blades are usually made from wood, fibreglass or composite polymers. These materials provide the proper combination of strength and flexibility and don't cause interference with radio signals.

Generators specifically designed for small wind turbines often use permanent magnet alternators. A low-speed direct drive generator is an important feature of small turbines since gearboxes or belts are unreliable in these small sizes.

The least expensive tower is the guyed-lattice tower, such as those commonly used for ham radio antennas. Smaller guyed towers are sometimes constructed with tubular sections or pipe. The tubular towers are only used on small turbines of 1 kW or less.

Towers, particularly guyed towers, can be hinged at their base and suitably equipped to allow them to be tilted up or down using a winch. This allows all installation and maintenance work to be done at ground level.

The rated power of a wind turbine is not a good basis for comparing turbines. Manufacturers are free to pick the wind speed at which they rate turbines and if the rated wind speeds are not the same then comparing the two products is very misleading. Rotor diameter can be a better method of comparing wind turbines, however without accurate site data and computer modelling it is difficult to predict power output.

The American Wind Energy Association (AWEA) has adopted a standard method of rating energy production performance. Manufacturers who follow the AWEA standard provide information on the Annual Energy Output (AEO) at various annual average wind speeds. These AEO figures allow you to compare products fairly, but they are not a good indication of actual performance.

9.2. Wind Turbines

The small wind turbine market in North America is not large. Only a limited number of manufacturers produce turbines for this market.

Bergey Windpower has manufactured wind turbines for residential applications since 1980. They manufacture two sizes of wind turbine and have a third in development.

- The Bergey XL 1 is a 1 kW unit with a 2.5 m rotor diameter. The output from the low speed permanent magnet alternator is rectified to 24 V DC and is presently available only for battery charging systems. It is possible to grid-tie this turbine with an inverter such as the SW series manufactured by Xantrex Technologies or the MultiMode inverter from Advanced Energy. A direct grid-tie version is under development.
- The BWC Excel is a 10 kW unit with a 7 m diameter rotor. This turbine also uses a permanent magnet alternator, however the output is three phase, variable frequency AC that is regulated to 240 V single phase AC for grid-tie applications by the GridTek 10 inverter. Bergey has manufactured this turbine for 19 years.
- The BWC XL50 is a 50 kW unit with a 14 m diameter rotor. They expect this turbine to be available by late 2002.

Atlantic Orient Corporation is a wind turbine manufacturer located in Vermont with a Canadian office in Nova Scotia. They presently manufacture only a single turbine and have a second in development. Their turbine technology is the result of research and development initiated by Enertech in the 1970's.

- The AOC 15/50 Wind Turbine is 50 kW turbine with 15 m rotor diameter. It uses a three-phase 480 V asynchronous generator designed to operate at 1800 rpm, which is coupled to the rotor by a planetary gearbox.
- The Windlite is a 10 kW turbine with an 8 m rotor diameter. The output from the directly coupled permanent magnet alternator is rectified to 120 V DC.

Wind Turbine Industries manufactures Jacobs wind turbines. Jacobs wind turbines have been manufactured since the 1920s. Wind Turbine Industries bought the rights to the Jacobs wind turbine name and assets in 1986. They only sell a single turbine.

- The 20 kW Jacobs® wind turbine has an 8.8 m diameter rotor. The rotor is coupled to a brushless, three phase synchronous generator by an offset hypoid gear drive. Output is variable frequency three phase AC which is conditioned by the inverter to produce 208 V or 240 V, single phase AC.

There are other small wind turbine manufacturers that produce turbines for the off-grid market. These turbines are all designed to operate as battery chargers, but can be grid-tied in much the same way as the Bergey XL1. Southwest Windpower is perhaps the largest of these manufacturers.

9.3. Economics of Small Wind Turbines

The energy produced by a wind turbine is very site specific and in the absence of detailed site information only a very simple analysis is presented.

Bergey Wind Power sells complete grid-tie packages for the BWC Excel wind turbine directly from the factory. The complete package, exclusive of shipping costs, taxes and installation is US$28 730. This package includes wind turbine, inverter, 30 m guyed lattice tower and a wiring kit. Additional costs are estimated by Bergey to be US$2500 to US$8000.

The following assumption were used in the analysis:

- Coastal location (Weibull factor of K=3)
- Average wind speed 5.3 m/s at 10 m height
- Weibull wind distribution
- Complete system cost CAN$49 970 paid in first year with no financing.
- 0% interest, 8% discount rate and all capital costs incurred in first year.
- O&M (operating and maintenance) costs of $0.005 / kWh
- Interconnection costs include an on-site acceptance check, estimated at $200 (BC Hydro).

Under these conditions, the levelized cost of electricity over 20 years is estimated at $0.33 per kWh. Table 15 in the Appendix details the cash flow of such a system.

If the average wind speed is 6.1 m/s, as recorded at Sandspit in the Queen Charlotte Islands, the levelized electricity cost is estimated at approximately $0.23 per kWh. Table 16 in the Appendix shows the cash flow for this wind energy system located in Sandspit.

9.4. Conclusion

Residential or small-scale wind power is much closer than photovoltaic power to being competitive with utility power in British Columbia, especially if suitable, high wind locations can be found. While it is difficult to predict the customer uptake of such systems, it is certain that the premium for producing this form of green energy will not deter customers who perceive social and environmental value in producing their own green energy. The potential for small-scale wind power production in BC has been estimated at 25 GWh/year based on 10kW installations at 1900 residential sites. [7]

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Appendix

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Table 11

BC Green Energy Study - Phase 2 - BIPV Solar

Assumptions	Value	Notes:
Installed Capacity (kWp)	3	
Peak Sun Hours (Hours)	1380	south facing 30 degree array
Annual Energy Production (kWh)	2898	
BIPV Modules ($/kW)	8000	Metal Roof BIPV modules
BOS ($/kW)	1500	
Installation ($/kW)	600	
BIPV Materials offset ($/kW)	0	Metal roof
Interconnection Cost ($)	200	Acceptance check
Total Capital Cost ($)	30500	
O&M Cost ($/kWh)	0.02	
Inflation	0.00%	
Discount	8.00%	

Scenario:		
System Type	Residential BIPV Roofing	
Location	Vancouver	
PV Technology	Amorphous Silicon	

Cash Flow																						
	Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Energy Production (kWh)		0	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898	2898
Annual Operating Expenses ($)			58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
Capital Expenses ($)		30,500																				
Total Costs ($)		30,500	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
Discount factor		1.0000	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21
Discounted costs ($)	31,069	30500	54	50	46	43	39	37	34	31	29	27	25	23	21	20	18	17	16	15	13	12
Discounted Energy Output (kwh)	28,453	-	2,683	2,485	2,301	2,130	1,972	1,826	1,691	1,566	1,450	1,342	1,243	1,151	1,066	987	914	846	783	725	672	622
Levelized cost of energy ($/kWh)	1.09																					

Table 12

BC Green Energy Study - Phase 2 - BIPV Solar

Assumptions	Value	Notes:
Installed Capacity (kWp)	2	
Peak Sun Hours (Hours)	1330	south facing 30 degree array
Annual Energy Production (kWh)	1862	
BIPV Modules ($/kW)	7000	PV roofing slates
BOS ($/kW)	1500	
Installation ($/kW)	600	
BIPV Materials offset ($/kW)	-1000	Slate roof
Interconnection Cost ($)	200	Acceptance check
Total Capital Cost ($)	16400	
O&M Cost ($/kWh)	0.02	
Inflation	0.00%	
Discount	8.00%	

Scenario:		
System Type	Residential BIPV Roofing	
Location	Prince George	
PV Technology	Crystalline Silicon	

Cash Flow

	Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy Production (kWh)		0	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862
Annual Operating Expenses ($)			37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
Capital Expenses ($)		16400																				
Total Costs ($)		16400	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
Discount factor		1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21
Discounted costs ($)	16,766	16400	34	32	30	27	25	23	22	20	19	17	16	15	14	13	12	11	10	9	9	8
Discounted Energy Output (kwh)	18,281	-	1,724	1,596	1,478	1,369	1,267	1,173	1,086	1,006	931	862	799	739	685	634	587	544	503	466	431	399
Levelized cost of energy ($/kWh)	0.92																					

Table 13

BC Green Energy Study - Phase 2 - BIPV Solar

Assumptions	Value	Notes:
Installed Capacity (kWp)	10	
Peak Sun Hours (Hours)	945	south facing vertical array
Annual Energy Production (kWh)	6615	
BIPV Modules ($/kW)	5000	standard modules
BOS ($/kW)	1200	
Installation ($/kW)	400	
BIPV Materials offset ($/kW)	-4000	laminated/fritted glass
Interconnection Cost ($)	1000	
Total Capital Cost ($)	27000	
O&M Cost ($/kWh)	0.02	
Inflation	0.00%	
Discount	8.00%	

Scenario:		
System Type	Commercial BIPV Curtain Wall	
Location	Vancouver	
PV Technology	Amorphous Silicon	

Cash Flow

	Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Energy Production (kWh)		0	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615	6615
Annual Operating Expenses ($)			132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132
Capital Expenses ($)		27000																				
Total Costs ($)		27000	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132	132
Discount factor		1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21
Discounted costs ($)	28,299	27000	123	113	105	97	90	83	77	71	66	61	57	53	49	45	42	39	36	33	31	28
Discounted Energy Output (kwh)	64,947	-	6,125	5,671	5,251	4,862	4,502	4,169	3,860	3,574	3,309	3,064	2,837	2,627	2,432	2,252	2,085	1,931	1,788	1,655	1,533	1,419
Levelized cost of energy ($/kWh)	0.44																					

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Table 14

BC Green Energy Study - Phase 2 - BIPV Solar

Assumptions	Value	Notes:
Installed Capacity (kWp)	20	
Peak Sun Hours (Hours)	1024	south facing vertical array
Annual Energy Production (kWh)	14336	
BIPV Modules ($/kW)	7000	custom modules
BOS ($/kW)	1200	
Installation ($/kW)	400	
BIPV Materials offset ($/kW)	-4000	laminated/fritted glass
Interconnection Cost ($)	1000	
Total Capital Cost ($)	93000	
O&M Cost ($/kWh)	0.02	
Inflation	0.00%	
Discount	8.00%	

Scenario:		
System Type	Commercial BIPV Curtain Wall	
Location	Prince George	
PV Technology	Amorphous Silicon	

Cash Flow	Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy Production (kWh)		0	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336	14336
Annual Operating Expenses ($)			287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287
Capital Expenses ($)		93,000																				
Total Costs ($)		93,000	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287	287
Discount factor		1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21
Discounted costs ($)	95,815	93000	265	246	228	211	195	181	167	155	143	133	123	114	105	98	90	84	77	72	66	62
Discounted Energy Output (kwh)	140,753	-	13274	12291	11380	10537	9757	9034	8365	7745	7172	6640	6148	5693	5271	4881	4519	4185	3875	3588	3322	3076
Levelized cost of energy ($/kWh)	0.68																					

Table 15

BC Green Energy Study - Phase 2 – Small-Scale Wind

Assumptions	Value	Notes:
Installed Capacity (kWp)	10	
Average Wind Speed (m/s)	5.3	Weibul K = 3
Annual Energy Production (kWh)	15803	
Wind Turbine and Inverter	36500	Bergey Excel
Tower	11270	30 meter
Installation and BOS	2000	
Interconnection Cost ($)	200	Acceptance check
Total Capital Cost ($)	49970	
O&M Cost ($/kWh)	0.005	
Inflation	0.00%	
Discount	8.00%	

Scenario:		
System Type	Residential Scale Wind	
Location	BC Coast	
Technology	Vertical Axis Wind Turbine	

Cash Flow																						
	Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy Production (kWh)		0	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803	15803
Annual Operating Expenses ($)			79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Capital Expenses ($)		49970																				
Total Costs ($)		49970	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Discount factor		1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21
Discounted costs ($)	50,746	49970	73	68	63	58	54	50	46	43	40	37	34	31	29	27	25	23	21	20	18	17
Discounted Energy Output (kwh)	155156	-	14632	13549	12545	11616	10755	9959	9221	8538	7905	7320	6778	6276	5811	5380	4982	4613	4271	3955	3662	3391
Levelized cost of energy ($/kWh)	0.327																					

Table 16

BC Green Energy Study - Phase 2 – Small-Scale Wind

Assumptions	Value	Notes:
Installed Capacity (kWp)	10	
Average Wind Speed (m/s)	601	Weibul K = 3
Annual Energy Production (kWh)	22667	
Wind Turbine and Inverter	36500	Bergey Excel
Tower	11270	30 meter
Installation and BOS	2000	
Interconnection Cost ($)	200	Acceptance check
Total Capital Cost ($)	49970	
O&M Cost ($/kWh)	0.005	
Inflation	0.00%	
Discount	8.00%	

Scenario:		
System Type	Residential Scale Wind	
Location	Sandspit	
Technology	Vertical Axis Wind Turbine	

Cash Flow																						
	Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Energy Production (kWh)		0	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667	22667
Annual Operating Expenses ($)			113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
Capital Expenses ($)		49970																				
Total Costs ($)		49970	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113	113
Discount factor		1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58	0.54	0.50	0.46	0.43	0.40	0.37	0.34	0.32	0.29	0.27	0.25	0.23	0.21
Discounted costs ($)	51083	49970	105	97	90	83	77	71	66	61	57	52	49	45	42	39	36	33	31	28	26	24
Discounted Energy Output (kwh)	222548	0	20988	19433	17994	16661	15427	14284	13226	12246	11339	10499	9721	9001	8335	7717	7146	6616	6126	5672	5252	4863
Levelized cost of energy ($/kWh)	0.230																					