Implementing Solar Electricity On-Farm

Final Report

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1 Executive Summary

The British Columbia Ministry of Agriculture ("AGRI") commissioned Midgard Consulting Incorporated ("Midgard") and its sub-consultant Environmental Dynamics Incorporated ("EDI") to complete a report on the *Socio-Economic and Environmental Analysis of Implementing Solar Electricity On-Farms in BC*. The purpose of the report is to support further solar feasibility assessments and to highlight the potential benefits of implementing solar electricity on farms in British Columbia ("BC") (e.g. offsetting energy usage, promoting the use of renewable energy, etc.).

1.1 Regional Scan

The report begins by providing a high-level review of solar-related benefits and opportunities for agricultural producers looking to develop rooftop solar Photovoltaic ("PV") projects in four different regions across North America; BC, Alberta, Ontario and Arizona.

PV solar projects (the most common solar-electric technology) use solar irradiance to generate electricity. Conditions such as available solar irradiance and regional temperatures influence the overall performance and efficiency of solar PV projects. As a result, the economic viability of a solar PV project varies from region to region, and the development of solar PV projects in regions with comparatively low irradiance levels (e.g. BC) tend to be more challenging.

Advancements in technology coupled with decreasing costs has resulted in a widespread growth of solar PV projects across North America. Specifically, between 2010 and 2017, PV module costs have decreased by 86%, inverter costs have decreased by 58%, and non-module / non-inverter costs have decreased by 46%[1]. In addition to these cost savings, some regions have solar-related policies and incentive programs to help promote and encourage the development of solar projects.

1.2 Viability of Rooftop Solar on Farms in BC

The second half of the report focuses on the viability of implementing rooftop solar projects on dairy farms, poultry farms, or vineyard/winery farms located in three diverse farming regions of BC: Vancouver Island, the Fraser Valley, and the Okanagan. Rooftop solar project viability is assessed from an economic, environmental, and social perspective (as summarized in the following subsections).

1.2.1 Economic Assessment

To estimate the capital cost and payback period for a rooftop solar project, the two key inputs are the rooftop solar project capacity (in kW) and the corresponding annual production of energy (in kWh per year). However, the input parameters are dependent on various factors such as solar irradiance

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[1] National Renewable Energy Laboratory (NREL). U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Link

(location specific), rooftop area and sun exposure (farm specific), annual electricity requirements (farm specific), and local utility requirements for interconnection (location specific).

As a result, the following flowchart helps agricultural producers estimate their potential rooftop solar capacity and resulting annual electricity production.

Figure 1: Flowchart

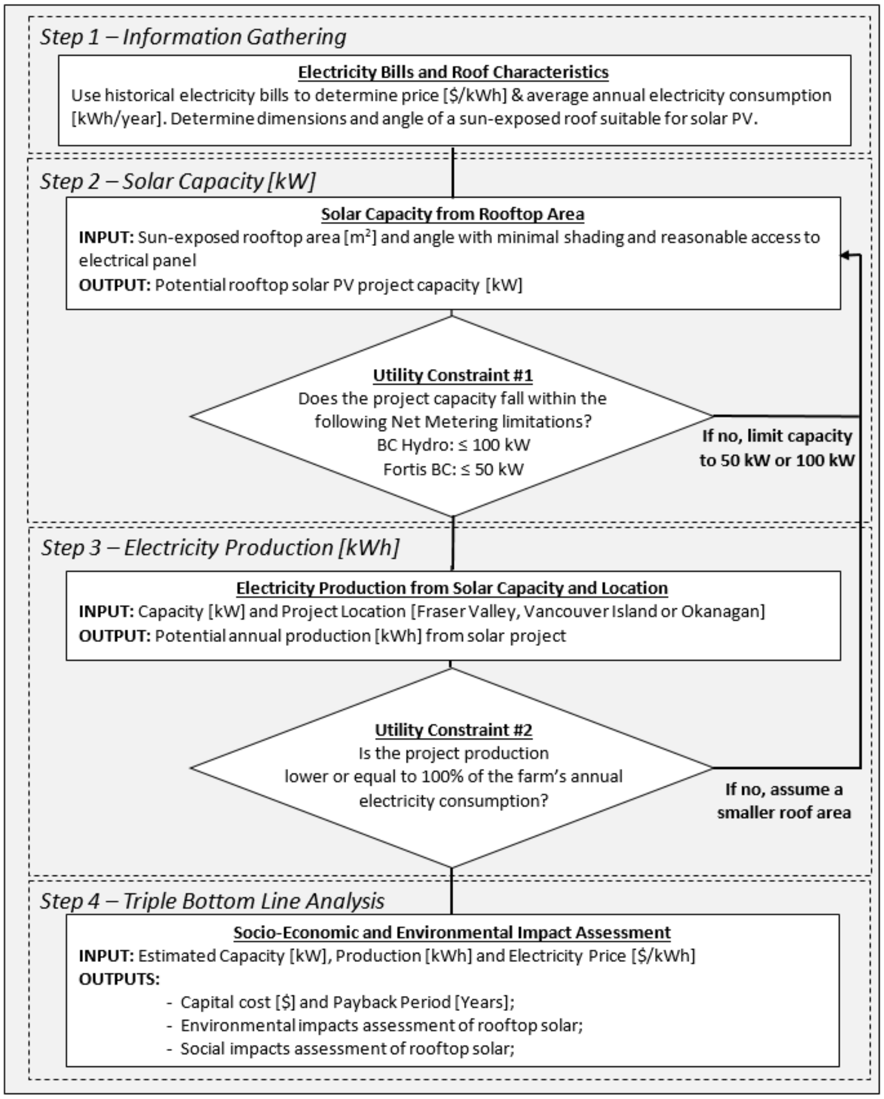

Table 1 below contains the flowchart process results for a set of three volunteer agricultural producers from the Fraser Valley, Okanagan, and Vancouver Island regions. Table 1 summarizes all-in solar install costs, average annual electricity savings, and the approximate payback periods for each of the three volunteer agricultural producers.

Table 1: Representative Agricultural Producer Economic Results

Farm ID	Producer Type	Rooftop Solar Capacity	All-In Cost	Average Savings	Payback Period

3	Dairy	50 kW	$190,000	≈$9,000 /Yr	≈21 Years
5	Poultry	40 kW	$160,000	≈$6,500 /Yr	≈24 Years
8	Vineyards and Wineries	20 kW	$84,000	≈$3,500 /Yr	≈24 Years

1.2.2 Environmental Assessment

Solar power is a relatively clean source of electricity when compared to other types of power generation. Although the manufacturing PV modules generates undesirable waste products, solar PV projects emit no greenhouse gas (“GHG”) or air pollutants during normal operations. Additionally, the emissions that are produced during solar PV raw material extraction / manufacturing are low relative to traditional fossil fuel based electricity production such as coal and natural gas.

Rooftop solar PV systems have no land disturbance impacts since the systems are installed on existing building footprints. Wildlife resources potentially affected by rooftop solar PV systems are restricted to species which use rooftops for perching, roosting, and / or nesting (e.g. primarily birds), however, the potential impacts associated with loss or changes in habitat, sensory disturbance, and direct mortality are expected to be low.

1.2.3 Social Assessment

From the perspective of potential solar developers and their neighbours, the key social impacts are related to the aesthetics and visual appeal of a rooftop solar project. Perceptions of visual aesthetics is subjective and can vary from person to person. However, solar panel visual appeal has generally improved in recent years (e.g. less intrusive designs that are better at visually integrating with a building), therefore aesthetics is likely not a primary issue for most potential solar developers.

1.3 Conclusions

Rooftop solar is a clean source of electricity with relatively low environmental and social impacts when compared against alternative forms of electricity supply. The economic viability of developing rooftop solar in BC is challenging due to low solar irradiance and low grid-supplied electricity pricing. However, overall solar install costs have decreased by over 60% in the last seven years, with cost reductions expected to continue (albeit at a slower rate). Therefore, considering downward trending solar install costs, ongoing solar technology improvements, increasing grid-supplied electricity prices, and further development of solar-related policies / incentive programs, the economic viability of rooftop solar in BC is expected to improve in future years.

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List of Acronyms

2013 LTEP	Ontario's Long-Term Energy Plan
AC	Alternating Current
ACC	Arizona Corporation Commission

AESO	Alberta Electric System Operator
AGRI	British Columbia Ministry of Agriculture
APS	Arizona Public Service
BC	British Columbia
DC	Direct Current
EDI	Environmental Dynamics Incorporated
FIT	Feed-In-Tariff
GHG	Greenhouse Gas
GHI	Global Horizontal Irradiation
IESO	Independent Electricity System Operator
ITC	Investment Tax Credit
Midgard	Midgard Consulting Incorporated
O&M	Operation and Maintenance
OEB	Ontario Energy Board
PV	Photovoltaic
REP	Renewable Electricity Program
REST	Renewable Energy Standard and Tariff
SOP	Standing Offer Program
U.S.	United States of America

2 Introduction

The British Columbia Ministry of Agriculture ("AGRI") has commissioned Midgard Consulting Incorporated ("Midgard") and its sub-consultant Environmental Dynamics Incorporated ("EDI") to complete a *Socio-Economic and Environmental Analysis of Implementing Solar Electricity On-Farms in BC*. The scope of work is intended to help inform the feasibility assessment and potential benefits of implementing solar electricity on farms in British Columbia ("BC") to offset energy requirements and promote the use of renewable energy.

The first half of this report provides a high-level review of solar-related benefits and opportunities for agricultural producers looking to develop rooftop solar Photovoltaic ("PV") projects in four different regions across North America; BC, Alberta, Ontario and Arizona. The report begins by providing a general overview of common solar PV technologies and all-in project cost trends across North America, and identifies solar-related benefits and opportunities for agricultural producers looking to develop rooftop solar PV projects. Key opportunities and programs with the potential to facilitate agriculture producer participation in the power sector are also reviewed. Finally, the potential challenges and risks to implementing solar developments are discussed with a focus on those applicable to BC.

The second half of the report focuses on the viability of implementing rooftop solar projects on either dairy, poultry, or vineyard & winery-type farms located in three diverse farming regions of the province: Vancouver Island, Fraser Valley, and the Okanagan. Rooftop solar project viability is discussed in terms of general economic, environmental and social impact assessments, and via a flowchart that enables producers to assess viability for their specific situation.

3 Solar PV Energy

Solar-electric technologies use the sun's energy to generate electricity, and the most common technology is PV panels placed in locations that get good exposure to the sun (in the northern hemisphere this generally means south-facing areas). When solar irradiance hits the solar PV panel arrays, electricity is produced inside individual PV cells and the electricity is then collected and aggregated for conveyance onto electrical wires for use by an electrical load. In the majority of installations solar panels are installed in fixed orientations, but in some installations actuators are added to the system so that the panels "follow" the sun over the course of the day. PV panels can be installed in small arrays distributed across many sites (e.g. home or agricultural building rooftops) or in large arrays at a single site (e.g. utility-scale solar farms or PV power stations typically mounted on the ground).

Solar energy is an intermittent resource, meaning that energy production fluctuates throughout the day with changing sunlight conditions (e.g. the sun sets at night and cloud cover changes throughout the day). Although the amount of energy that intermittent resources will generate in the long term (e.g. annually) is often predictable, instantaneous capacity or short-term energy generation can be unpredictable (e.g. due to changes in local cloud cover). As a result of this variability, intermittent generation sources must be "firmed" either by means of energy storage or by a dispatchable generation source which responds to changing generation levels. From the perspective of grid-connected agricultural producers, the intermittency solar PV is not an issue because producers can rely on the electrical grid to meet their on-farm capacity and electricity demands regardless of changing sunlight and environmental conditions.

3.1 Solar Technologies

Solar technologies have improved over the years in terms of efficiency, longevity, and range of available products. Two types of solar technologies typically used in rooftop applications include solar PV and solar thermal technologies. Solar PV technology facilitates the direct conversion of the sun's energy into electricity, while solar thermal technology captures heat energy from the sun. For the purposes of this report, only solar PV technologies for rooftop applications will be discussed.

3.1.1 Solar PV Modules

Solar PV technologies for rooftop applications are primarily classified based on the manufacturing process of each technology type. Solar PV cells are manufactured using different techniques and assembled into panels. Rooftop applications typically involve an array of panels that are electrically interconnected. The three predominant types of solar PV cell technologies available in the North American market are Monocrystalline, Polycrystalline and Thin-Film.

Table 2 provides a comparison of the primary advantages and disadvantages of these three solar PV cell technologies.

Table 2: Summary of Solar PV Cell Technologies[2,3]

Technology Type	Advantages	Disadvantages
Monocrystalline	• Highest energy conversion efficiency (up to 22.5%), hence high physical space efficiency • Long life span (over 25 years) • Widely considered to have better aesthetic appeal than polycrystalline cells	• High financial cost • Larger amount of waste silicon from manufacturing
Polycrystalline	• Relatively low financial cost • Competitively high energy conversion efficiency (up to 16%) • Small amount of waste silicon from manufacturing • Long life span (over 25 years)	• Lower physical space efficiency than monocrystalline cells
Thin-film	• Low financial cost of mass production • Relatively easy to make flexible panels • Low impact on performance by shading or high temperatures	• Lower space efficiency than crystalline cells (not yet practical in many rooftop applications) • Relatively short life span compared to crystalline cells

3.1.2 Inverters

Solar PV modules generate direct current ("DC") electricity, and then inverters convert the DC output from the solar PV cells to alternating current ("AC") electricity that is utilized by grid connected applications. Two primary inverter configurations typically used in rooftop solar applications:

- Micro inverters
- String inverters

Table 3 below provides a brief description and comparison of the two configuration types.

Table 3: Inverter Configuration Overview[4]

Technology Type	Description	Advantages	Disadvantages
Micro Inverter	• Individual small inverters usually implemented at panel level resulting in a solar PV array of panels acting like multiple AC sources	• Systems are minimally impacted by shading of a few panels. • Lower DC voltages in the system hence potentially lower installation costs for large systems.	• Higher financial cost compared to String inverter systems

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[2] Environment Canada. Assessment of the Environmental Performance of Solar Photovoltaic Technologies. Link

[3] Solar Reviews. Link

[4] Enphase. Comparing Inverters. Link

Technology Type	Description	Advantages	Disadvantages
String Inverter	- A singular unit that receives multiple DC inputs from a solar PV array of panels and outputs AC power	- Lower financial cost compared to micro inverter systems	- Potential hazards due to large DC voltage - Systems are significantly affected by shading of only a few panels

3.2 Solar Cost Trends

Historically, solar project prevalence was lower than today due to significant costs associated with solar PV technology. However, technological improvements, bolstered by large-scale production, competitive markets, and improvements to manufacturing processes over the past decade have resulted in a significant decrease in solar PV costs, resulting in solar projects being more economically viable.

The following subsections provide an overview of trends in the all-in cost of grid-connected residential and non-residential solar PV systems[5]. The data presented in this report is derived from United States of America ("U.S.") solar PV system installed costs benchmarks[6] as of the first quarter of 2017.

As part of this analysis, the following assumptions have been made:

1. The all-in costs account for all system and project-development costs incurred during the installation of fixed tilt solar PV systems, assuming typical installation techniques and business operations, and all costs are represented from the perspective of the developer. Costs do not account for incentives programs such as tax credits, capital cost rebates, etc.
2. All costs are presented in real 2017 Canadian Dollars[7]
3. The cost trends across the United States are assumed to be representative of installed solar PV pricing throughout North America.
4. Operation and Maintenance ("O&M") cost changes are considered minor relative to capital cost changes, and thus, have not been included in the trending analysis.

3.2.1 Historical Trends

Historical all-in cost trends for residential (4.4 kW[8]), commercial (150 kW) and utility-scale (75,000 kW) systems over the last seven years are shown in Figure 2 below.

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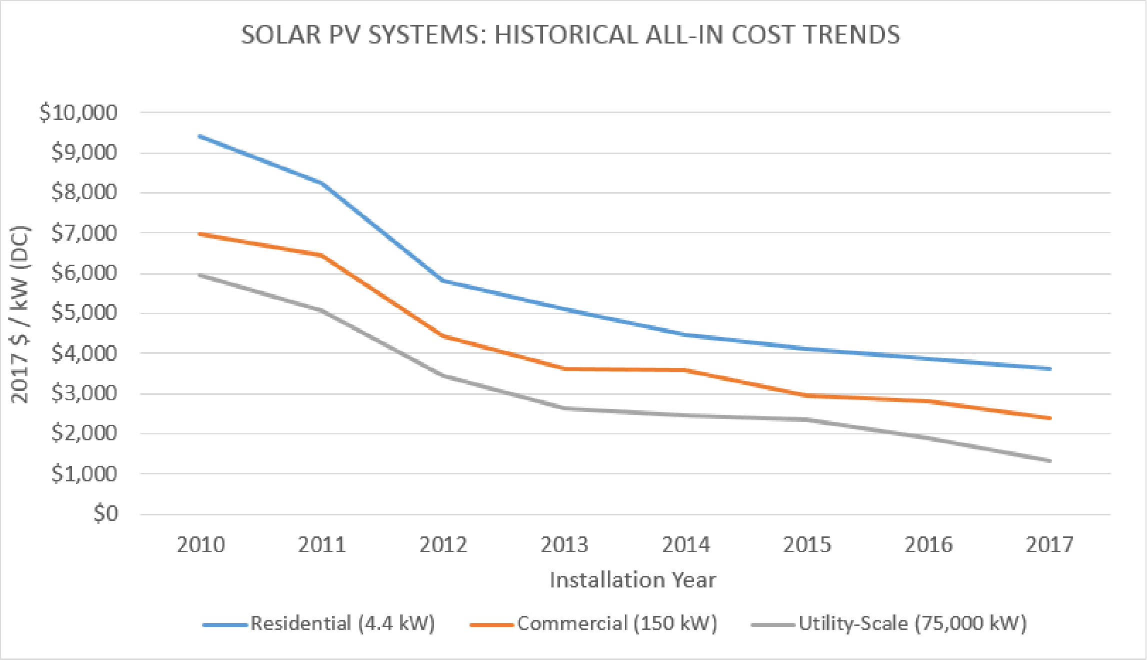
[5] National Renewable Energy Laboratory (NREL). U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Link

[6] The benchmarks are national averages weighted by state installed capacities.

[7] Based on the 2017 annual average USD/CAD exchange rate at 1 USD = 1.2986 CAD. Source: Bank of Canada "Annual Exchange Rates" Assessed Feb 8 2018 Link

[8] All solar capacities are in AC, unless otherwise specified.

Figure 2: Historical All-In Cost Trends - 2010 to 2017

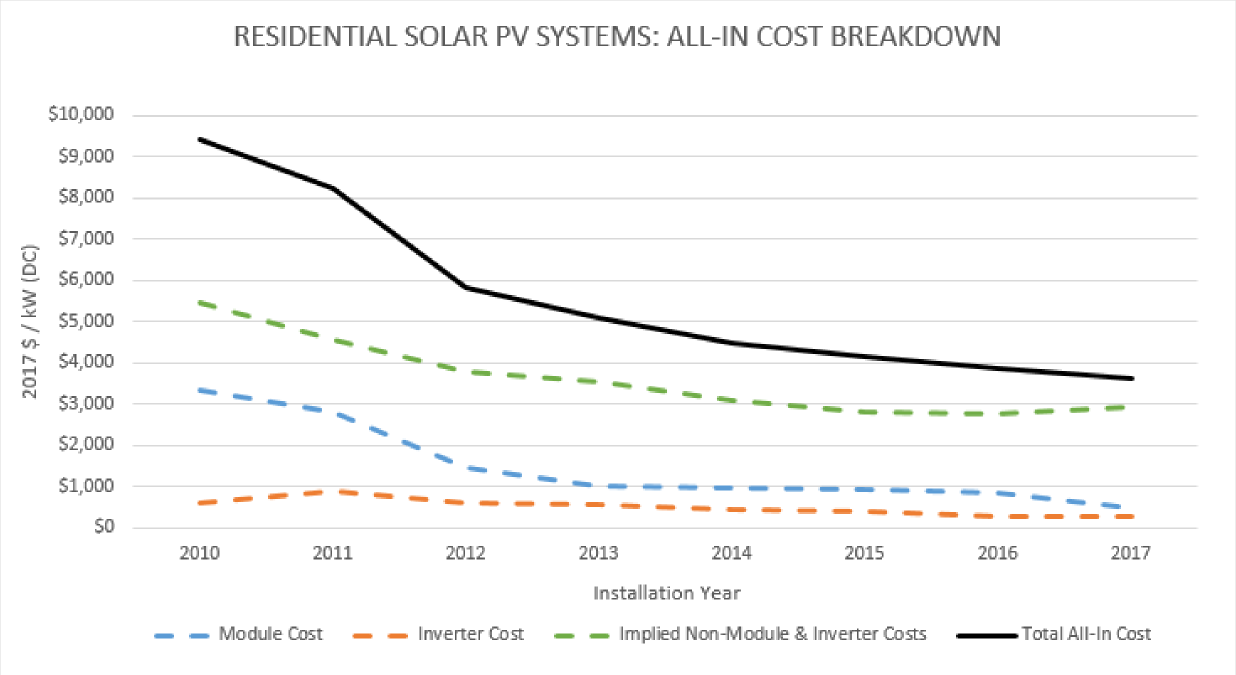


Note: "All-In Cost" refers to the all-in price paid by the PV system owner, prior to receipt of incentives, and includes both hardware (e.g. module and inverter costs) and non-hardware costs (e.g. installation costs, owner's costs).

In all three scenarios observed above, regardless of the installation size the installed solar costs have decreased by more than 60% in the last seven years.

The all-in cost trends observed in Figure 2 can be further broken down into three main cost components, namely the PV module, inverter, and all other non-module and non-inverter costs. Figure 3 provides a further breakdown of historical trends by cost component for residential PV systems over the last seven years.

Figure 3: Residential Solar PV System All-In Cost Breakdown - 2010 to 2017



Between 2010 and 2017, PV module and inverter costs have decreased by approximately 86% and 58% respectively, and the non-module and non-inverter costs have decreased by approximately 46%. Although the percentage decreases are considerable for all three cost components, the significant decrease in PV module costs observed in Figure 3 is the primary driver responsible for much of the decrease in all-in costs of solar PV over the last seven years.

Historically, PV module costs have been responsible for approximately 35% of all-in solar costs. Following the reduction in PV module costs, they now represent approximately 13% of the all-in solar cost. Conversely, the non-module and non-inverter cost components which historically represented just over half (58%) of the all-in solar costs, now represents over 80% of the all-in cost. Inverter costs have decreased but their percentage of all-in costs has remained relatively constant over time. A comparison of the relative cost component weights between 2010 and 2017 are shown in Table 4.

Table 4: All-In Cost Breakdown Comparison between 2010 and 2017

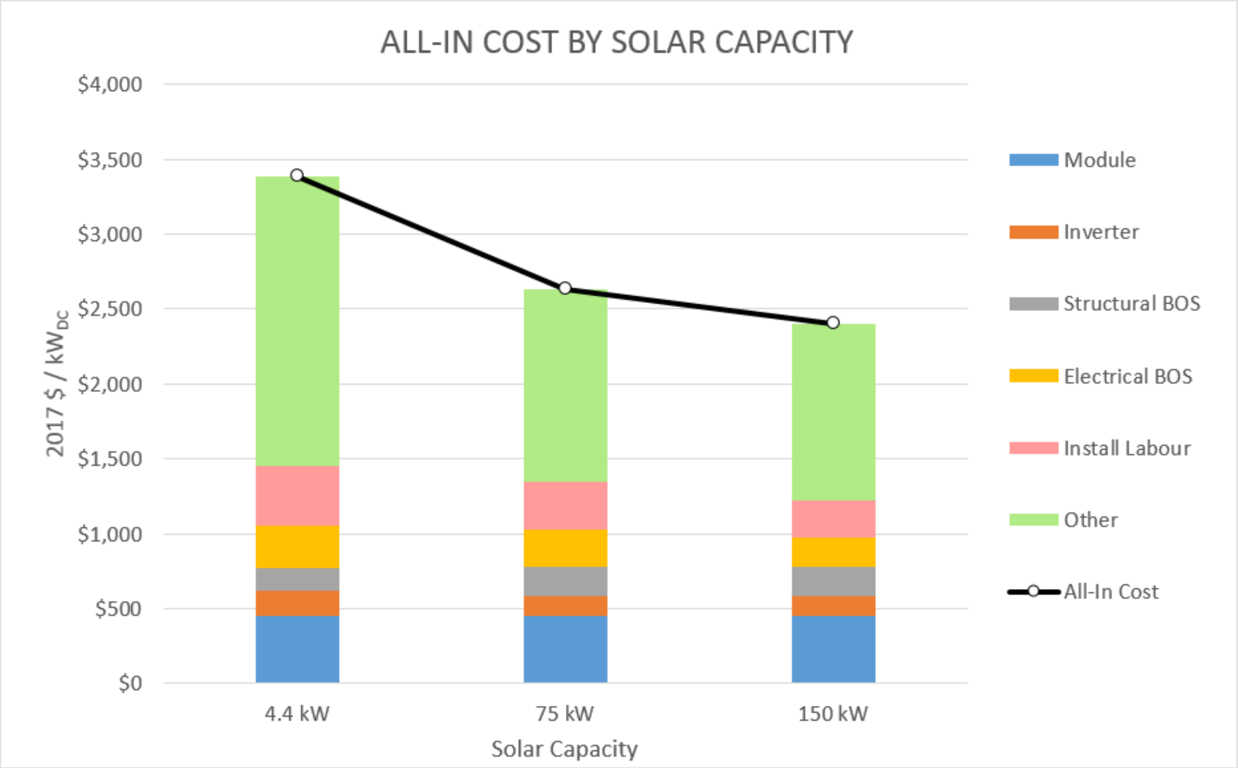
Cost Component	Relative Weight	
	Year 2010	Year 2017
PV Module Cost	35%	13%
Inverter Cost	6%	7%
Implied Non-Module & Inverter Costs	58%	81%
TOTAL:	**100%**	**100%**

Based on the above results, further decreases in module and inverter cost will have less impact on the all-in cost of solar, and future cost reduction opportunities now largely reside with the non-module and non-inverter cost components.

3.2.2 Economy of Scale

The data presented in the previous section is representative of all-in costs trends over a range of project sizes. As solar rooftop applications tend to be smaller, an economy of scale assessment has also been included to highlight how all-in cost varies with installed solar PV system capacities ranging from 4.4 kW to 150 kW. The results of this assessment are presented in Figure 4 below.

Figure 4: All-In Cost of Solar PV by System Capacity



The general observation is that economy of scale effects are more pronounced for smaller-sized systems, and becomes less significant for systems with installed capacities above 75 kW. Larger systems tend to be more cost effective overall, but the incremental benefits of the economy of scale effect decline with increasing project size. To demonstrate, a cost comparison of developing a 4.4 kW system, a 75 kW system, and a 150 kW system is shown below. The potential cost benefits are summarized as follows:

1. A 75 kW system is approximately 22% less expensive on a per kW basis than a 4.4 kW system.

2. A 150 kW system is approximately 29% less expensive on a per kW basis than a 4.4 kW system.
3. A 150 kW system is approximately 9% less expensive on a per kW basis than a 75 kW system.

3.2.3 Future Projections

Although the all-in cost of solar PV has decreased significantly over the last 7 years, the cost reductions over time associated with PV modules and Inverters are declining as these are maturing technologies. As a result, unless there is an unforeseen change in technological advancement, today's prices are a good indication of future prices of PV modules and Inverters, with less dramatic price decreases expected in the coming years.

Nevertheless, opportunities for further cost reductions related to the non-module and non-inverter cost component, which now represent over 80% of the all-in cost of solar (shown in Table 4), are still possible.

4 Jurisdictional Scan – Region Overview

The following sections focus on identifying key solar-related opportunities and programs facilitating the development of rooftop solar PV suitable for agricultural applications in BC, Alberta, Ontario and Arizona. Key reasons behind the selection of each region are summarized below.

- **British Columbia** – The current scope of work focuses on the feasibility and potential benefit of implementing solar energy on farms specifically located on Vancouver Island, Fraser Valley and the Okanagan. As a result, the province of BC was included to provide pertinent and up to date information on solar-related policies, standards and incentive programs available to agriculture producers in BC looking to potentially implement rooftop solar PV.
- **Alberta** – Alberta is in the process of phasing out coal-fired electricity generation and is looking to transition to renewable energy generation of electricity. As a result, the province is in the process of developing and implementing policies, programs and incentives for the development of renewable energy projects, with a focus on solar and wind developments. Alberta was included to highlight recent changes and improvements being made to promote renewable energy in one of Canada's most agriculturally-intensive provinces.
- **Ontario** – Within Canada, Ontario is the leading province for solar capacity with over 2,100 MW of installed capacity[9]. Ontario was included because of the robust and well-established set of solar policies, programs and contractual arrangements available to solar developers in Ontario.
- **Arizona** – The State of Arizona was included as it is a smaller and simpler solar market that benefits from high solar irradiation, and is a potential indicator of future behavior in certain BC regions (assuming a continued decline in total cost of solar to offset BC's lower irradiation).

Although solar technology improvements and declining solar costs have encouraged the implementation of solar projects, climate, and more specifically solar irradiation, influence the overall performance and efficiency of solar PV panels. The following section provides an overview of solar resources and climates in each region.

4.1 Solar Resources

The availability of solar irradiation is the most important determinant of the energy generation potential of a solar PV system. Solar irradiation, commonly referred to as Global Horizontal Irradiation ("GHI"), is a measure of total radiation received by a surface horizontal to the ground[10] in kWh/m^2. The annual average GHI measured between 1999 and 2013 across North America is shown in Figure 5 below.

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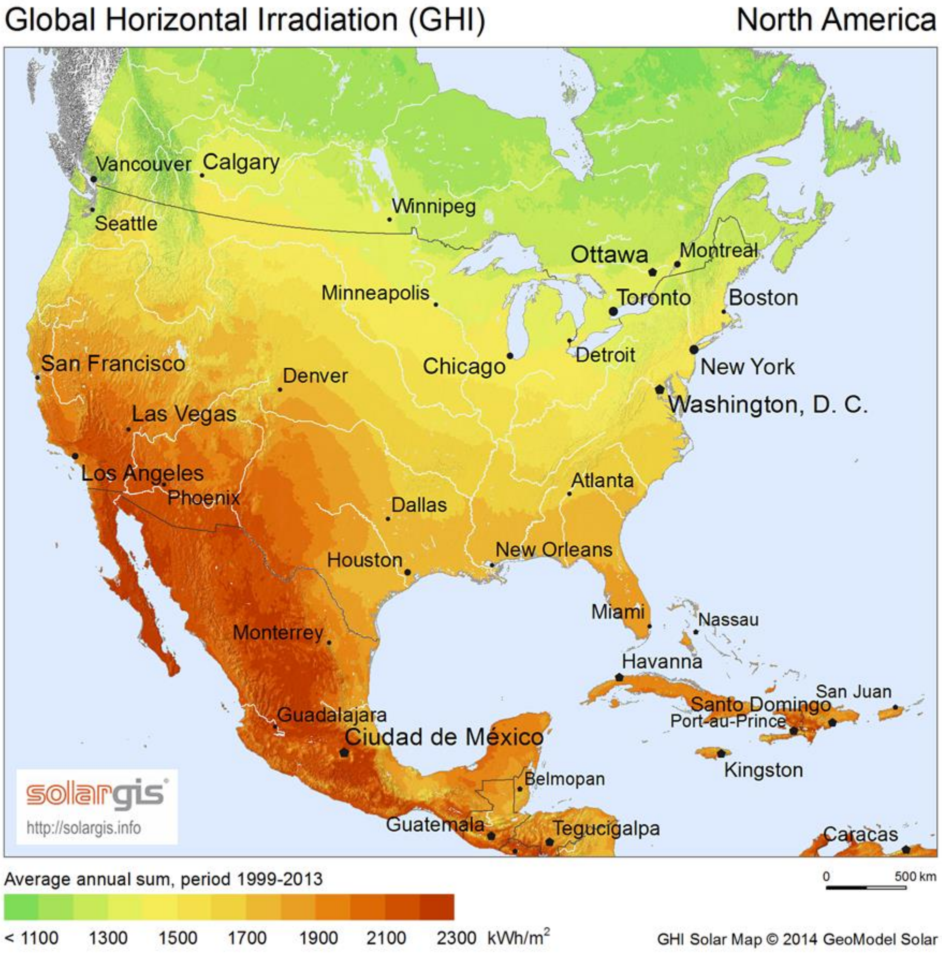
[9] National Energy Board. Canada's Renewable Power Landscape (2016). Link

[10] Vaisala Energy. What is Global Horizontal Irradiance? Link

Figure 5: Average Annual GHI across North America[11]



Based on this map, the State of Arizona located in the southwestern region of the U.S. is observed to have excellent GHI values, meaning that the state has good potential for solar power. Among the Canadian provinces, Alberta and Ontario are observed to have similar GHI values, with BC ranking last in terms of resource potential for solar power among the four regions.

4.2 Climate

In addition to GHI, the performance of solar panels is also impacted by temperature. Although solar PV panels react differently ambient temperatures, the general trend is that solar PV efficiency decreases with increasing temperatures[12]. This means that cold, sunny days are better for solar generation than hot sunny days.

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[11] SolarGIS. Solar Resource Maps for North America. Link

[12] The Greenage. The Impact of Temperature on Solar Panels. Link

4.2.1 Other Climate Conditions

Other climate conditions that can influence the performance of solar generation, including the amount of cloud coverage as well as the amount of snow, precipitation and dust coverage in the region. This can cause soiling/blockage of the panels. Although the effects of cloud coverage is inevitable, the effects of snow, precipitation and dust can be mitigated by means of a diligent O&M programs, including regular clearing of the panels.

5 Renewable Portfolio Standards

As highlighted in the previous section, variable climates and solar resources can materially influence the performance of solar generation, which means that solar PV projects of similar sizes and configurations will perform differently from one region to the next. Areas with higher GHI and favourable climates tend to have larger numbers of solar developments when compared to regions with less favourable conditions for solar. For example, solar projects are far less common in low GHI areas with lots of precipitation (e.g. the Fraser Valley) when compared to high GHI areas such as Arizona. Each region has its own set of solar-related policies, standards and incentive programs to help promote solar developments.

Renewable Portfolio Standards are policies, standards and/or goals that are designed to increase electricity generation from renewable resources such as solar, wind, geothermal, biomass or hydroelectricity[13]. These standards, developed at both federal and state/provincial levels, create opportunities in the electrical energy industry by setting targets to reduce greenhouse gas ("GHG") emissions by means of fossil fuel (e.g. coal generation) retirements, shifts towards renewable generation (e.g. solar, wind) and energy efficiency improvements. These global trends toward sustained GHG reductions and increased renewable energy generation in the economy have been driving investments in the power sector and promoting the development and implementation of incentive programs that facilitate the development of renewable energy projects such as solar PV.

The following sections describe in more detail the key policies, standards and targets that exist in each of the four regions, and discuss how these policies, standards and goals can be beneficial from an agriculture producer standpoint.

5.1 British Columbia

The two major electric utilities in BC are BC Hydro and FortisBC, with BC Hydro serving approximately 95% of the province's population[14]. The backbone of BC's electricity supply mix is formed by large, crown-owned hydroelectric generation on the Columbia and Peace River systems. As a result, more than 90% of BC Hydro's generation is produced by hydroelectric generation[15].

Energy policy in BC is largely driven by BC's Clean Energy Act[16]. As of November 2017, some of the energy objectives outlined in the Act include, but are not limited to, the following:

- "*To achieve electricity self-sufficiency;*
- *to generate at least 93% of the electricity in British Columbia from clean or renewable resources and to build the infrastructure necessary to transmit that electricity;*
- *to reduce BC greenhouse gas emissions*

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[13] U.S Energy Information Administration. Today in Energy. Link
[14] BC Hydro. Quick Facts. Link
[15] BC Hydro. Generation System. Link
[16] Government of BC. Clean Energy Act. Link

   i. *by 2012 and for each subsequent calendar year to at least 6% less than the level of those emissions in 2007,*
   ii. *by 2016 and for each subsequent calendar year to at least 18% less than the level of those emissions in 2007,*
   iii. *by 2020 and for each subsequent calendar year to at least 33% less than the level of those emissions in 2007,*
   iv. *by 2050 and for each subsequent calendar year to at least 80% less than the level of those emissions in 2007, and*
   v. *by such other amounts as determined under the Greenhouse Gas Reduction Targets Act; resources to help achieve provincial GHG reduction targets;*
- *to encourage the switching from one kind of energy source or use to another that decreases greenhouse gas emissions in British Columbia"*

Since the province of BC has an abundance of renewable energy resources which largely meet the objectives listed above, there currently is not a large provincial drive for additional renewable energy generation. BC Hydro and Fortis BC continue to offer incentive programs to help offset the costs of implementing smaller-scale solar PV projects and other types of renewable energy projects in the Province. Details of these incentive programs are discussed further in Section 6.

5.2 Alberta

Alberta's electricity market was de-regulated in 1996 in favor of a market-based system. In this open marketplace, electricity infrastructure is owned by a combination of investor-owned and municipally owned companies, electricity generators and consumers buy and sell power at fluctuating market rates, and the transmission resources required to facilitate the market approach is overseen by the independent, government-appointed Alberta Electric System Operator ("AESO")[17].

In contrast to BC, Alberta has traditionally relied on coal and natural gas-fired generation as a low-cost source of electricity. Alberta's first step towards cleaner energy occurred in 2008 when Alberta launched its Climate Change Strategy which set out GHG reduction targets for the Province[18]. In 2015, Alberta introduced a Climate Leadership Plan stipulating that there will be no pollution from coal-fired electricity generation by 2030, and as a result, all coal-fired generation in the province is forecast to be phased out by 2030. In support of this goal, the province is aiming by 2030 to have one-third of Alberta's electricity supplied by renewable sources, such as solar, wind and hydro[19], with the remaining two-thirds supplied by natural gas.

To help achieve these goals, the government of Alberta launched the Renewable Electricity Program ("REP"), which aims to add 5,000 MW of renewable electricity capacity by 2030[20]. The REP is intended

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[17] AESO. Guide to Understanding Alberta's Electricity Market. Link
[18] Government of Alberta. Alberta's 2008 Climate change Strategy. Link
[19] Government of Alberta. Phasing out Coal Pollution. Link
[20] Government of Alberta. Renewable and Alternative Energy. Link

to incentivise the development of renewable electricity generation through the purchase of renewable attributes. Additional details are included in Section 6.

5.3 Ontario

The electricity market in Ontario is led by the Independent Electricity System Operator ("IESO"), with the Ontario Energy Board ("OEB") responsible for regulating the energy sector. Major transmission assets are controlled primarily by Hydro One, a crown and investor-owned utility. Following the phase-out of coal-fired generation in 2014, Ontario's electricity is now predominantly supplied by nuclear generation, with hydro, natural gas, and renewables supplying the remainder[21].

Ontario is the most advanced province in terms of adopting and implementing clean energy policies and phasing out coal-fired electricity. Ontario first committed to eliminating all its coal-fired electricity generation back in 2003, and by 2014, had successfully phased-out the use of coal[22]. In parallel to this commitment, Ontario also issued the Green Energy and Economy Act in 2009 to promote the growth of renewable energy projects by means of incentive programs[23], which was followed by the 2013 Ending Coal for Cleaner Air Act intended to prevent any future coal plants from being built in Ontario[24].

In 2013, Ontario also published its Long-Term Energy Plan ("2013 LTEP") which forecasts that almost all electricity demand growth to 2032 will be offset by new conservation programs and improved building codes and standards. Notwithstanding the 2013 LTEP energy forecasts, the Ontario government also committed to increasing the amount of renewable energy to 20,000 MW of capacity by 2025, an amount equalling almost half of Ontario's current installed capacity[25]. The projected increase in renewables includes gradual increases of wind, solar and bioenergy capacity to 10,700 MW by 2021, and increases in hydroelectric capacity to 9,300 MW by 2025.

Most recently, the Ontario government issued a Climate Change Mitigation and Low-carbon Economy Act in 2016[26] to reduce GHG emissions and provide a framework for Ontario's cap and trade program designed to fight climate change and reward businesses that reduce GHG emissions. Together, these sets of standards, policies and targets are helping to promote and encourage further development of solar and other renewable projects within Ontario. Incentive program details are discussed further in Section 6.

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[21] IESO. Supply Overview. Link
[22] Ontario Ministry of Energy. The End of Coal. Link
[23] Government of Ontario. Green Energy and Green Economy Act (2009). Link
[24] Legislative Assembly of Ontario. Bill 138m Ending Coal for Cleaner Air Act, 2013. Link
[25] Government of Ontario. 2013 Long-Term Energy Plan. Link
[26] Government of Ontario. Bill 172 – an Act respecting GHG. Link

5.4 Arizona

The electricity market in Arizona is regulated by the Arizona Corporation Commission ("ACC"). There are 16 different electric utilities in Arizona[27], but the market is primarily driven by the Arizona Public Service ("APS") Company and the Salt River Project. Historically, coal has contributed the largest percentage of Arizona's electricity generation, but in recent years coal generation has decreased and has been replaced with nuclear, natural gas, and renewable generation such as hydro, wind, and solar PV.

The State of Arizona has an abundance of solar irradiation and consequently a significant solar power resource potential. In 2006 the ACC adopted a set of requirements under a Renewable Energy Standard and Tariff ("REST") program requiring regulated electric utilities to generate 15% of their energy from renewable resources by 2025, with 30% of the renewable energy to be derived from distributed energy technologies in the form of solar, wind, biomass, biogas, geothermal and other types of clean energy installed by homes and businesses[28]. Since the implementation of this program, utilities have developed and implemented a variety of distributed generation incentive programs to encourage customers to install solar and other renewable energy technologies for their homes and businesses. The State of Arizona also provides renewable energy production tax credits for qualified systems which encourage the implementation of solar PV.

Although Arizona's renewable energy standard is modest compared to other regions in this report, the industry recruitment measures and incentive programs have been successful in attracting renewable resources. Details of these incentive programs are discussed further in Section 6.

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[27] Arizona Corporation Commission. Map of Arizona's Electric Companies. Link

[28] Arizona Corporation Commission. Renewable Energy Standard & Tariff. Link

6 Market for Solar

Mechanisms for encouraging solar electricity installations can be both state/provincially or federally mandated, and can vary from grid connection programs to small financial incentives. Utilities will often develop incentive programs where the utility buys energy and/or capacity from the producer at preferred prices, enabling customers to participate in the power sector and reduce their electricity bills by generating their own electricity. Incentive programs are typically accessible under a codified and public set of requirements which set out the minimum requirements needed to be eligible to participate in the incentive program.

6.1 Provincial Incentive Programs

Mechanisms to support renewable energy projects such as solar PV can vary in terms of objectives, level of support and overall design between jurisdictions. Examples of provincial/state mandated programs and mechanisms that encourage the implementation of solar projects include[29]:

- **Feed-In-Tariffs (“FIT”) Program** - FIT programs usually offer long-term (e.g. 20 year) contracts and set payments, often specific to a particular technology. Standard terms make it easier for small projects and new applicants to qualify.
- **Standing Offer Programs (“SOP”)** - SOP for renewable projects allow entrants to apply at any time the program is in effect and provides guaranteed payments which, in contrast to FITs, are typically the same for all types of renewable energy technologies.
- **Net Metering Programs** - Net Metering programs allow customers to generate their own electricity and either sell their excess production to the grid or use it to offset purchased power. Net Metering programs exist in most Canadian jurisdictions, but typically contain requirements which limit a significant investment (e.g. size caps).

In some cases, incentive programs can also facilitate group specific development opportunities such as programs for agriculture producers or First Nation communities. Program requirements typically include well-defined eligibility criteria to create a fair playing field for non-utility participants such as producers and First Nations. The following sections provide information on incentive programs within each of the four regions which facilitate the development of solar PV projects and are applicable to agricultural producers.

6.1.1 British Columbia

The main procurement programs available within BC for acquiring energy and for facilitating the implementation of solar projects include BC Hydro’s SOP and Net Metering programs offered through both BC Hydro and Fortis BC. An overview of eligibility requirements and a measure of incentive opportunities are highlighted in Table 5.

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[29] National Energy Board. Canada’s Renewable Power Landscape (2016). Link

Table 5: BC Solar Incentive Program Overview

Program	Eligibility Requirements	Incentive
SOP[30]	• **Capacity:** > 100 kW, < 15 MW • **Generation Fuel:** Renewable • **Interconnection Voltage:** Transmission or Distribution voltage • **Other:** Not located in protected area	• **Base Price:** \$102 - \$110 / MWh
Micro-SOP (subset of the SOP Program)[31]	• **Capacity:** > 100 kW, < 1 MW • **Generation Fuel:** Renewable • **Interconnection Voltage:** Distribution voltage • **Other:** Have First Nations or Community involvement; not located in protected area	• **Base Price:** \$102 - \$110 / MWh
Net Metering Program[32]	• **Capacity:** ≤ 100 kW (BC Hydro); ≤ 50 kW (FortisBC) • **Generation Fuel:** Renewable • **Interconnection Voltage:** Distribution voltage • **Other:** Be owned or leased by and located on premise of a residential or general service customer	• **Base Price:** \$99.90 / MWh for net generation (BC Hydro)

Note: Renewable Resource, as defined in Standing Offer Program Rules, comprises biomass, biogas, geothermal heat, hydro, solar, ocean, wind or any biogenic waste, waste heat and any additional prescribed resources

The annual target volume accepted as part of the SOP and Micro-SOP programs is currently full, meaning that all new renewable energy project applications have been put on hold. In addition, the SOP and Micro-SOP programs are currently under review by the Province, so BC Hydro has suspended accepting any new applications for these programs until the review is complete[33]. As a result, the only incentive options currently available to producers in BC are through the Net Metering program.

6.1.2 Alberta

In Alberta, there is a *Micro-Generation Regulation* which allows Albertans to meet their own electricity needs by generating electricity from renewable energy sources[34]. Under this program, generators produce electricity for their own use and can receive credits for additional electricity sent back to the grid, making it a type of Net Metering program. Alberta also has two procurement programs specifically for acquiring solar energy and facilitating the implementation of solar projects for producers in Alberta. An overview of eligibility requirements and a measure of incentive opportunities are highlighted in Table 6.

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[30] BC Hydro. Standing Offer Program Rules. Link

[31] BC Hydro. Micro-SOP Program Rules. Link

[32] BC Hydro. Rate Schedule 1289 - Net Metering Service. Link

[33] BC Hydro. Standing Offer Program. Link

[34] Province of Alberta. Micro-Generation Regulation. Link

Table 6: Alberta Solar Incentive Program Overview

Program	Eligibility Requirements	Incentive
Net Metering under the *Micro-Generation Regulation*[35]	• **Capacity:** < 150 kW • **Generation Fuel:** Renewable • **Other:** The applicant has to be accepted by the Alberta Utilities Commission as a Small Micro-Generator.	• **Excess Power Tariff:** Retailer's retail electricity price
Residential and Commercial Solar Program[36]	• **Capacity:** Residential <15 kW, Commercial <5 MW • **Generation Fuel:** Solar PV • Must be grid-connected • **Other:** Must be approved under Alberta's Micro-Generation Legislation • Cannot be combined with incentives from any other provincial solar program in Alberta	• **Grant Amount**: $0.75 /Watt[37]
On-Farm Solar Photovoltaics Program[38]	• **Capacity:** ≤ 150 kW • **Generation Fuel:** Solar PV • **Other:** Applicant must have an Electrical Distribution Rate Class that is rated as Farm, or equivalent • Must be grid-connected • Must be approved under Alberta's Micro-Generation Legislation • Cannot be combined with incentives from any other provincial solar program in Alberta	• **Grant Amount:** ≤100 kW: $0.75/W to maximum 35% eligible cost share 100.01 – 150 kW: $0.56/W to maximum 27% eligible cost share

Although producers in Alberta can apply to any of the above listed options for developing on-farm solar PV, the producers cannot combine incentive programs, and thus, must choose the best option available to them.

6.1.3 Ontario

Most of the growth in renewable project development in Ontario has occurred by means of FIT and MicroFIT Programs, which promote the use of renewable energy sources including solar PV, on-shore wind, hydro, biomass, biogas, and landfill gas. Ontario also offers a Net Metering program option. An overview of eligibility requirements and a measure of incentive opportunities applicable for producers in Ontario are highlighted in Table 7.

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[35] Province of Alberta. Micro-Generation Regulation. Link

[36] Energy Efficiency Alberta. Residential and Commercial Solar Program. Link

[37] The maximum payable incentive of the lesser of $500,000 and 25% of eligible system costs for the commercial sector and the lesser of $10,000 and 30% of eligible system costs for the residential sector

[38] Government of Alberta. Growing Forward 2 – On-farm solar Photovoltaics. Link

Table 7: Ontario Solar Incentive Program Overview

Program	Eligibility Requirements	Incentive
FIT Program[39]	- **Capacity**: > 10 kW, < 500 kW - **Generation Fuel:** Renewable - **Interconnection Voltage:** Transmission or Distribution voltage - **Other:** Application fee will apply	- **Base Price (Rooftop PV):** > 10kW ≤ 100kW: $223/MWh > 100kW ≤ 500kW: $207/MWh
MicroFIT Program[40]	- **Capacity:** ≤ 10 kW - **Generation Fuel:** Renewable - **Interconnection Voltage:** Distribution voltage	- **Base Price (Rooftop):** ≤ 6kW: $311/MWh > 6kW ≤ 10kW: $288/MWh
Net Metering Program[41]	- **Capacity:** < 500 kW - **Generation Fuel:** Renewable - **Interconnection Voltage:** Distribution Voltage - **Other:** The generated electricity must be generated primarily for own use.	- **Excess Power Tariff:** Credit for future electrify bills will be received[42]

Depending on the size of rooftop solar PV, producers in Ontario have the option of applying to any of the above programs.

6.1.4 Arizona

Since the implementation of the REST program in Arizona, utilities have developed and implemented a variety of distributed generation incentive programs to encourage customers to install solar and other renewable energy technologies for their homes and businesses. However, for the purposes of this report, only the state-wide incentives, including various tax incentives and a Net Metering program have been reviewed and are summarized in Table 8 below.

Table 8: Arizona Solar Incentive Program Overview

Program	Eligibility Requirements	Incentive
Residential Income Tax Incentive[43]	- **Capacity:** Not Specified - **Generation Fuel:** Solar Energy - **Interconnection Voltage:** Not specified - **Other:** The individual has to install the system at their residence in the state of Arizona.	- **Tax Credit:** Tax credit on 25% (maximum $1000) of costs for buying and installing a solar energy device.
Non-Residential Income Tax Incentive[44]	- **Capacity:** Not Specified - **Generation Fuel:** Solar Energy - **Interconnection Voltage:** Not specified	- **Tax Credit:** Tax credit on 10%[45] of costs for buying and installing a solar energy device.

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[39] IESO. Feed-in Tariff Program. Link

[40] IESO. Micro-Fit Program. Link

[41] Ontario Energy Board. What Initiatives are Available? Link

[42] The credit will last for a maximum time period of 12 months.

[43] Arizona. 2015 Credit for Solar Energy Devices. Link

[44] Arizona Commerce Authority. Commercial / Industrial Solar Energy Tax Credit Program. Link

[45] Maximum $25,000 for one (1) building in the same year and maximum $50,000 per business in total tax credit

Program	Eligibility Requirements	Incentive
Property Tax Incentive[46]	• **Capacity:** Not specified • **Generation Fuel:** Renewable • **Interconnection Voltage:** Transmission or Distribution voltage	• **Tax Credit:** Solar Equipment is not assessed for property tax if the electricity is utilized on site.
Net Metering Program[47]	• **Capacity:** Not specified • **Generation Fuel:** Renewable or Combined Heat and Power • **Interconnection Voltage:** Distribution Voltage • **Other:** Currently, a monthly fee of $0.70/kW monthly fee is charged to owners • **Note:** Arizona Regulators voted to replace the retail rate net metering with a lower rate. However, that rate has yet to be finalized. • The size of a customer's Solar system is limited to a maximum of 125 percent of the customer's total connected load	• **Excess Power Tariff:** Credit for future electricity bills will be received; reconciled annually at the avoided-cost rate

Producers residing in the state of Arizona can benefit from the above listed programs and can also contact their local utility for additional incentive programs available with the potential to facilitate the implementation of solar PV on-farms.

6.2 Federal Incentive Programs

Mechanisms to support renewables can also be developed at a federal level by means of tax credit programs or accelerated capital cost allowance programs. Although there are no federal incentives specifically for residential solar PV projects in Canada, there are incentives for businesses which can also apply for agriculture producers. Examples of the Canada-based and U.S.-based federal incentives are summarized in Table 9.

Table 9: Federal Solar Incentive Program Overview

Program	Eligibility Requirements	Incentive
Capital Cost Allowance for Renewable Energy[48] **(Canada)**	• **Capacity:** Not specified • **Generation Fuel:** Renewable • **Interconnection Voltage:** Not specified • **Other:** Only businesses are able to apply	• **Cost Allowance:** Certain capital costs of Renewable system are eligible for accelerated capital cost allowance. Eligible equipment may be deducted 30% to 50% / year on a declining balance basis.

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[46] American Council on Renewable Energy (ACORE). Renewable Energy in Arizona. Link

[47] Arizona Corporation Commission. Net Metering. Link

[48] NRCAN. Technical Guide to Class 43.1 and 43.2. Link

Program	Eligibility Requirements	Incentive
Canadian Renewable and Conservation Expenses[49] (Canada)	• **Capacity:** Not specified • **Generation Fuel:** Renewable • **Interconnection Voltage:** Not specified • **Other:** Only businesses are able to apply	• **Tax Credit:** Certain expenses related to development of a renewable system are 100% written-off. E.g. GHI Data Resource, Determine technology and capacity of system
The Solar Investment Tax Credit[50] (U.S.)	• **Capacity:** Not Specified • **Generation Fuel:** Solar Energy • **Interconnection Voltage:** Not specified	• **Tax Credit:** Federal tax credit of 30% claimed against the tax liability of investors in solar energy property.

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[49] NRCAN. Technical Guide to Canadian Renewable and Conservation Expenses. Link

[50] Solar Energy Industries Association (SEIA). ITC Fact Sheet. Link

7 Challenges & Risks in BC

As discussed in the previous sections, ongoing solar technology improvements, downward trends in solar costs, and solar-related policies and incentive programs have facilitated and promoted the development of solar PV projects throughout North America. Historical trends tend to be indicative of future trends, therefore it is reasonable to assume continued growth of solar projects across North America going forward.

Despite what the historical trends indicate, there are still various challenges and risks to developing solar projects in BC. Examples of challenges and risks specific to BC, are summarized below.

1. **Low Solar Irradiance -** In northern latitudes and cloudy/rainy/snowy climates, available solar irradiance is lower than closer to the equator and in sunnier locations. Solar panel efficiencies are improving over time, but location and climate are important factors in total solar energy production.
2. **Inexpensive Grid Supplied Electricity Costs -** BC's grid supplied electricity costs are among the lowest in North America. Although installed solar costs have decreased by over 60% in the last 7 years and cost reductions will continue, grid supplied electricity will remain less expensive than BC based solar generation in the coming years.

8 Viability of Rooftop Solar in BC

Building upon the review of solar-related trends, benefits and opportunities for agricultural producers looking to develop rooftop solar PV projects in various regions across North America, the remainder of the report focuses on the viability of implementing rooftop solar projects on either dairy, poultry, or vineyard & winery-type farms located in three regions of BC: Vancouver Island, Fraser Valley, and the Okanagan.

The viability of rooftop solar will be evaluated and discussed in terms of economic, environmental and social impacts. First, a flowchart is described for determining the optimal rooftop solar PV capacity (measured in kW) for a farm, and estimating the associated annual electricity production (measured in kWh/year). Next, approaches for gathering baseline data pertaining to farm operations, historical electricity usage, solar suitability, and perception of solar and other renewable energies is described, and then key findings are summarized.

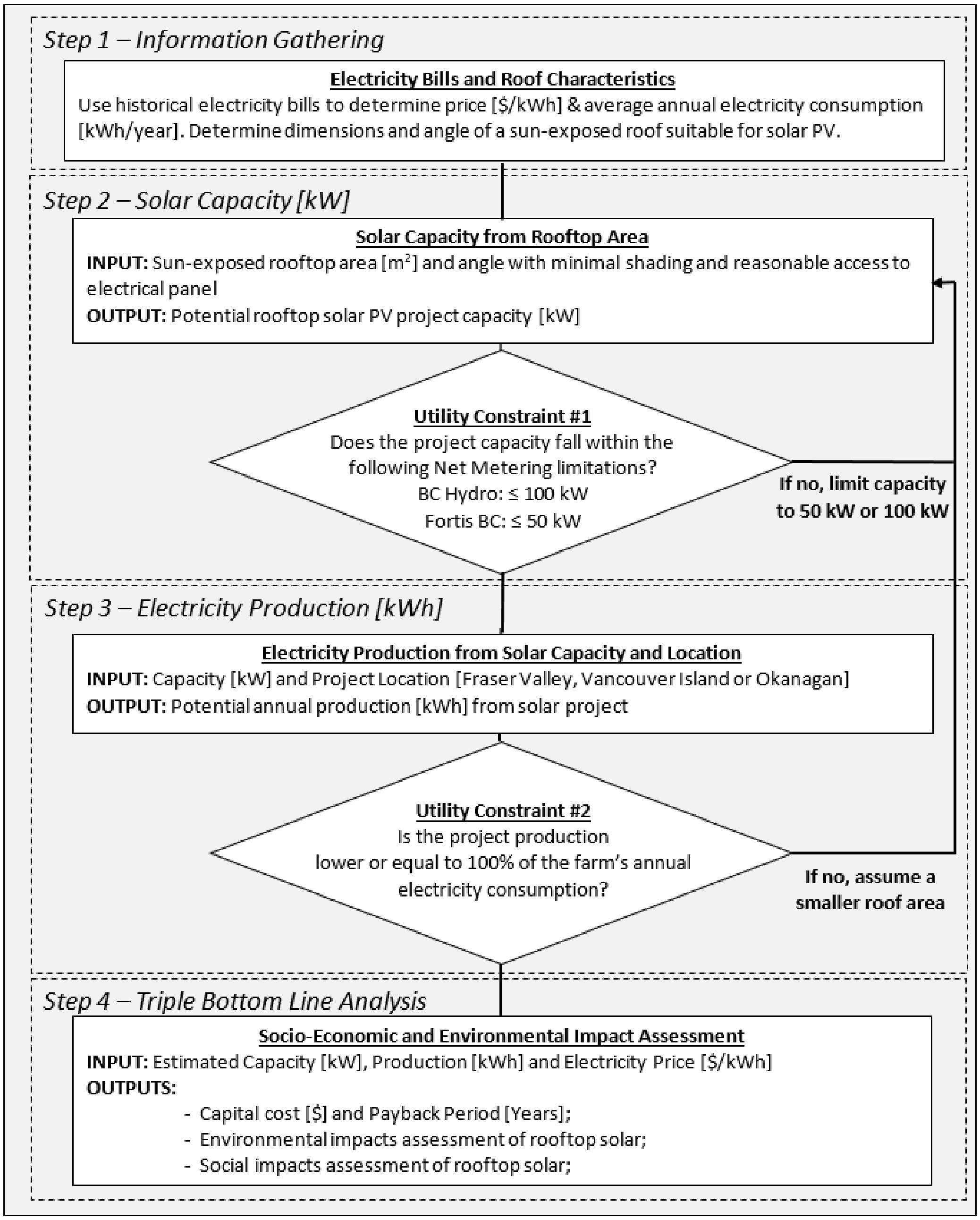
To facilitate flowchart implementation for the intended audience (e.g. farm owners), a representative set of scenarios (one scenario for each type of producer) was selected from the baseline data received and passed through the flowchart to determine the optimal solar project capacity and annual production. The scenarios are informative and fall within the bounds of the provided survey data, and other producers should be able to follow a similar process while estimating the potential rooftop solar project capacity and annual production specific to their operations. The economic, environmental and social impact assessment is introduced and findings summarized.

8.1 Approach

To estimate the capital cost and payback period for a rooftop solar project, two key inputs are the estimated rooftop solar capacity (in kW) and corresponding annual production (in kWh per year). These will vary between producers and farm types since these inputs are dependent on factors such as GHI (location specific), rooftop area & sun-exposure, annual electricity requirements, and local utility requirements for interconnection.

To obtain realistic inputs for the economic analysis, the following flowchart was developed taking producer-specific variables into consideration.

Figure 6: Flowchart



The flowchart helps producers estimate their potential rooftop solar capacity and resulting annual electricity production based on their specific situation. Solar capacity and energy production can then be input into a socio-economic and environmental impact assessment to help determine the potential impacts and benefits of their project, and to estimate the capital cost and payback period for their specific project. At each step in the process, a matrix of possible inputs and outputs is presented to facilitate the producer's participation in the process and to determine the best possible solution under specific circumstances.

Steps 1 through 4 of the flowchart are described in the following sections.

8.2 Step 1: Information Gathering

The first step of the flowchart is to gather the information required to complete the flowchart process. The following is a list of information required from the producer to reasonably estimate a rooftop solar PV capacity:

1) Historical Electricity Usage: Gather electricity bills to determine the average annual electricity consumption in kWh/year;
2) Electricity Price: Gather your most recent electricity bill to determine the price of electricity (e.g. energy charge) in $/kWh[51].
3) Roof Characteristics: Identify the horizontal roof area (length x width), type of roof (flat, pitched), and the roof angle (if pitched) of a sun-exposed roof most suitable for rooftop solar PV (e.g. ideally south facing with little to no shade); and
4) Electrical Service: Confirm reasonable access to an existing electrical panel.

8.3 Step 2: Solar Capacity

In step 2, the potential rooftop solar project capacity will be estimated based on the horizontal roof dimensions and roof angle under the assumption that the sun-exposed roof is south facing. The following matrix provides a variety of rooftop-related inputs based on the bounds of the information received, and corresponding outputs derived using an algorithm for determining the potential solar project capacity. Please refer to Appendix A: Matrix A for additional details on how these numbers were derived, and Appendix B: High-Resolution Matrices for additional input/output combinations.

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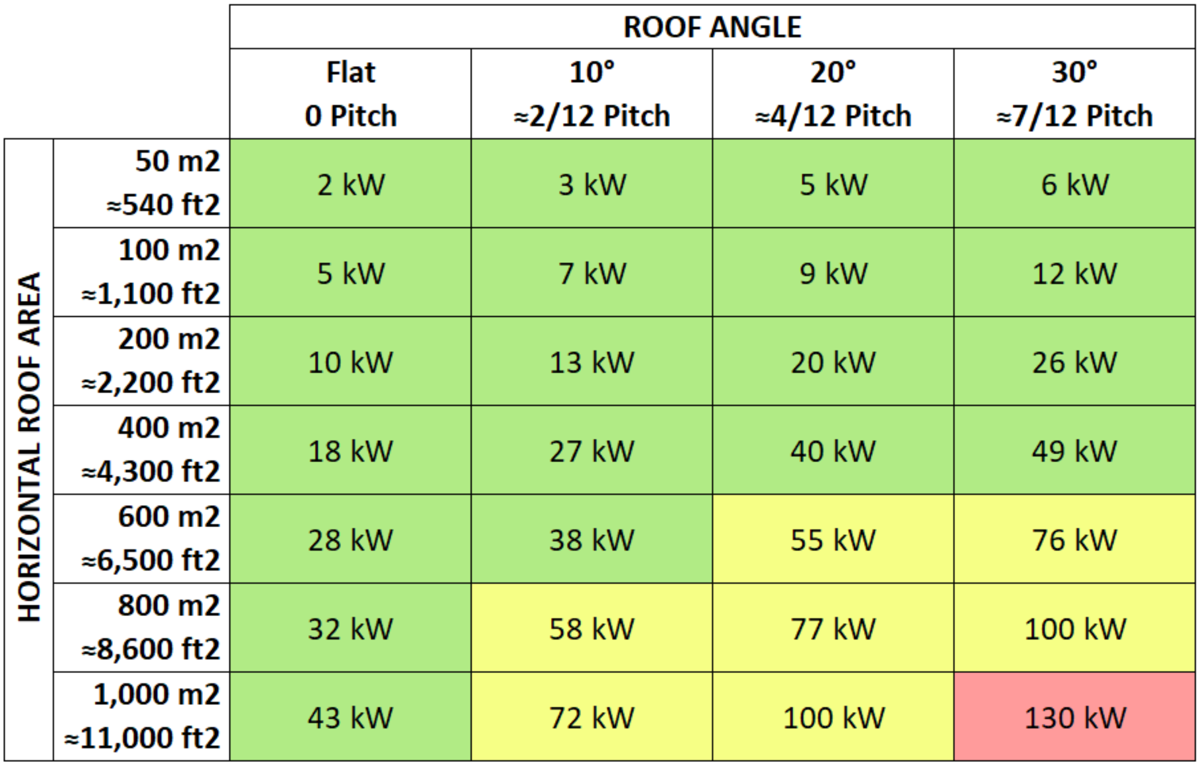
[51] In addition to an energy charge, electricity bills may also include a basic charge and a demand charge. The basic charge covers general cost of service items such as metering and billing, and the demand charge is related to the peak power needed during a billing period. For the purposes of this analysis, only the energy charge is considered because that basic charge will not change with a solar installation, the peak demand may not be altered by a solar installation (e.g. if the peak demand occurs after the sun has set), and since the energy charge is what the potential cost savings from a rooftop solar project will be applied against.

Table 10: Solar Capacity Matrix



		ROOF ANGLE			
		Flat 0 Pitch	10° ≈2/12 Pitch	20° ≈4/12 Pitch	30° ≈7/12 Pitch
HORIZONTAL ROOF AREA	50 m2 ≈540 ft2	2 kW	3 kW	5 kW	6 kW
	100 m2 ≈1,100 ft2	5 kW	7 kW	9 kW	12 kW
	200 m2 ≈2,200 ft2	10 kW	13 kW	20 kW	26 kW
	400 m2 ≈4,300 ft2	18 kW	27 kW	40 kW	49 kW
	600 m2 ≈6,500 ft2	28 kW	38 kW	55 kW	76 kW
	800 m2 ≈8,600 ft2	32 kW	58 kW	77 kW	100 kW
	1,000 m2 ≈11,000 ft2	43 kW	72 kW	100 kW	130 kW

Using the above matrix, typical producers should be able to place themselves somewhere within the matrix to determine the potential size of rooftop solar. If the inputs don't match up exactly, producers can either estimate a capacity that falls within the range of applicable capacities, or select the smaller of the two capacity options.

8.3.1 Utility Constraint #1

In BC, mechanisms to facilitate implementation of renewable energy projects such as solar PV can vary in terms of objectives, level of support and overall design constraints. The most feasible programs currently available for acquiring energy and for facilitating the implementation of solar projects in BC are typically Net Metering programs, such as those offered through BC Hydro and Fortis BC [52]. Net Metering programs allow customers to generate their own electricity to offset purchased power and sell any excess production to the grid. The Net Metering requirements offered by both BC Hydro and Fortis BC are summarized in Table 11 below.

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[52] Net Metering programs offered by BC Hydro and FortisBC are the focus of this report as their service territories cover the vast majority of BC. Other municipal utilities have Net Metering programs as well. For example, the District of Summerland has a Net Metering program, but it's currently under review so there is no information available online. The City of Penticton also has a Net Metering program, but their design capacity is up to 300 kW, which will significantly change the matrices and possible input/output combinations. To simplify the discussion, net metering programs from smaller-scale municipal electric utilities, such as the District of Summerland and the City of Penticton, have not been described in this report.

Table 11: Net Metering Program Requirements

Utility	Eligibility Requirements
BC Hydro[53]	• **Design Capacity:** ≤ 100 kW • **Generation Fuel:** Clean or Renewable Resource[54] • **Interconnection Voltage:** Distribution voltage • **Rate Schedules:** Applicable to any Residential Service Customer[55] and any General Service Customer[56] • **Location:** Be owned or leased by and located on the same parcel of land as the Customer's premises • **Other:** Must apply and receive consent from BC Hydro
FortisBC[57]	• **Design Capacity:** ≤ 50 kW • **Generation Fuel:** Clean or Renewable Resource[54] • **Interconnection Voltage:** Distribution voltage • **Rate Schedules:** Applicable to any Residential Service Customers[58], Commercial Service Customers[59] (excluding large commercial service), and Irrigation and Drainage Customers[60]. • **Location:** Located on the Customer-Generator's Premises • **Other:** Must apply and receive consent form FortisBC

The project capacities included in the Solar Capacity Matrix (Table 10) are categorized by three different colors:

- Green cells represent projects below or equal to 50 kW;
- Yellow cells represent projects between 50 to 100 kW; and
- Red cells represent projects larger than 100 kW.

The three colour categorization is important since producers will have to comply with capacity limitations to qualify for their specific utility's Net Metering program. Based on the Net Metering requirements outlined in Table 11, project capacities identified by green cells are eligible under either the BC Hydro or the FortisBC Net Metering programs. Project capacities identified by yellow cells exceed the FortisBC requirements but are eligible under the BC Hydro Net Metering program, and

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[53] BC Hydro. Rate Schedule 1289 – Net Metering Service. Link

[54] Clean or renewable resources include sources of energy that are constantly renewed by natural processes, such as water power, solar energy, wind energy, geothermal energy, wood residue energy, and energy from organic municipal waste.

[55] Residential Service Rate Schedules include: 1101, 1121, 1105, 1107, 1127, 1148, 1151, and 1161. Farms are typically included under the Exempt Residential Service (Rate Schedule 1151, 1161)

[56] General Service Rate Schedules include: 1200, 1201, 1210, 1211, 1205, 1206, 1207, 1234, 1253, 1255, 1256, 1265, 1266, 1268, 1278, 1280, 1300, 1301, 1310, 1311, 1500, 1501, 1510, 1511, 1600, 1601, 1610, and 1611.

[57] FortisBC. Schedule 95 – Net Metering. Link

[58] Applicable Residential Service Rate Schedules includes: 1 and 2A. Exempt residential services, including customers in FortisBC's Residential Conservation Rate control group (Schedule 3) and farms (Schedule 3A), are not eligible under the Net Metering program. If customers under Schedule 3 or 3A want to apply for Net Metering, one option is to switch to other rate schedules applicable under the program.

[59] Applicable Commercial Service Rate Schedules include: 20, 21, 22A, and 23A.

[60] Applicable Irrigation and Drainage Rate Schedules include: 60 and 61.

project capacities identified by red cells exceed both the FortisBC and BC Hydro Net Metering program requirements[61].

Based on the Net Metering capacity constraints, producers should choose the lesser of their estimated solar capacity potential or their utility's maximum allowable Net Metering capacity.

8.4 Step 3: Electricity Production

The estimated solar project capacity determined in Step 2 will be used to estimate the project's annual electricity production (in kWh/year) based on approximate project location.

To estimate the project's annual electricity production, a capacity factor[62] is required. The capacity factor for a solar PV system is highly dependent on the available solar irradiation of a region. An algorithm was derived to determine average capacity factors in each of the three regions (Okanagan, Fraser Valley, and Vancouver Island) for project sizes up to 100 kW. Based on project capacity, location, and associated capacity factor, the following matrix was derived to provide a range of estimated annual electricity production outputs for various combinations of inputs.

Please refer to Appendix A: Matrix A for additional details on how these numbers were derived, and Appendix B: High-Resolution Matrices for additional input/output combinations.

Table 12: Electricity Production Matrix by Location and Project Size[63]

		SOLAR CAPACITY						
		5 kW	10 kW	20 kW	40 kW	60 kW	80 kW	100 kW
LOCATION	Okanagan	8,800 kWh	18,000 kWh	36,000 kWh	72,000 kWh	110,000 kWh	150,000 kWh	180,000 kWh
	Fraser Valley	8,100 kWh	16,000 kWh	33,000 kWh	67,000 kWh	100,000 kWh	130,000 kWh	170,000 kWh
	Vancouver Island	8,300 kWh	17,000 kWh	34,000 kWh	68,000 kWh	100,000 kWh	140,000 kWh	170,000 kWh

8.4.1 Utility Constraint #2

In accordance with the BC Hydro and FortisBC Net Metering requirements, when Net Metering program customers are a net consumer of energy over a specified timeframe (e.g. energy consumption is > 0 kWh for a billing period), they are billed for their net consumption in accordance with the applicable Rate Schedule under which they are receiving service.

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[61] Note: Some smaller-scale utilities (e.g. City of Penticton) have higher Net Metering capacity limits (e.g. 300 kW), but for simplicity net metering programs from smaller-scale municipal electric utilities have not been described.

[62] Capacity factors represent the ratio of electricity produced over a normal year divided by electricity produced if the generator is producing at its rated power every hour for a full year.

[63] Note: The estimated annual electricity production numbers are meant to be indicative of the potential electricity production from a rooftop solar PV project. The actual production numbers will vary based on actual project location and orientation, on equipment selected, and on the amount of shading, for example.

Similarly, when Net Metering program customers are net generators of energy over a specified timeframe (i.e. energy consumption is < 0 kWh for a billing period), the excess generation is valued at the rates specified in the applicable Rate Schedule under which they are receiving service and this amount is credited to the customer's account.

If, at the end of the calendar year, a customer has a net generation credit balance remaining, the credit can either be carried over to the next billing cycle or be purchased by the utility (e.g. BC Hydro will pay 9.99 cents per kWh of net generation). Net Metering programs are not intended to encourage customers to build projects that constantly exceed their annual electricity requirements, rather, these programs are intended to help offset a portion or all the customer's electricity requirements.

It is assumed that the target maximum size of a Net Metering solar installation should be less than or equal to 100% of the farm's annual electricity consumption requirements.

Based on this assumption, the next step is to compare the solar project's resulting annual production with the farm's average annual electricity consumption in kWh/year (from Step 1). If the projected annual solar production is less than or equal to 100% of the farm's annual electricity requirements, the project is appropriately sized. However, if the solar project production is more than approximately 100%[64] of the farm's annual electricity consumption, then the solar project is potentially oversized and should be re-evaluated for a lower installed capacity (and smaller roof area) by repeating Steps 1 through 3 until an appropriate annual production number is determined.

8.5 Step 4: Triple Bottom Line Analysis

Once the solar project capacity and associated annual production is estimated, the final step is to complete a socio-economic and environmental analysis (also referred to as a triple bottom line analysis) that estimates the project's all-in cost and payback period and determines the potential impacts and benefits of a solar PV project.

8.5.1 Economic Analysis

The following three parameters from previous steps will be used to estimate the project's all-in cost, average annual savings, and payback period:

1. Electricity price (in $/kWh) gathered in Step 1;
2. Solar capacity (in kW) determined in Step 2[65]; and
3. Electricity production (in kWh/year) determined in Step 3.

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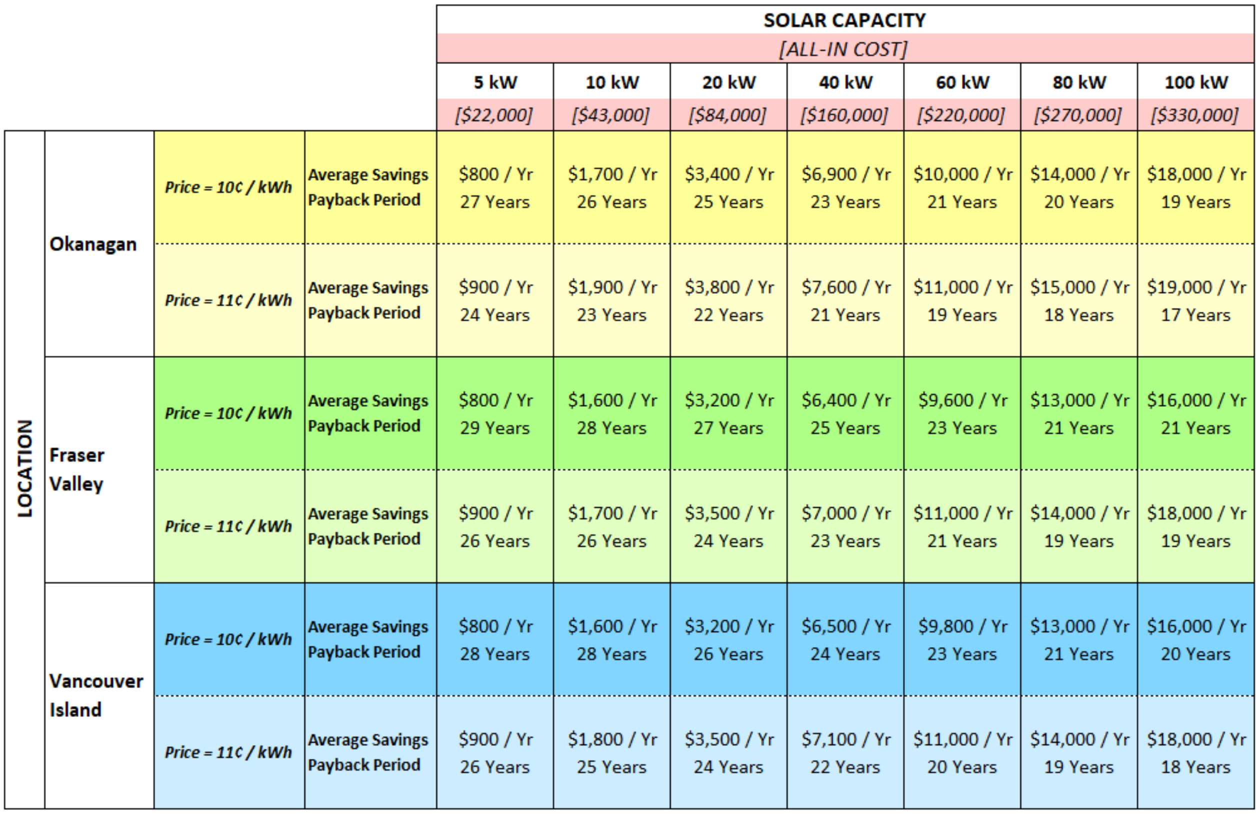
[64] Note: solar installations that are projected to produce slightly more than 100% of the farm's annual electricity requirements are likely acceptable since solar panel efficiency will degrade over time.

[65] The all-in cost estimate, which is dependent on the solar capacity, was derived based on the National Renewable Energy Laboratory's 2017 U.S. Solar Photovoltaic System Cost Benchmark study, which was previously discussed in Section 0.

The following economic analysis matrix calculates the all-in solar project cost, average annual savings, and total payback period based on solar capacity, location, and electricity price. Please refer to Appendix A: Matrix A for additional details on how these numbers were derived, and Appendix B: High-Resolution Matrices for additional input/output combinations.

Table 13: Economic Analysis Matrix



				SOLAR CAPACITY						
				[ALL-IN COST]						
				5 kW	**10 kW**	**20 kW**	**40 kW**	**60 kW**	**80 kW**	**100 kW**
				[$22,000]	[$43,000]	[$84,000]	[$160,000]	[$220,000]	[$270,000]	[$330,000]
LOCATION	**Okanagan**	Price = 10¢ / kWh	Average Savings Payback Period	$800 / Yr 27 Years	$1,700 / Yr 26 Years	$3,400 / Yr 25 Years	$6,900 / Yr 23 Years	$10,000 / Yr 21 Years	$14,000 / Yr 20 Years	$18,000 / Yr 19 Years
		Price = 11¢ / kWh	Average Savings Payback Period	$900 / Yr 24 Years	$1,900 / Yr 23 Years	$3,800 / Yr 22 Years	$7,600 / Yr 21 Years	$11,000 / Yr 19 Years	$15,000 / Yr 18 Years	$19,000 / Yr 17 Years
	Fraser Valley	Price = 10¢ / kWh	Average Savings Payback Period	$800 / Yr 29 Years	$1,600 / Yr 28 Years	$3,200 / Yr 27 Years	$6,400 / Yr 25 Years	$9,600 / Yr 23 Years	$13,000 / Yr 21 Years	$16,000 / Yr 21 Years
		Price = 11¢ / kWh	Average Savings Payback Period	$900 / Yr 26 Years	$1,700 / Yr 26 Years	$3,500 / Yr 24 Years	$7,000 / Yr 23 Years	$11,000 / Yr 21 Years	$14,000 / Yr 19 Years	$18,000 / Yr 19 Years
	Vancouver Island	Price = 10¢ / kWh	Average Savings Payback Period	$800 / Yr 28 Years	$1,600 / Yr 28 Years	$3,200 / Yr 26 Years	$6,500 / Yr 24 Years	$9,800 / Yr 23 Years	$13,000 / Yr 21 Years	$16,000 / Yr 20 Years
		Price = 11¢ / kWh	Average Savings Payback Period	$900 / Yr 26 Years	$1,800 / Yr 25 Years	$3,500 / Yr 24 Years	$7,100 / Yr 22 Years	$11,000 / Yr 20 Years	$14,000 / Yr 19 Years	$18,000 / Yr 18 Years

An alternative approach to using the above economic analysis matrix (Table 13) is the following formula. Please refer to Appendix A: Matrix A for additional details on how this formula was derived.

$$Payback\ Period\ [Years] = \frac{All - In\ \ Cost\ [\$]}{Annual\ Solar\ Production\ \left[\frac{kWh}{Year}\right] * Electricity\ Price\ \left[\frac{\$}{kWh}\right] * 0.95}$$

Because the economic analysis matrix will become obsolete with a change in all-in cost or electricity price, the above formula can be updated with revised all-in cost, electricity price, and annual solar production estimates.

8.5.2 Environmental & Social Impact Assessment

A desktop analysis of potential environmental and social impacts was conducted by reviewing available literature in regions where on-farm installations have been instituted, such as in Alberta, Europe and the U.S.. Other grey literature[66] sourced included PV cell manufacturers, BC Hydro, lobby groups, associations and solar installers. Perception information was gleaned from grey literature, a survey sent to a subset of farmers in BC asking for their opinions on solar power, and a BC Hydro survey provided to their Net Metering program participants regarding their satisfaction with the Net Metering program.

The potential environmental and social impacts of rooftop solar PV projects were categorized based on the following severity ranking:

1. **High** = impact is substantial and could be considered a major obstacle as far as feasibility, delivery or success of the project. It would be very difficult to mitigate.
2. **Medium** = impact is present and can be partially mitigated; other factors such as duration, frequency, geographical extent may influence this impact.
3. **Low** = there is an impact, but it can be fully mitigated.
4. **None** = there is no impact perceived.

For additional information, please refer to Appendix C: Socio-Environmental Analysis of Implementing Solar Electricity On-Farm*.*

8.5.2.1 GHG Production

Impacts on air quality were reviewed in the context of the GHG produced during the life-cycle of PV cells from obtaining the raw materials to installation on the farm and disposal. For an analysis of GHG emissions per kWh of panel installed throughout the fabrication, procurement, installation, and decommissioning phases of a Solar PV project, please refer to Appendix C: Socio-Environmental Analysis of Implementing Solar Electricity On-Farm*.*

Solar PV systems emit no GHGs or air pollutants during normal operation, natural gas baseline scenarios[67] were developed to show the potential emission savings of solar generation versus natural gas generation. In order to estimate a solar project's potential emission savings, an algorithm was derived to determine average annual CO_2 emissions associated with the annual production numbers derived for the systems in Step 3, assuming the electricity generation fuel was natural gas instead of the sun.

The following matrix was derived to provide a range of estimated annual emissions (in carbon dioxide equivalence, CO_2eq) for various combinations of inputs. Please refer to Appendix A: Matrix A for additional details on how these numbers were derived, and Appendix B: High-Resolution Matrices for additional input/output combinations.

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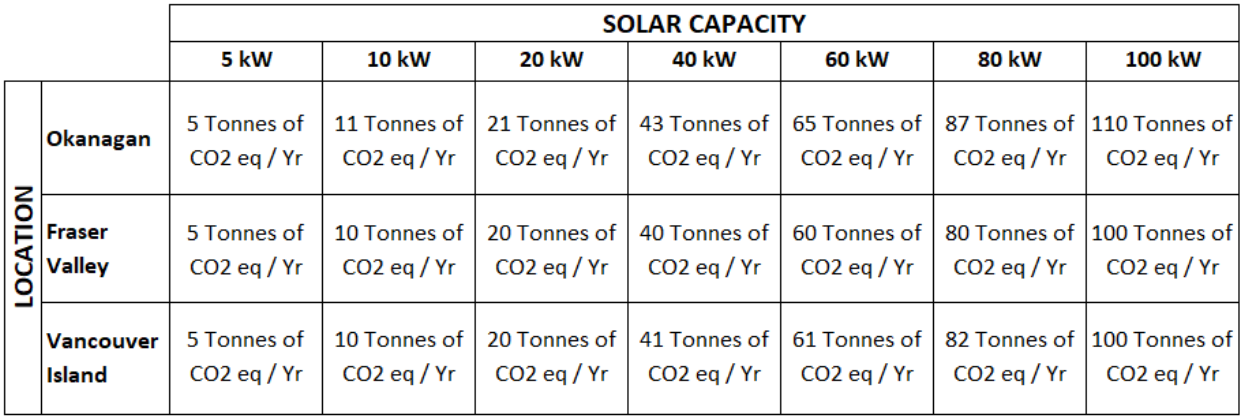
[66] Grey literature refers to literature that is not based on materials from academic-based distribution channels (e.g. material from PV cell manufacturers, BC Hydro, lobby groups, associations and solar installers and not academic-based (peer reviewed) channels.

[67] Since over 90% of BC's electricity is currently being supplied from hydroelectric generating stations and the remainder is mainly supplied by natural gas, natural gas is the assumed marginal fuel to be offset for the purposes of this analysis.

Table 14: GHG Emissions Matrix



		SOLAR CAPACITY						
		5 kW	10 kW	20 kW	40 kW	60 kW	80 kW	100 kW
LOCATION	**Okanagan**	5 Tonnes of CO2 eq / Yr	11 Tonnes of CO2 eq / Yr	21 Tonnes of CO2 eq / Yr	43 Tonnes of CO2 eq / Yr	65 Tonnes of CO2 eq / Yr	87 Tonnes of CO2 eq / Yr	110 Tonnes of CO2 eq / Yr
	Fraser Valley	5 Tonnes of CO2 eq / Yr	10 Tonnes of CO2 eq / Yr	20 Tonnes of CO2 eq / Yr	40 Tonnes of CO2 eq / Yr	60 Tonnes of CO2 eq / Yr	80 Tonnes of CO2 eq / Yr	100 Tonnes of CO2 eq / Yr
	Vancouver Island	5 Tonnes of CO2 eq / Yr	10 Tonnes of CO2 eq / Yr	20 Tonnes of CO2 eq / Yr	41 Tonnes of CO2 eq / Yr	61 Tonnes of CO2 eq / Yr	82 Tonnes of CO2 eq / Yr	100 Tonnes of CO2 eq / Yr

9 Baseline Producer Data

To provide an example of how to use the flowchart and test messaging for intended newsletter audiences, baseline producer data is required. The Ministry of Agriculture provided Midgard a list of 15 producers to approach within the Fraser Valley, Okanagan, and Vancouver Island regions. The list included 5 dairy producers, 4 poultry producers, and 6 vineyard and winery producers. Correspondence with each producer was via email and/or telephone.

Surveys were developed for each type of producer assessed. The surveys included questions pertaining to operations, electricity usage and solar suitability, and also included general questions on perception of solar and other renewable technologies. Examples of these surveys are included in Appendix D: Blank Producer Surveys.

Midgard collaborated with producers and with their respective electricity utility providers to obtain historical electricity consumption data on either a monthly or bimonthly basis. Producers serviced by BC Hydro were required to fill out a BC Hydro Customer Account Information Request Form, and producers serviced by Fortis BC or other districts within the Okanagan region (e.g. District of Summerland) were required to fill out application forms developed by Midgard. Examples of both consent forms are provided in Appendix E: Consent Forms.

9.1 Survey Results

Among the 15 producers approached, 11 agreed to complete a survey. For confidentiality reasons, each producer was assigned a Farm ID number between 1 and 11 to allow tracking after the removal of all other identifying information. Table 15 provides a summary of the producer survey results, including farm type, the region where the farm is located, approximate roof area most suitable for rooftop solar, and annual production. Detailed survey results are included in Appendix F: Survey Results.

Table 15: Summary of Survey Results

Farm ID	Producer Type	Region	Horizontal Roof Area[1] [m^2]	Approximate Annual Production
1	Dairy	Okanagan	900	1,300,000 L of milk
2	Dairy	Okanagan	2,500	2,500,000 L of milk
3	Dairy	Okanagan	1,000	752,000 L of milk
4	Dairy	Fraser Valley	750	1,200,000 L of milk
5	Poultry	Fraser Valley	800	1,200,000 kg of meat
6	Poultry	Vancouver Island	600	1,300 kg of meat
7	Poultry	Fraser Valley	1,100	600,000 kg of meat
8	Vineyards and Wineries	Okanagan	200	100,000 L of wine
9	Vineyards and Wineries	Okanagan	200	18,000 L of wine

Farm ID	Producer Type	Region	Horizontal Roof Area[1] [m^2]	Approximate Annual Production
10	Vineyards and Wineries	Vancouver Island	600	58,500 L of wine
11	Vineyards and Wineries	Vancouver Island	400	40,500 L of wine

Note 1: Approximate roof area was derived from survey results and Google Earth imagery.

Of the 11 producers who provided survey results, 8 sets of historical electricity consumption data ranging from 2012 to 2017 were received. Table 16 provides a summary of each producer's electricity consumption related data, including utility provider, the applicable rate schedule, electricity price, and the average annual electricity consumption. Raw historical consumption datasets (with personal information removed) are included in Appendix G: Historical Consumption Data.

Table 16: Summary of Electricity Consumption Results

Farm ID	Utility Provider	Rate Schedule	Electricity Price [Energy Charge Only]	Average Electricity Consumption
3	BC Hydro	Rate Schedule 1151: Exempt Residential Rate	0.1028 $/kWh	92,000 kWh/Yr
5	BC Hydro	Rate Schedule 1151: Exempt Residential Rate	0.1028 $/kWh	74,000 kWh/Yr
6	BC Hydro	Rate Schedule 1300: Small General Service [< 35 kW]	0.1139 $/kWh;	44,000 kWh/Yr
7	BC Hydro	Rate Schedule 1151: Exempt Residential Rate	0.1028 $/kWh;	160,000 kWh/Yr
8	FortisBC	Rate Schedule 20: Small Commercial Service Rate	0.10195 $/kWh	76,000 kWh/Yr
9	District of Summerland	Rate Schedule E01: Residential	0.1143 $/kWh [<1000 kWh/month] 0.1257 $/kWh [>1000 kWh/month]	95,000 kWh/Yr
10	BC Hydro	Rate Schedule 1500: Medium General Service [> 35 kW, < 150 kW]	0.880 $/kWh	130,000 kWh/Yr
11	BC Hydro	Rate Schedule 1500: Medium General Service [> 35 kW, < 150 kW]	0.880 $/kWh	190,000 kWh/Yr

Based on the sample data received, the applicable electricity price and the electricity consumption data varies significantly between producers based on farm size, production levels, farm loads and equipment, peak production periods, and seasonal variances between regions.

To demonstrate flowchart usability by the intended audiences, a representative producer scenario (one for each type of producer) was selected as an exemplar to be passed through the flowchart process to determine potential project size and production. Although the chosen scenarios may not necessarily be the most common or average producer scenario, they are informative within the flowchart context (e.g. they exercise the flowchart to illustrate salient features of the flowchart), and they fall within the bounds of what was provided.

The following representative producer scenarios have been selected:

- **Dairy** - Farm ID 3
- **Poultry** - Farm ID 5
- **Vineyards & Wineries** - Farm ID 8

10 Representative Producer Scenarios

To provide an example of how to use the flowchart and test messaging for intended newsletter audiences, Steps 1 through 4 have been exercised based on the representative dairy, poultry and wine producer scenarios selected in Section 9.

10.1 Step 1: Information Gathering

The representative producer scenario information required to complete the flowchart process is summarized in the following table.

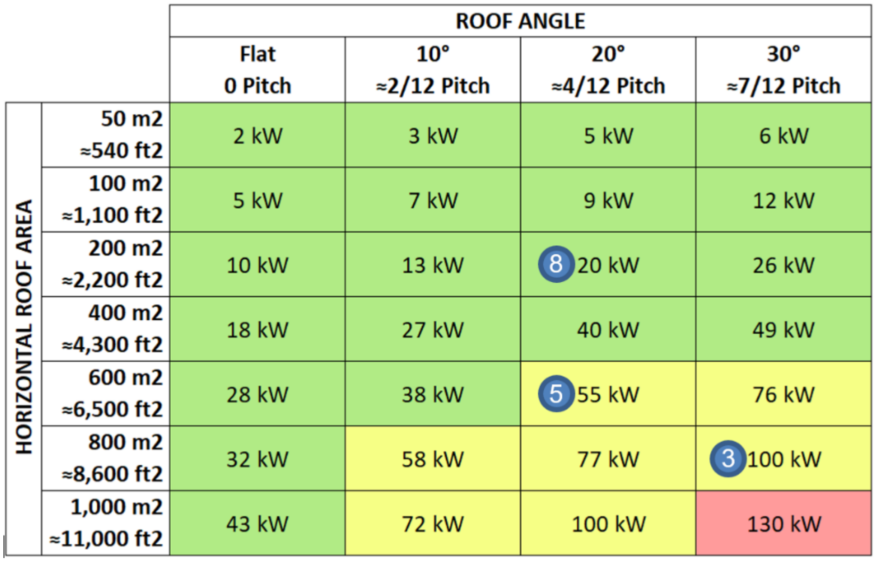
Table 17: Representative Producer Scenarios – Information Gathering Results

Farm ID	Producer Type	Region	Horizontal Roof Area	Approximate Roof Angle	Electricity Price	Average Electricity Consumption
3	Dairy	Okanagan	1,000 m^2	30°	\$0.1028 / kWh	92,000 kWh/Yr
5	Poultry	Fraser Valley	800 m^2	20°	\$0.1028/ kWh	74,000 kWh/Yr
8	Vineyards and Wineries	Okanagan	200 m^2	20°	\$0.10195/ kWh	76,000 kWh/Yr

10.2 Step 2: Solar Capacity

Based on the horizontal roof area and roof angles identified in Step 1 (Table 17), the representative producer scenarios are identified in the following solar capacity matrix by the ● symbol.

Table 18: Solar Capacity Matrix – Representative Producer Scenario Placement



		ROOF ANGLE			
		Flat 0 Pitch	10° ≈2/12 Pitch	20° ≈4/12 Pitch	30° ≈7/12 Pitch
HORIZONTAL ROOF AREA	50 m2 ≈540 ft2	2 kW	3 kW	5 kW	6 kW
	100 m2 ≈1,100 ft2	5 kW	7 kW	9 kW	12 kW
	200 m2 ≈2,200 ft2	10 kW	13 kW	⑧ 20 kW	26 kW
	400 m2 ≈4,300 ft2	18 kW	27 kW	40 kW	49 kW
	600 m2 ≈6,500 ft2	28 kW	38 kW	⑤ 55 kW	76 kW
	800 m2 ≈8,600 ft2	32 kW	58 kW	77 kW	③ 100 kW
	1,000 m2 ≈11,000 ft2	43 kW	72 kW	100 kW	130 kW

The resulting matrix outputs indicate potential rooftop solar capacities of 130 kW, 77 kW, and 20 kW for Farm ID 3, Farm ID 5, and Farm ID 8, respectively.

10.2.1 Utility Constraint #1

The representative producer scenario capacities, associated utility providers, and applicable Net Metering constraints are summarized in Table 19.

Table 19: Utility Constraint #1

Farm ID	Producer Type	Potential Solar Capacity	Utility Provider	Net Metering Constraints	Does it Comply?	Revised Solar Capacity
3	Dairy	130 kW	BC Hydro	≤ 100 kW	**No**	100 kW
5	Poultry	77 kW	BC Hydro	≤ 100 kW	Yes	n/a
8	Vineyards and Wineries	20 kW	FortisBC	≤ 50 kW	Yes	n/a

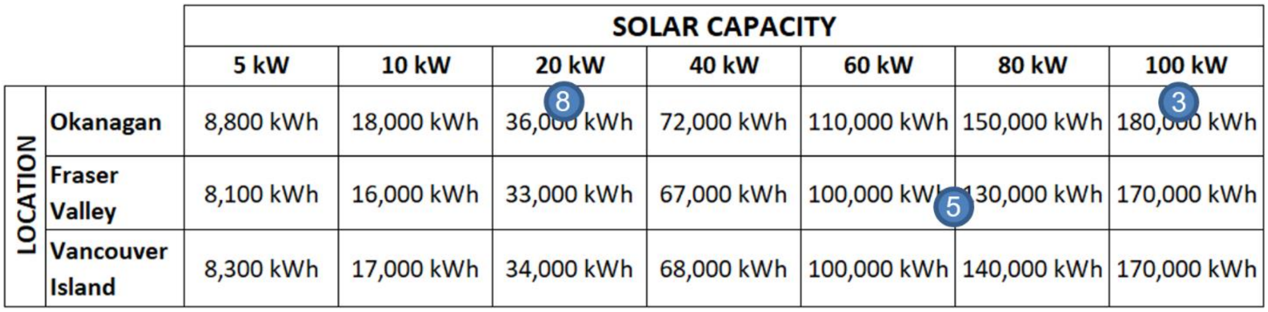
In the event that the project capacity exceeds the applicable Net Metering constraints, project capacity is restricted to the allowable capacity under Net Metering requirements (e.g. 50 kW for Fortis BC customer or 100 kW for a BC Hydro customer). Based on the above information, Farm ID 3 does not comply with the BC Hydro Net Metering constraints. The revised solar capacity for Farm ID 3 will therefore be reduced from 130 kW to 100 kW.

Since the capacities for Farm ID 5 and Farm ID 8 are within their respective Net Metering program constraints, there are no further compliances issues.

10.3 Step 3: Electricity Production

Based on the solar capacities determined in Step 2 and on the representative producer scenario locations (Farm ID 5 is located in Fraser Valley, and Farm ID 3 and 8 are both located in the Okanagan region), the placement of the representative producer scenarios in the Electricity Production Matrix is identified by the ● symbol in Table 20 below.

Table 20: Electricity Production Matrix - Representative Producer Scenario Placement



		SOLAR CAPACITY						
		5 kW	**10 kW**	**20 kW**	**40 kW**	**60 kW**	**80 kW**	**100 kW**
LOCATION	**Okanagan**	8,800 kWh	18,000 kWh	⑧ 36,000 kWh	72,000 kWh	110,000 kWh	150,000 kWh	③ 180,000 kWh
	Fraser Valley	8,100 kWh	16,000 kWh	33,000 kWh	67,000 kWh	100,000 kWh	⑤ 130,000 kWh	170,000 kWh
	Vancouver Island	8,300 kWh	17,000 kWh	34,000 kWh	68,000 kWh	100,000 kWh	140,000 kWh	170,000 kWh

In the event that solar capacities do not match up, producers can either choose the nearest energy production number or estimate an annual production that falls within the applicable range. The resulting annual production numbers for the representative producer scenarios are summarized in Table 21.

Table 21: Representative Producer Scenarios - Production Results

Farm ID	Producer Type	Potential Solar Capacity	Region	Estimated Annual Production Range		Estimated Annual Production
				Lower Limit	Upper Limit	
3	Dairy	100 kW	Okanagan	-	-	180,000 kWh/Yr
5	Poultry	77 kW	Fraser Valley	100,000 kWh/Yr	130,000 kWh/Yr	≈120,000 kWh/Yr
8	Vineyards and Wineries	20 kW	Okanagan	-	-	36,000 kWh/Yr

10.3.1 Utility Constraint #2: Generation ≈ Consumption

The utility constraint #2 comparison between the estimated annual solar production and the producer's average annual electricity consumption as determined in Step 1 is presented in Table 22.

Table 22: Utility Constraint #2

Farm ID	Producer Type	Estimated Annual Production Range	Estimated Annual Production	100% of the Average Annual Consumption	Does it Comply?
3	Dairy	-	180,000 kWh/Yr	92,000 kWh/Yr	**No**
5	Poultry	100,000 - 130,000 kWh/Yr	≈ 120,000 kWh/Yr	74,000 kWh/Yr	**No**
8	Vineyards and Wineries	-	36,000 kWh/Yr	76,000 kWh/Yr	Yes

Based on the results, the estimated annual solar project production for Farm ID 8 is below the annual electricity consumption, confirming that this is an appropriate assumption.

Farm ID 3 and Farm ID 5, do not comply with utility constraint #2 since the project production is significantly higher than the farm's annual electricity consumption. As a result, the solar projects are oversized and should be re-evaluated for a smaller installed capacity (and smaller roof area) by repeating Steps 1 through 3 until an appropriate annual production number is reached.

10.3.1.1 Second Iteration: Farm ID 3

Since Farm ID 3 did not comply with utility constraint #2, a second iteration is required. Assuming Farm ID 3 utilizes only 50% of the available roof area (500 m^2) for the rooftop solar project, this corresponds to a revised solar capacity between 49 kW and 76 kW in the Solar Capacity Matrix (Table 18).

Since the inputs do not match up exactly, options include estimating a capacity that falls within the range of applicable capacities, or selecting the smaller of the two capacity options. For simplicity, a 50 kW project for Farm ID 3 is assumed.

In accordance with the Electricity Production Matrix (Table 20), a 50 kW project developed in Okanagan has an estimated annual production range between 72,000 kWh/year – 110,000 kWh/year, or approximately 91,000 kWh/year, which is lower than Farm ID 3's historical annual consumption of 92,000 kWh/year. As a result, the revised 50 kW solar project complies with utility constraint 2 and is a feasible option for Farm ID 3 based on its current average annual electricity consumption.

10.3.1.2 Second Iteration: Farm ID 5

Similarly, since Farm ID 5 did not comply with utility constraint 2, a second iteration is also required. Assuming Farm ID 5 utilizes only 50% of the available roof area (400 m^2) for the rooftop solar project, this corresponds to a revised solar capacity of 40 kW in the Solar Capacity Matrix (Table 18). In accordance with the Electricity Production Matrix (Table 20), a 40 kW project developed in Fraser Valley has an estimated annual production of 67,000 kWh/year, which is lower than Farm ID 5's historical annual consumption of 74,000 kWh/year. As a result, the revised 40 kW solar project complies with utility constraint 2 and is therefore a feasible option for Farm ID 5 based on its current average annual electricity consumption limitation.

In both cases, if the annual electricity consumption happens to increase in the future, it is important to note that there exists an opportunity to expand the solar projects since there is additional roof area available and additional capacity available under the Net Metering program requirements.

The final results are summarized in Table 23.

Table 23: Representative Producer Scenario Results

Farm ID	Producer Type	Rooftop Solar Capacity	Estimated Annual Production
3	Dairy	50 kW	91,000 kWh/Yr
5	Poultry	40 kW	67,000 kWh/Yr
8	Vineyards and Wineries	20 kW	36,000 kWh/Yr

Once the necessary iterations are completed and the resulting project capacities and annual production numbers are confirmed, the next step is inputting the data into an economic model to determine the all-in costs and associated payback period for the investment, and to complete an environmental and social impact assessment to determine the potential impacts and benefits of the rooftop solar project.

The results of this triple bottom line analysis will help producers make informed decisions on whether it is economically, environmentally and socially viable to proceed to the next phase of the solar project development.

10.4 Step 4: Triple Bottom Line Analysis

10.4.1 Economic Analysis

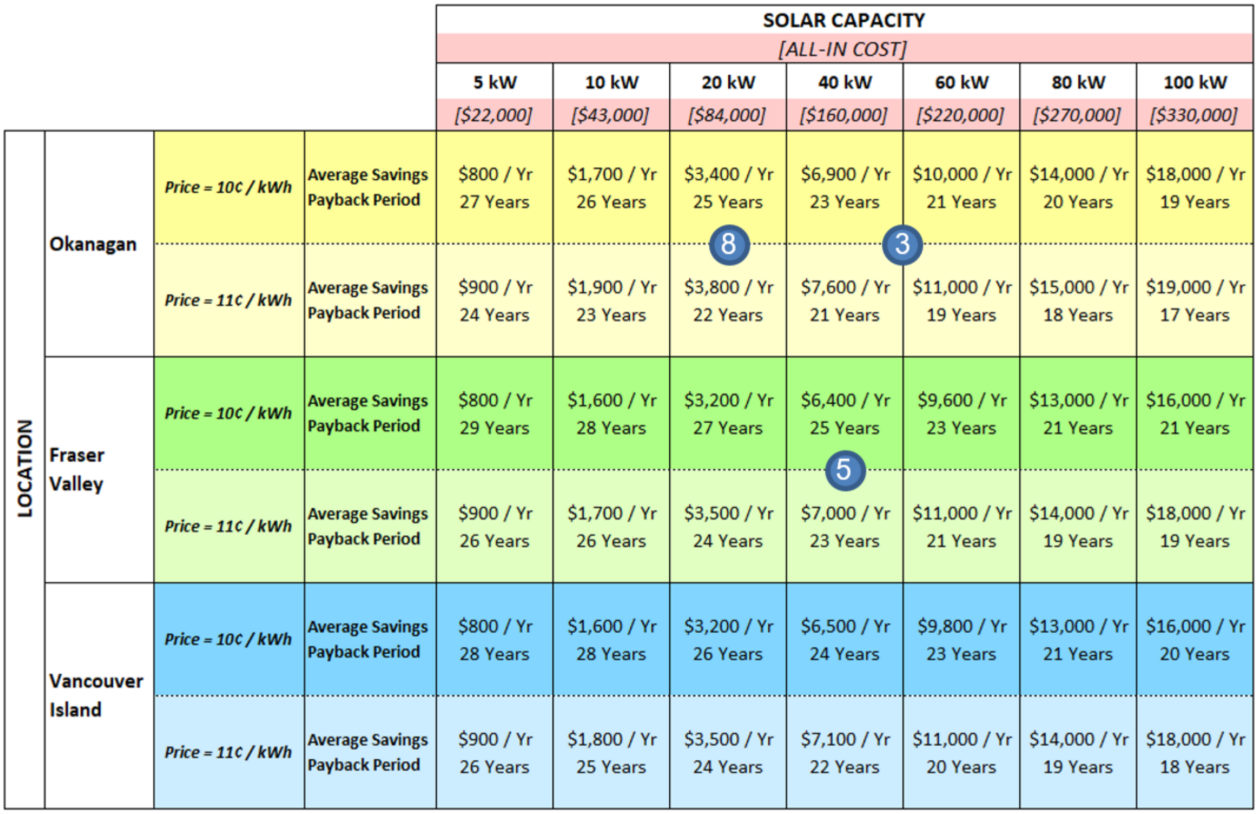
The representative producer scenario information required to complete the economic analysis is listed in Table 24.

Table 24: Economic Analysis Inputs

Farm ID	Producer Type	Region	Rooftop Solar Capacity	Estimated Annual Production	Electricity Price
3	Dairy	Okanagan	50 kW	91,000 kWh/Yr	$0.1028 /kWh
5	Poultry	Fraser Valley	40 kW	67,000 kWh/Yr	$0.1028 /kWh
8	Vineyards and Wineries	Okanagan	20 kW	36,000 kWh/Yr	$0.10195 /kWh

The placement of the representative producer scenarios in the economic analysis matrix is identified by the ● symbol in Table 25 below.

Table 25: Economic Analysis Matrix - Representative Producer Scenario Placement



				SOLAR CAPACITY						
				[ALL-IN COST]						
				5 kW	**10 kW**	**20 kW**	**40 kW**	**60 kW**	**80 kW**	**100 kW**
				[$22,000]	*[$43,000]*	*[$84,000]*	*[$160,000]*	*[$220,000]*	*[$270,000]*	*[$330,000]*
LOCATION	**Okanagan**	*Price = 10¢ / kWh*	**Average Savings** **Payback Period**	$800 / Yr 27 Years	$1,700 / Yr 26 Years	$3,400 / Yr 25 Years	$6,900 / Yr 23 Years	$10,000 / Yr 21 Years	$14,000 / Yr 20 Years	$18,000 / Yr 19 Years
		Price = 11¢ / kWh	**Average Savings** **Payback Period**	$900 / Yr 24 Years	$1,900 / Yr 23 Years	$3,800 / Yr 22 Years	$7,600 / Yr 21 Years	$11,000 / Yr 19 Years	$15,000 / Yr 18 Years	$19,000 / Yr 17 Years
	Fraser Valley	*Price = 10¢ / kWh*	**Average Savings** **Payback Period**	$800 / Yr 29 Years	$1,600 / Yr 28 Years	$3,200 / Yr 27 Years	$6,400 / Yr 25 Years	$9,600 / Yr 23 Years	$13,000 / Yr 21 Years	$16,000 / Yr 21 Years
		Price = 11¢ / kWh	**Average Savings** **Payback Period**	$900 / Yr 26 Years	$1,700 / Yr 26 Years	$3,500 / Yr 24 Years	$7,000 / Yr 23 Years	$11,000 / Yr 21 Years	$14,000 / Yr 19 Years	$18,000 / Yr 19 Years
	Vancouver Island	*Price = 10¢ / kWh*	**Average Savings** **Payback Period**	$800 / Yr 28 Years	$1,600 / Yr 28 Years	$3,200 / Yr 26 Years	$6,500 / Yr 24 Years	$9,800 / Yr 23 Years	$13,000 / Yr 21 Years	$16,000 / Yr 20 Years
		Price = 11¢ / kWh	**Average Savings** **Payback Period**	$900 / Yr 26 Years	$1,800 / Yr 25 Years	$3,500 / Yr 24 Years	$7,100 / Yr 22 Years	$11,000 / Yr 20 Years	$14,000 / Yr 19 Years	$18,000 / Yr 18 Years

In the event that solar capacities do not match up exactly, producers can either choose the nearest energy production number or estimate an annual production that falls within the applicable range. The resulting all-in costs, average annual savings, and payback periods for the representative producer scenarios are summarized in Table 26.

Table 26: Economic Analysis Results

Farm ID	Producer Type	Rooftop Solar Capacity	All-In Cost	Average Savings	Payback Period
3	Dairy	50 kW	$190,000	≈$9,000 /Yr	≈21 Years
5	Poultry	40 kW	$160,000	≈$6,500 /Yr	≈24 Years
8	Vineyards and Wineries	20 kW	$84,000	≈$3,500 /Yr	≈24 Years

The following payback periods were calculated for each representative producer scenario, which align with the matrix results:

Farm ID 3:

$$Payback\ Period\ [Years] = \frac{\$190{,}000}{91{,}000\ {}^{kWh}/_{Year} * 0.1028\ {}^{\$}/_{kWh} * 0.95} \approx 21.4\ Years$$

Farm ID 5:

$$Payback\ Period\ [Years] = \frac{\$160{,}000}{67{,}000\ {}^{kWh}/_{Year} * 0.1028\ {}^{\$}/_{kWh} * 0.95} \approx 24.4\ Years$$

Farm ID 8:

$$Payback\ Period\ [Years] = \frac{\$84{,}000}{36{,}000\ {}^{kWh}/_{Year} * 0.10195\ {}^{\$}/_{kWh} * 0.95} \approx 24.1\ Years$$

10.4.2 Environmental Impact Assessment

The results of the rooftop solar environmental impact assessment, including the potential impacts, the severity of the impact, and the associated mitigations are summarized in Table 27.

Table 27: Environmental Impact Assessment – Summary of Impacts and Mitigations

Resource	Potential Impact	Severity	Mitigation	Comments
Vegetation	Habitat Loss	None	-	Pruning of trees associated with installation and operations is likely minimal and will grow back after the panels are decommissioned.
Wildlife	Change in Habitat	Low	Plant alternate vegetation / nest structures to help mitigate increased exposure	Ranked low as birds will likely adapt to the presence of solar panels and changes in microsite conditions.
Wildlife	Sensory Disturbance	Low	Conduct works outside the regional bird nesting window; or conduct a passive pre-clearing nest survey in advance of works.	Ranked low as disturbance to birds can be minimized through the timing of works.
Wildlife	Direct Mortality	Low	Conduct works outside the regional bird nesting window; or conduct a passive pre-clearing nest survey in advance of works.	Injury or taking of birds can be mitigated through the timing of works.
Water	Change in water quantity / quality	None	-	Using water for cleaning solar panels is akin to regular window washing (Environment Canada 2012)

For further information, please refer to Appendix C: Socio-Environmental Analysis of Implementing Solar Electricity On-Farm.

10.4.3 Social Impact Assessment

The results of the rooftop solar social impact assessment, including the potential impacts, the severity of the impact, and the associated mitigations are summarized in Table 28.

Table 28: Social Impact Assessment – Summary of Impacts and Mitigations

Resource	Potential Impact	Severity	Mitigation	Comments
Employment and Training	Limited training programs available to support market need and limited distribution of installers, especially in rural areas.	Medium	Increased education options within BC; phased or limited update of solar development to manage demand.	-
Site Preparations and Procurement	Limited rurally-based installers	Low	Additional cost to travel to rural areas borne by producer; installer registry.	-
Disposal	Limited options exist for recycling or reuse.	Low	Consider in the long-term options for recycling or reuse as the market matures; opportunities exist for pilot program or start-up.	Ranked low as it not an imminent issue and could be resolved once solar installed.
Aesthetics	Small number of "speciality" farms may consider PV cells unsightly.	Low	Small number of farms may find this an issue; strategic placement of the panels may resolve any issues.	-
Perceptions and Barriers	Various perceptions around calculation of costs, financing/funding, Return on investment ("ROI"), energy savings, supply chain criteria, quality installers roster, maintenance, and end-of-life options.	Medium	Consider stakeholder working group(s); education programs to address issues, concerns and misconceptions.	The report, fact sheet and newsletter are a step towards public education.
Safety and Health	Possible risk of electrical exposure of first responders.	None	Panels installed to building code address risks.	-

For further information, please refer to Appendix C: Socio-Environmental Analysis of Implementing Solar Electricity On-Farm.

10.4.4 GHG Production

Material extraction and production stages account for almost all emissions in the PV cell life-cycle. However, these emissions are minimal compared with the total lifecycle emissions from traditional fossil fuel-based electricity production. Comparisons between total life cycle emissions for various sources of power generation are summarized in Table 29.

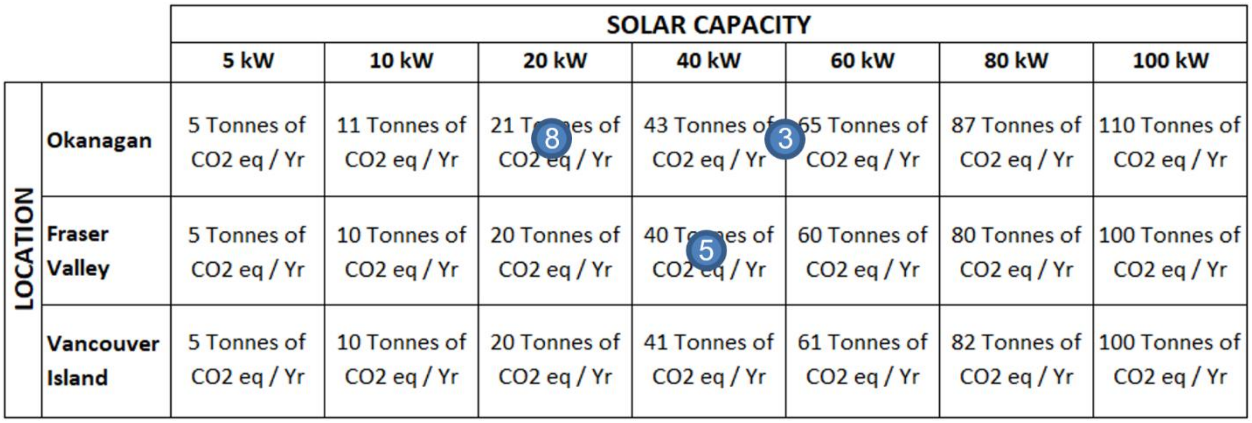
Table 29: Total Life Cycle Emissions for Various Sources of Power Generation[68]

Pollutant	Tonnes CO_2 eq / TWh			
	Nuclear	Coal	Natural Gas	PV
GHG Emissions U.S.	1,837	1,051,215	540,391	26,000 – 36,000
GHG Emissions Canada	-	853,032	460,674	18,000 – 72,000

For additional information, please refer to Appendix C: Socio-Environmental Analysis of Implementing Solar Electricity On-Farm.

An algorithm was derived to determine average annual emissions associated with the annual production numbers derived for the systems in Step 3, assuming the system fuel was natural gas[69] instead of solar power. Based on the solar capacities determined in Step 2 and on the representative producer scenario locations, the placement of the representative producer scenarios in the GHG Emissions Matrix is identified by the ● symbol in Table 30 below.

Table 30: GHG Emissions Matrix - Representative Producer Scenario Placement



		SOLAR CAPACITY						
		5 kW	10 kW	20 kW	40 kW	60 kW	80 kW	100 kW
LOCATION	Okanagan	5 Tonnes of CO2 eq / Yr	11 Tonnes of CO2 eq / Yr	21 T ⑧ es of CO2 eq / Yr	43 Tonnes of CO2 eq / Yr ③	65 Tonnes of CO2 eq / Yr	87 Tonnes of CO2 eq / Yr	110 Tonnes of CO2 eq / Yr
	Fraser Valley	5 Tonnes of CO2 eq / Yr	10 Tonnes of CO2 eq / Yr	20 Tonnes of CO2 eq / Yr	40 T ⑤ es of CO2 eq / Yr	60 Tonnes of CO2 eq / Yr	80 Tonnes of CO2 eq / Yr	100 Tonnes of CO2 eq / Yr
	Vancouver Island	5 Tonnes of CO2 eq / Yr	10 Tonnes of CO2 eq / Yr	20 Tonnes of CO2 eq / Yr	41 Tonnes of CO2 eq / Yr	61 Tonnes of CO2 eq / Yr	82 Tonnes of CO2 eq / Yr	100 Tonnes of CO2 eq / Yr

In the event that solar capacities do not match up exactly, producers can either choose the nearest energy production number or estimate an annual production that falls within the applicable range. The resulting GHG emission savings for the representative producer scenarios are summarized in Table 31.

Table 31: GHG Emission Offset Results

Farm ID	Producer Type	Rooftop Solar Capacity	GHG Emission Savings
3	Dairy	50 kW	54 Tonnes CO_2 eq / Yr

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[68] Sources: Jazayeri at al. 2008; Fthenakis et al. 2011b; US NREL 2012 Environment Canada 2010a

[69] Since over 90% of BC's electricity is currently being supplied from hydroelectric generating stations and the remainder is mainly supplied by natural gas, natural gas is the assumed marginal fuel to be offset for the purposes of this analysis.

5	Poultry	40 kW	40 Tonnes CO_2 eq / Yr
8	Vineyards and Wineries	20 kW	21 Tonnes CO_2 eq / Yr

The results of the triple bottom line analysis should help producers make informed decisions on whether it is economically, environmentally and socially viable to proceed to the next phase of the solar project development.

11 Conclusion

Rooftop solar is a clean source of electricity with relatively low environmental and social impacts when compared against alternative forms of electricity supply. The economic viability of developing rooftop solar in BC is challenging due to low solar irradiance and low grid-supplied electricity pricing. However, solar install costs have decreased by over 60% in the last seven years, with cost reductions expected to continue (albeit at a slower rate). Therefore, considering downward trending solar install costs, ongoing solar technology improvements, increasing grid-supplied electricity prices, and further development of solar-related policies / incentive programs, the economic viability of rooftop solar in BC is expected to improve in future years.

Appendix A: Matrix Algorithms

A.1 Step 2: Solar Capacity Determination

The potential solar capacity [in kW] is derived from the number of solar PV panels the selected rooftop can fit, while arranged in a manner that minimizes shading losses between rows. For the purposes of this study, the panels are assumed to be arranged in east-west oriented rows, on a south-facing roof[70].

The following formula is used to estimate the solar capacity of the solar PV system:

$$P_{AC} = \frac{n_{Rows} * n_{Panels/Row} * P_{Panel}}{1 + K_{Overbuild}} \qquad 1$$

Where:

n_{Rows}	Number of rows (this factor will be explained in the following subsections)
$n_{Panels/Row}$	Number of panels per row (this factor will be explained in the following subsections)
P_{Panel}	$= 0.320kW$ (individual solar PV panel capacity[71])
$K_{Overbuild}$	$= 30\%$ (assumed solar PV system overbuild[72] percentage)
P_{AC}	Total solar capacity

Based on Formula 1 above, the total number of rows and number of panels per row has to first be determined in order to estimate the potential solar capacity for different combinations of roof sizes and angles.

A.1.1 Generic Roof Dimensions

To determine the potential solar capacity per roof area [in kW/m^2], the shape of the roof has to be assumed.

Horizontal roof area data included in the producer survey results from 11 different producers was used to determine a representative roof shape suitable for solar PV panels. The resulting roof shape is a rectangle with dimensions and orientation shown in Figure 7 below.

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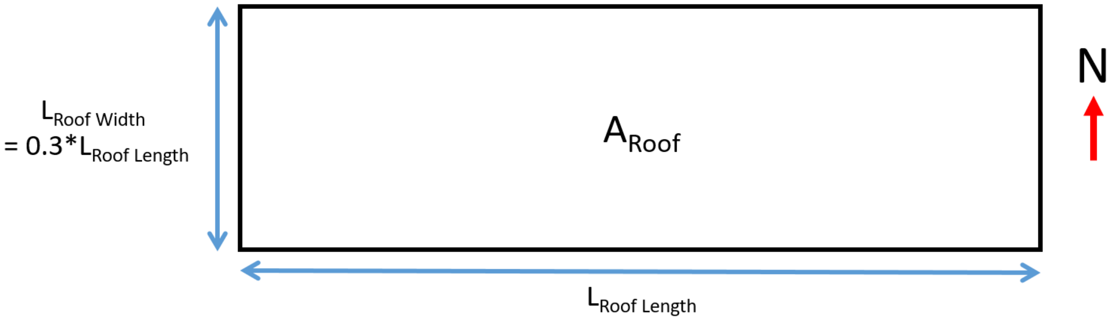
[70] A south-facing roof is ideal for solar PV developers located in the northern hemisphere.

[71] CanadianSolar "MAXPOWER CS6X 320P" July 2016 Link

[72] Solar PV system overbuild is the ratio between the array's name plate DC power rating at Standard Test Conditions to the inverter's rated AC output. Typically, the array is oversized in order to improve solar PV system performance.

Figure 7: Representative Roof Shape



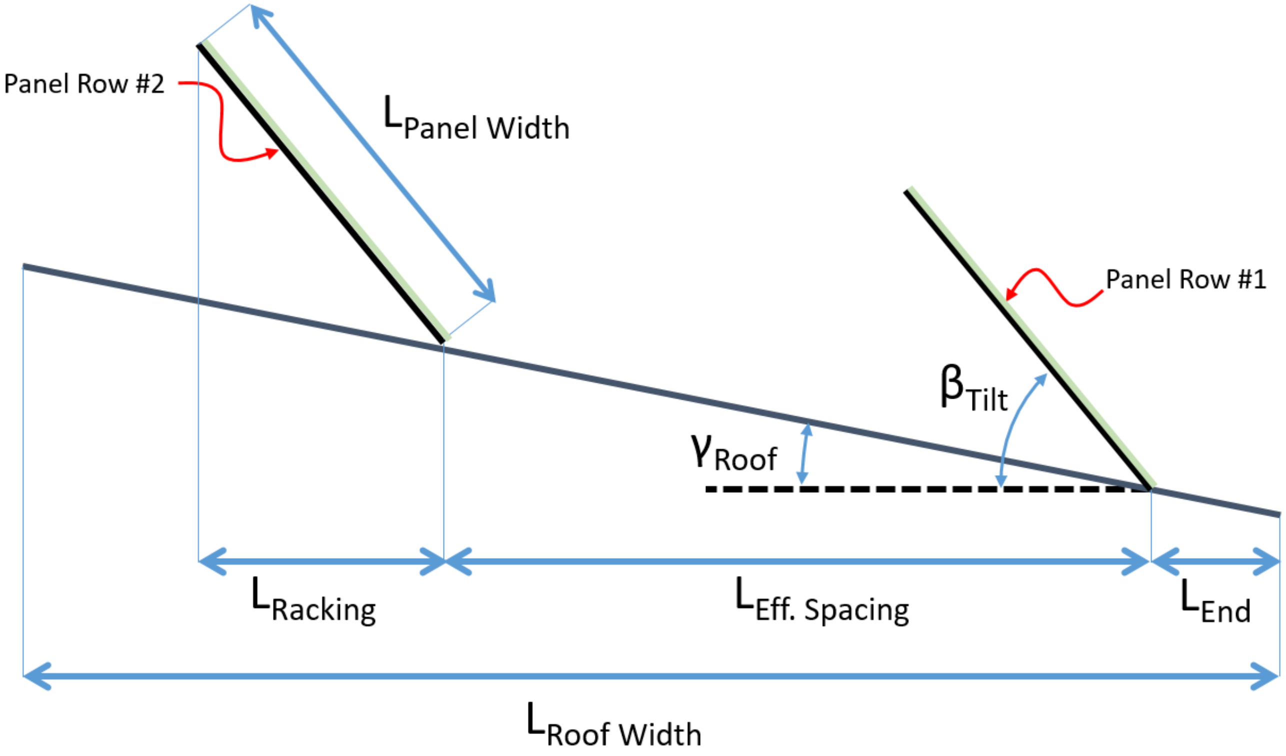
Where:

$L_{Roof\ Length}$	The length of the representative roof shape
$L_{Roof\ Width}$	The horizontal width of the representative roof shape (assumed as 30% of $L_{Roof\ Length}$)
A_{Roof}	The resulting horizontal area of the representative roof shape. As A_{Roof} varies, $L_{Roof\ Length}$ and $L_{Roof\ Width}$ will adjust accordingly to preserve the roof shape.

A.1.2 Number of Rows

The number of rows (n_{Rows}) is calculated by summing the space requirements for each row to determine the maximum number of rows the roof can support. Figure 8 shows the various components that are taken into consideration when determining the maximum number of rows.

Figure 8: Components Considered when determining the Number of Panel Rows



Where:

$L_{Panel\ Width}$ $= 0.982m$ (the assumed width of the solar PV panel used in this study[73])

β_{Tilt} $= 36°$ (the optimal tilt angle assumed for the three (3) regions: Okanagan, Fraser Valley, and Vancouver Island)

γ_{Roof} South tilting roof angle

$L_{Roof\ Width}$ The horizontal width of the representative roof shape (displayed in Figure 7)

L_{End} $= 0.1m * cos(\gamma_{Roof})$ (additional space assumed for mounting purposes)

$L_{Racking}$ $= L_{Panel\ Width} * cos(\beta_{Tilt})$ (additional space assumed for racking purposes under the northern-most row of panels)

$L_{Eff.\ Spacing}$ The horizontal spacing between panel rows. Spacing is a function of the roof's south tilting angle (γ_{Roof}). This function is derived in the following sub-section

When determining the optimal number of panel rows for a specific roof area, the following condition in Formula 2 needs to be met:

$$L_{Racking} + L_{Eff.Spacing} * (n_{Rows} - 1) + L_{End} < L_{Roof\ Width} \tag{2}$$

From Formula 2, n_{Rows} is derived as follows:

$$n_{Rows} < \frac{L_{Roof\ Width} - L_{Racking} - L_{End}}{L_{Eff.Spacing}} + 1 \tag{3}$$

A.1.2.1 Row Spacing

Adequate spacing between rows is important to minimize inter-row shading effects since partially shaded solar PV panels leads to drastic drops in performance. The closer the roof angles are to the optimal tilt angle of the solar PV panel (e.g. 36°), the less space is required between rows. Since roof angles will vary between producers, spacing requirements for various roof angles is also required.

For the purposes of this study, it is assumed that when the sun's position is at the critical point where inter-row shading is about to begin (or end) for a flat roof scenario, the same situation should theoretically happen for a pitched roof scenario as well (see Figure 9). These assumptions are used to determine the optimal spacing between rows.

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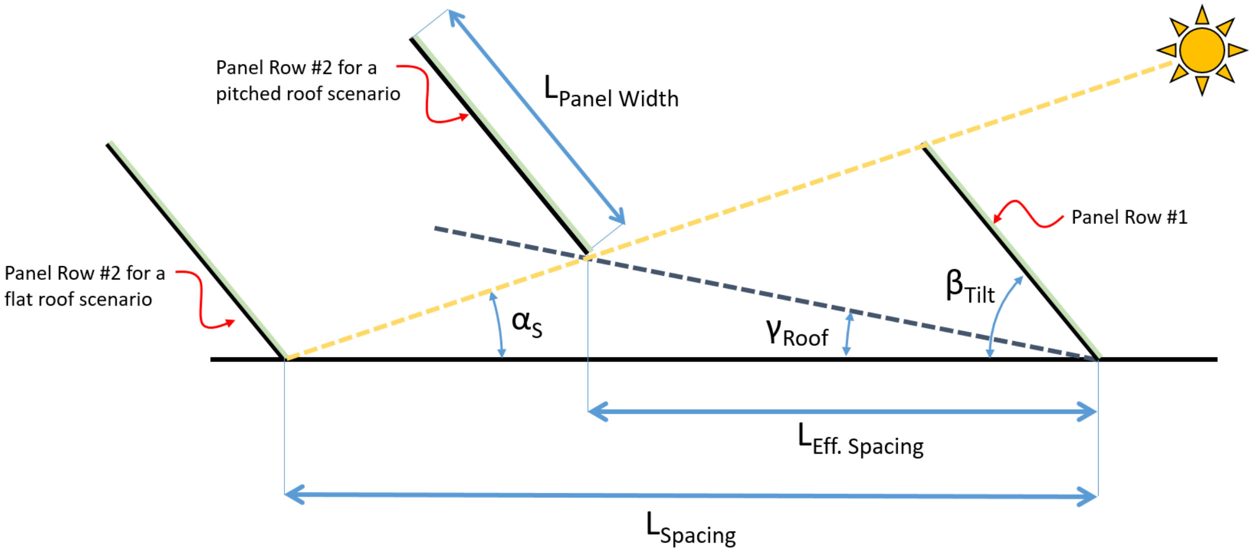
[73] CanadianSolar "MAXPOWER CS6X 320P" July 2016 Link

Figure 9: Critical Sun Position Scenarios



Where:

$L_{Spacing}$ = $3.0m$ (assumed panel row spacing for flat roof scenarios)

α_S Altitude angle of the sun at the critical point where inter-row shading is about to begin (or end)

From Figure 4, the following two formulas can be derived:

$$\tan(\alpha_S) = \frac{L_{Panel\,Width} * \sin(\beta_{Tilt})}{L_{Spacing} - L_{Panel\,Width} * cos(\beta_{Tilt})} \qquad 4$$

$$(L_{Spacing} - L_{Eff.Spacing}) * \tan(\alpha_S) = L_{Eff.Spacing} * \tan(\gamma_{Roof}) \qquad 5$$

Merging Formulas 4 and 5 gives Formula 6:

$$(L_{Spacing} - L_{Eff.Spacing}) * \frac{L_{Panel\,Width} * \sin(\beta_{Tilt})}{L_{Spacing} - L_{Panel\,Width} * cos(\beta_{Tilt})} = L_{Eff.Spacing} * \tan(\gamma_{Roof}) \qquad 6$$

Finally, $L_{Eff.Spacing}$ is derived as follows:

$$L_{Eff.Spacing} = \frac{L_{Spacing}}{\left[1 + \frac{\tan(\gamma_{Roof}) * (L_{Spacing} - L_{Panel\,Width} * cos(\beta_{Tilt}))}{L_{Panel\,Width} * sin(\beta_{Tilt})}\right]} \qquad 7$$

A.1.3 Number of Panels per Row

The final factor required to estimate the potential solar capacity in Formula 1 is the number of panels per row ($n_{Panels/Row}$). When estimation of the number of panels per row the following condition needs to be met:

$$L_{Panel\ Length} * n_{Panels/Row} + 2 * L_{End} < L_{Roof\ Length} \tag{8}$$

Where:

$n_{Panels/Row}$ Number of panels per row (number has to be rounded down to the closest integer)

$L_{Panel\ Length}$ $= 1.954m$ (The length of the solar PV panel used in this study[74])

From Formula 8, $n_{Panels/Row}$ is derived as follows:

$$n_{Panels/Row} < \frac{L_{Roof\ Length} - 2 * L_{End}}{L_{Panel\ Length}} \tag{9}$$

A.1.4 Resulting Solar Capacity Matrix

The final step is to combine Formulas 1, 3, 7 and 9 to determine project capacities for different combinations of horizontal roof areas and angles. A combination of inputs and resulting outputs are summarized in the following matrix:

Figure 10: Solar Capacity Matrix

		ROOF ANGLE			
		Flat 0 Pitch	10° ≈2/12 Pitch	20° ≈4/12 Pitch	30° ≈7/12 Pitch
HORIZONTAL ROOF AREA	50 m2 ≈540 ft2	2 kW	3 kW	5 kW	6 kW
	100 m2 ≈1,100 ft2	5 kW	7 kW	9 kW	12 kW
	200 m2 ≈2,200 ft2	10 kW	13 kW	20 kW	26 kW
	400 m2 ≈4,300 ft2	18 kW	27 kW	40 kW	49 kW
	600 m2 ≈6,500 ft2	28 kW	38 kW	55 kW	76 kW
	800 m2 ≈8,600 ft2	32 kW	58 kW	77 kW	100 kW
	1,000 m2 ≈11,000 ft2	43 kW	72 kW	100 kW	130 kW

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[74] CanadianSolar “MAXPOWER CS6X 320P” July 2016 Link

A.2 Step 3: Production Determination

To estimate the annual production from a solar PV system, the following Formula 10 can be used:

$$E_{Annual} = P_{AC} * CF * 365\ Days * 24\ hours \quad (10)$$

Where:

E_{Annual}	Annual production from the solar PV system
CF	Capacity factor: Capacity factors represent the ratio of electricity produced over a normal year divided by electricity produced if the generator is producing at its rated power every hour for a full year.

The industry standard software PVSyst was used to determine capacity factors based on GHI data and ambient temperature data sourced from Meteonorm. Meteonorm GHI and temperature data is sufficiently granular to establish specific energy estimates for the purposes of this Study.

Capacity factor is a function of location and solar capacity. Six (6) iterations per region were modeled based on project capacities ranging from 3 kW to 80 kW to approximate how the capacity factor varies with solar capacity. Key inputs for the PVSyst model are listed in Table 32.

Table 32: Key PVSyst Inputs

Input	Value
Region – Okanagan	Summerland
Region – Fraser Valley	Abbotsford
Region – Vancouver Island	Cobble Hill
Solar PV Panel	Canadian Solar CS6X 320P (320W Polycrystalline)
Overbuild Target	30%
Panel Tilt Angle	36°
Inverters	Schneider Electric Conext RL 3000E-S, 5000E-S & 20000E

The results are presented in Table 33.

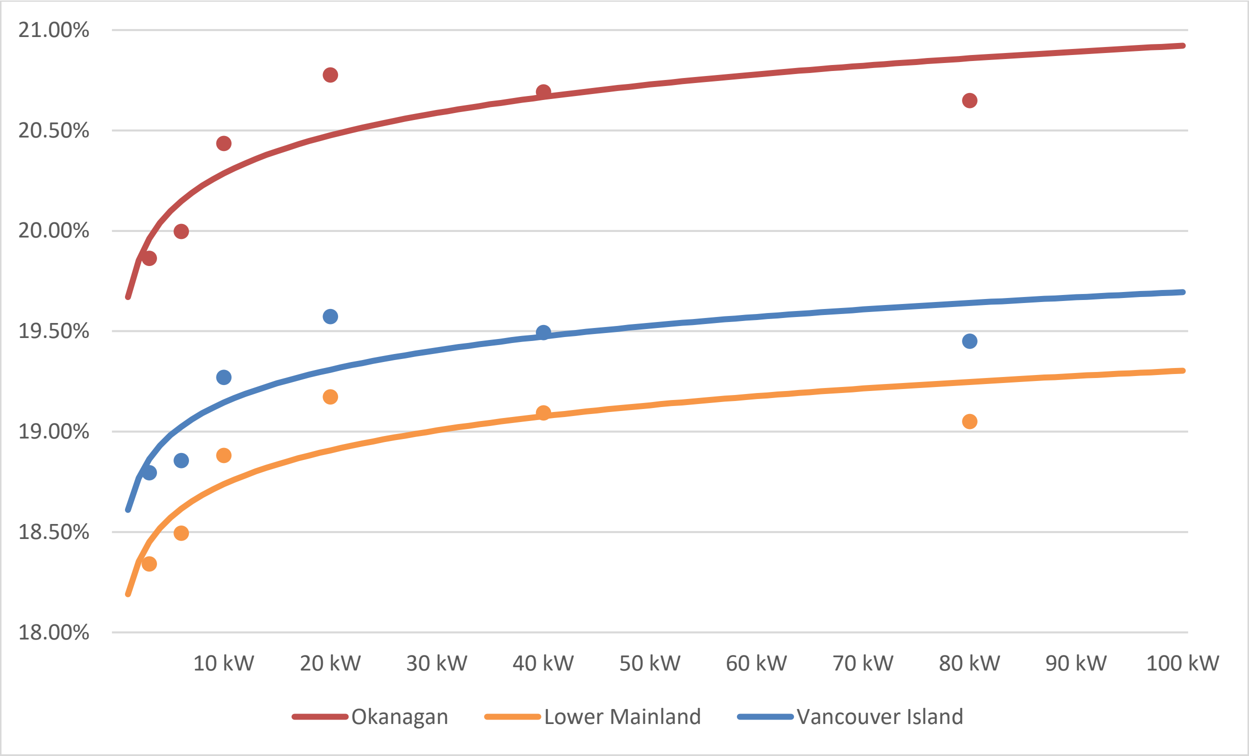
Table 33: PVSyst Outputs

Region	Solar Capacity (AC)	Array Capacity (DC)	Overbuild	Production	Capacity Factor
Okanagan	80.00 kW	108.00 kW	35.00%	144,700 kWh	20.6%
	40.00 kW	53.80 kW	34.50%	72,500 kWh	20.7%
	20.00 kW	26.88 kW	34.40%	36,400 kWh	20.8%
	10.00 kW	13.44 kW	34.40%	17,900 kWh	20.4%
	6.00 kW	8.00 kW	33.33%	10,510 kWh	20.0%
	3.00 kW	3.84 kW	28.00%	5,220 kWh	19.9%
Fraser Valley	80.00 kW	108.00 kW	35.00%	133,500 kWh	19.0%
	40.00 kW	53.80 kW	34.50%	66,900 kWh	19.1%

Region	Solar Capacity (AC)	Array Capacity (DC)	Overbuild	Production	Capacity Factor
	20.00 kW	26.88 kW	34.40%	33,590 kWh	19.2%
	10.00 kW	13.44 kW	34.40%	16,540 kWh	18.9%
	6.00 kW	8.00 kW	33.33%	9,720 kWh	18.5%
	3.00 kW	3.84 kW	28.00%	4,820 kWh	18.3%
Vancouver Island	80.00 kW	108.00 kW	35.00%	136,300 kWh	19.4%
	40.00 kW	53.80 kW	34.50%	68,300 kWh	19.5%
	20.00 kW	26.88 kW	34.40%	34,290 kWh	19.6%
	10.00 kW	13.44 kW	34.40%	16,880 kWh	19.3%
	6.00 kW	8.00 kW	33.33%	9,910 kWh	18.9%
	3.00 kW	3.84 kW	28.00%	4,939 kWh	18.8%
		AVERAGE:	**33.27%**		

The resulting capacity factor outputs from PVSyst (as shown in Table 33) were plotted, and an optimized trend line was used to determine the associated capacity factor formulas specific to each region. Figure 11 shows the plotted capacity factor data outputs from PVSyst and the resulting trend lines.

Figure 11: Capacity Factor by Solar Capacity and Region



The corresponding trend line formulas for each region are presented below in Formulas 11 through 13.

$$CP_{Okanagan} = 0.1967 * P_{AC}{}^{0.0134} \quad (11)$$

$$CP_{Fraser\ Valley} = 0.1819 * P_{AC}{}^{0.0139} \quad (12)$$

$$CP_{Vancouver\ Island} = 0.1819 * P_{AC}{}^{0.0139} \quad (13)$$

The final step is to use Formulas 11 through 13 together with Formula 10 to estimate the electricity production numbers for any combination of solar capacity and region inputs. The estimated electricity production numbers for solar capacities varying between 5 kW and 100 kW is summarized in the following matrix:

Figure 12: Solar Electricity Production Matrix

		SOLAR CAPACITY						
		5 kW	**10 kW**	**20 kW**	**40 kW**	**60 kW**	**80 kW**	**100 kW**
LOCATION	**Okanagan**	8,800 kWh	18,000 kWh	36,000 kWh	72,000 kWh	110,000 kWh	150,000 kWh	180,000 kWh
	Fraser Valley	8,100 kWh	16,000 kWh	33,000 kWh	67,000 kWh	100,000 kWh	130,000 kWh	170,000 kWh
	Vancouver Island	8,300 kWh	17,000 kWh	34,000 kWh	68,000 kWh	100,000 kWh	140,000 kWh	170,000 kWh

A.3 Step 4: Economics

The payback period in years was selected as the metric used to quantify the economic feasibility of rooftop solar PV in this study. Some drawbacks of using the payback period to measure the economic feasibility is that it does not take into account the time value of money and doesn't take any additional cash flows beyond the payback period into account, however, it is a simple metric that can be understood by a broader audience. Additionally, since the annual cash flow (savings in this case) is estimated to be fairly constant over the life of the solar PV project, the payback period was deemed an appropriate representation of the investment's economic feasibility.

The payback period represents the number of years after the initial investment where the cumulative savings are equal to the all-in cost of the system (i.e. number of years required to fully recover the initial investment). To calculate the payback period "N_{PP}", the following formula can be used:

$$C_{All-In\ Cost} = \sum_{Y=1}^{Y=N_{PP}} [S_{Savings,\ Y=1} + S_{Savings,\ Y=2} + \cdots + S_{Savings,\ Y=N_{PP}}] \quad (14)$$

Where:

N_{PP}	Payback period in years
$C_{All\text{-}In\ Cost}$	All-in estimated cost of the solar PV system
$S_{Savings}$	The annual electricity bill savings for a specific year

Y The year following system commissioning

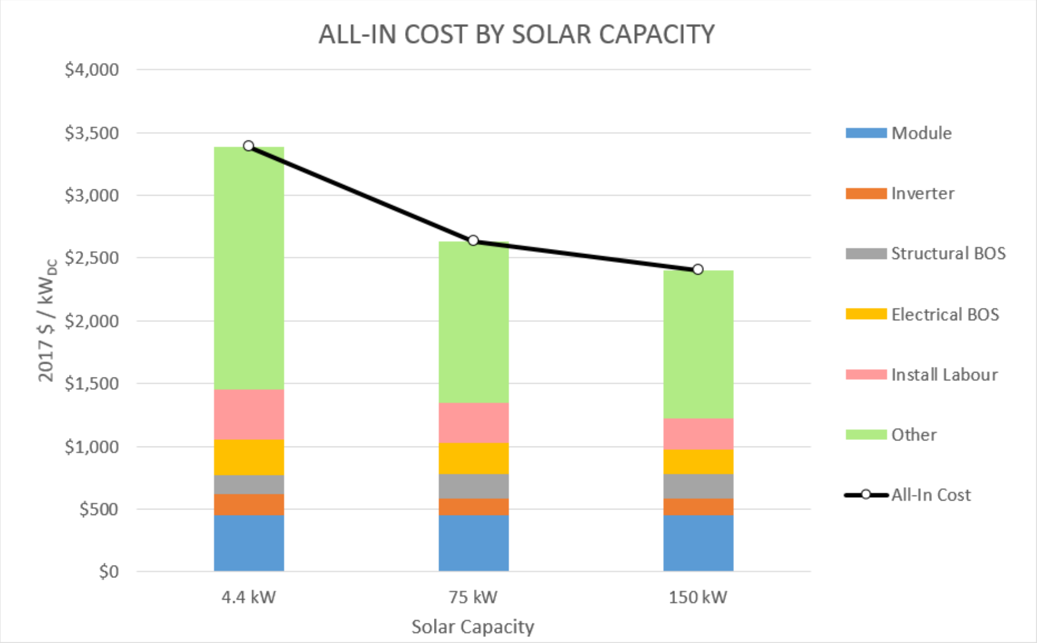
A.3.1 All-In Cost

The all-in costs ($C_{\text{All-In Cost}}$) for various solar PV capacities were derived based on a U.S. solar PV system cost benchmark[75] study performed by National Renewable Energy Laboratory ("NREL") as of the first quarter of 2017[76]. The benchmarks used as a proxy are representative of rooftop residential and non-residential solar PV all-in costs.

Since the all-in cost is dependent on the solar capacity, and since solar PV rooftop applications tend to be smaller for residential applications, an economy of scale assessment has also been included to account for how all-in cost varies with solar capacities ranging from 4.4 kW to 150 kW.

The results are presented in Figure 13 below. All-in costs for various solar capacities were extrapolated using the black curve which is based on NREL's benchmark scenarios (represented by the columns in Figure 13).

Figure 13: All-In Cost of Solar PV by Solar Capacity[77]



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[75] The benchmarks are national averages weighted by state installed capacities.

[76] National Renewable Energy Laboratory (NREL). U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017. Link

[77] The Solar Capacity on the x-axis represents the AC solar capacity. The all-in costs, however, are derived based on the DC capacity. The assumed overbuild between AC and DC is 30%.

A.3.2 Savings

The annual electricity bill savings are estimated using the following formula:

$$S_{Savings} = T_{Price} * E_{Annual} * (1 - K_{Degradation} * Y) \qquad 15$$

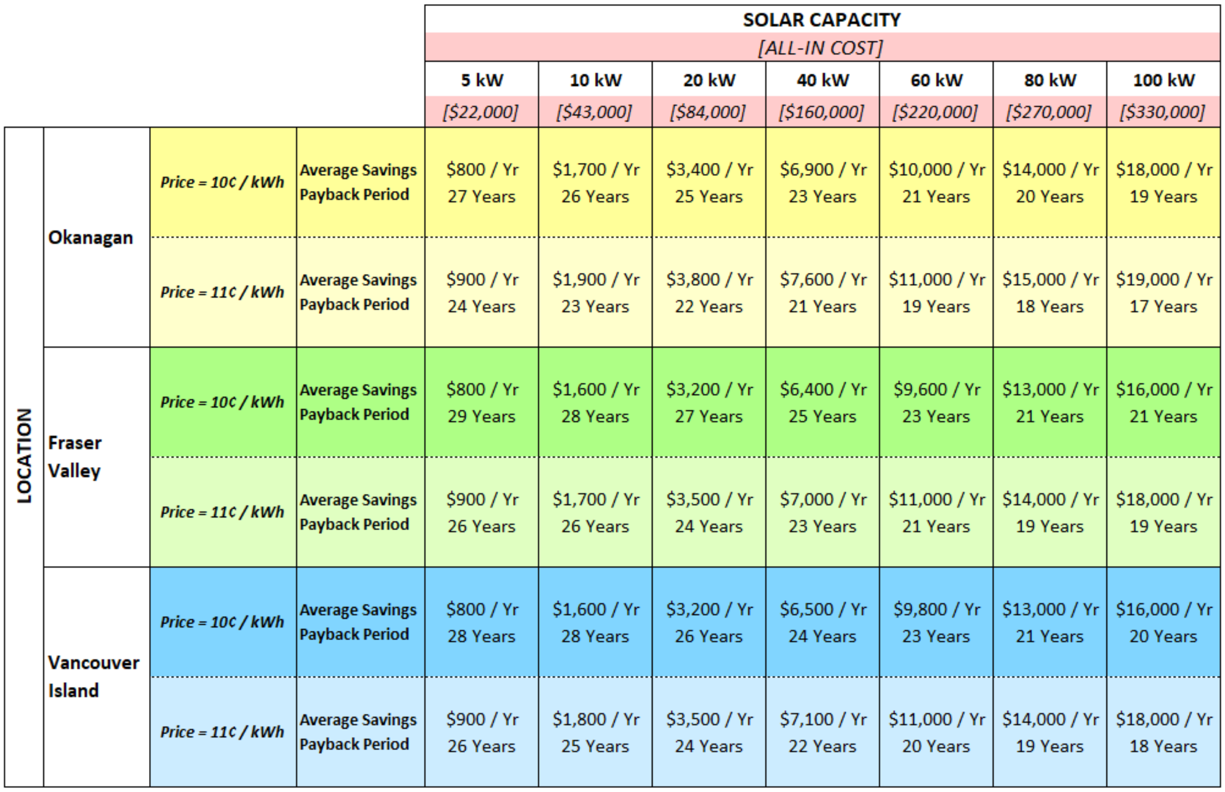
Where:

T_{Price}	The electricity price. For the purposes of this analysis, it is assumed that the electricity price increases with inflation.
E_{Annual}	Annual production of the solar PV system
$K_{Degradation}$	= 0.5%[78] (Annual solar PV panel degradation)

A.3.3 Payback period

Based on Formula 14, Formula 15, and how the all-in cost varies with solar capacity (Figure 13), the following economic matrix was derived (Figure 14).

Figure 14: Economic Analysis Matrix



				SOLAR CAPACITY *[ALL-IN COST]*						
				5 kW	**10 kW**	**20 kW**	**40 kW**	**60 kW**	**80 kW**	**100 kW**
				[$22,000]	*[$43,000]*	*[$84,000]*	*[$160,000]*	*[$220,000]*	*[$270,000]*	*[$330,000]*
LOCATION	**Okanagan**	***Price = 10¢ / kWh***	**Average Savings** **Payback Period**	$800 / Yr 27 Years	$1,700 / Yr 26 Years	$3,400 / Yr 25 Years	$6,900 / Yr 23 Years	$10,000 / Yr 21 Years	$14,000 / Yr 20 Years	$18,000 / Yr 19 Years
		Price = 11¢ / kWh	**Average Savings** **Payback Period**	$900 / Yr 24 Years	$1,900 / Yr 23 Years	$3,800 / Yr 22 Years	$7,600 / Yr 21 Years	$11,000 / Yr 19 Years	$15,000 / Yr 18 Years	$19,000 / Yr 17 Years
	Fraser Valley	***Price = 10¢ / kWh***	**Average Savings** **Payback Period**	$800 / Yr 29 Years	$1,600 / Yr 28 Years	$3,200 / Yr 27 Years	$6,400 / Yr 25 Years	$9,600 / Yr 23 Years	$13,000 / Yr 21 Years	$16,000 / Yr 21 Years
		Price = 11¢ / kWh	**Average Savings** **Payback Period**	$900 / Yr 26 Years	$1,700 / Yr 26 Years	$3,500 / Yr 24 Years	$7,000 / Yr 23 Years	$11,000 / Yr 21 Years	$14,000 / Yr 19 Years	$18,000 / Yr 19 Years
	Vancouver Island	***Price = 10¢ / kWh***	**Average Savings** **Payback Period**	$800 / Yr 28 Years	$1,600 / Yr 28 Years	$3,200 / Yr 26 Years	$6,500 / Yr 24 Years	$9,800 / Yr 23 Years	$13,000 / Yr 21 Years	$16,000 / Yr 20 Years
		Price = 11¢ / kWh	**Average Savings** **Payback Period**	$900 / Yr 26 Years	$1,800 / Yr 25 Years	$3,500 / Yr 24 Years	$7,100 / Yr 22 Years	$11,000 / Yr 20 Years	$14,000 / Yr 19 Years	$18,000 / Yr 18 Years

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[78] U.S. National Renewable Energy Laboratory (NREL) "Photovoltaic Degradation Rates — An Analytical Review" 2012 Link

Since the annual savings from year to year are relatively constant and only vary as a result of the solar PV panel degradation, a simplified formula (see below) was derived to estimate the payback period:

$$N_{PP} = \frac{C_{All-In\ Cost}}{T_{Price} * E_{Annual} * F_{Degradation}} \qquad 16$$

Where:

$F_{Degradation}$ = 0.95 (Factor accounting for the solar PV panel degradation over 20 years[79] of operation)

A.4 GHG Emission Savings

Since solar PV systems emit no GHGs or air pollutants during normal operation, natural gas baseline scenarios[80] were developed to show the potential emission savings of solar generation versus natural gas generation. In order to estimate a solar project's potential emission savings, an algorithm was derived to determine average annual GHG emissions associated with the annual production numbers derived for the systems in Step 3, assuming the electricity generation fuel was natural gas instead of the sun.

To estimate the annual GHG emission savings of the solar PV system, the following formula was used:

$$GHG_{Savings} = E_{Annual} * GHG_{NG/kWh} \qquad 17$$

Where:

E_{Annual}	Anticipated annual production in kWh/year of the solar PV system
$GHG_{NG/kWh}$	GHG emissions produced from natural gas electricity generation per kWh

To estimate the $GHG_{NG/kWh}$ value, it was assumed that the natural gas is consumed by a gas turbine and the emissions from natural gas contributing to global warming are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), where each emission component is multiplied by its global warming potential[81]. The formula used to calculate $GHG_{NG/kWh}$ is shown below.

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[79] 20 Years is a normal payback period for a rooftop solar PV system with a solar capacity range between 5 kW to 100 kW in southern BC.

[80] Since over 90% of BC's electricity is currently being supplied from hydroelectric generating stations and the remainder is mainly supplied by natural gas, natural gas is the assumed marginal fuel to be offset for the purposes of this analysis.

[81] Global warming potential is a factor which measures how much energy one unit of mass of a certain gas will absorb over a given timeframe (in this case 100 years) compared to the same unit of mass of carbon dioxide. Global warming potential is useful to compare different emission gasses.

$$GHG_{NG/kWh} = HR_{NG\ Turbine} * [(EF_{CO2} * GWP_{CO2}) + (EF_{CH4} * GWP_{CH4}) + (EF_{N2O} * GWP_{N2O})] \tag{18}$$

Where:

$HR_{NG\ Turbine}$ = 0.011214 mmBtu / kWh (The average tested heat rate for natural gas turbines in the U.S. from 2016[82])

EF_{CO2} =53.0600 kg CO_2 / mmBtu (Emission factor for carbon dioxide (CO_2)[83])

GWP_{CO2} =1 (100 – year global warming potential for carbon dioxide (CO_2)[83])

EF_{CH4} =0.0010 kg CH_4 / mmBtu (Emission factor for methane (CH_4)[83])

GWP_{CH4} =25 (100 – year global warming potential for methane (CH_4)[83])

EF_{N2O} =0.0001 kg N_2O / mmBtu (Emission factor for nitrous oxide (N_2O)[83])

GWP_{N2O} =298 (100 – year global warming potential for nitrous oxide (N_2O)[83])

Solving Formula 18 results in a $GHG_{NG/kWh}$ of 0.5956 CO_2 eq / kWh.

Based on Formula 17 and the result from Formula 18, the following GHG emissions matrix was derived (Table 34).

Table 34: GHG Emissions Matrix

		SOLAR CAPACITY						
		5 kW	**10 kW**	**20 kW**	**40 kW**	**60 kW**	**80 kW**	**100 kW**
LOCATION	**Okanagan**	5 Tonnes of CO2 eq / Yr	11 Tonnes of CO2 eq / Yr	21 Tonnes of CO2 eq / Yr	43 Tonnes of CO2 eq / Yr	65 Tonnes of CO2 eq / Yr	87 Tonnes of CO2 eq / Yr	110 Tonnes of CO2 eq / Yr
	Fraser Valley	5 Tonnes of CO2 eq / Yr	10 Tonnes of CO2 eq / Yr	20 Tonnes of CO2 eq / Yr	40 Tonnes of CO2 eq / Yr	60 Tonnes of CO2 eq / Yr	80 Tonnes of CO2 eq / Yr	100 Tonnes of CO2 eq / Yr
	Vancouver Island	5 Tonnes of CO2 eq / Yr	10 Tonnes of CO2 eq / Yr	20 Tonnes of CO2 eq / Yr	41 Tonnes of CO2 eq / Yr	61 Tonnes of CO2 eq / Yr	82 Tonnes of CO2 eq / Yr	100 Tonnes of CO2 eq / Yr

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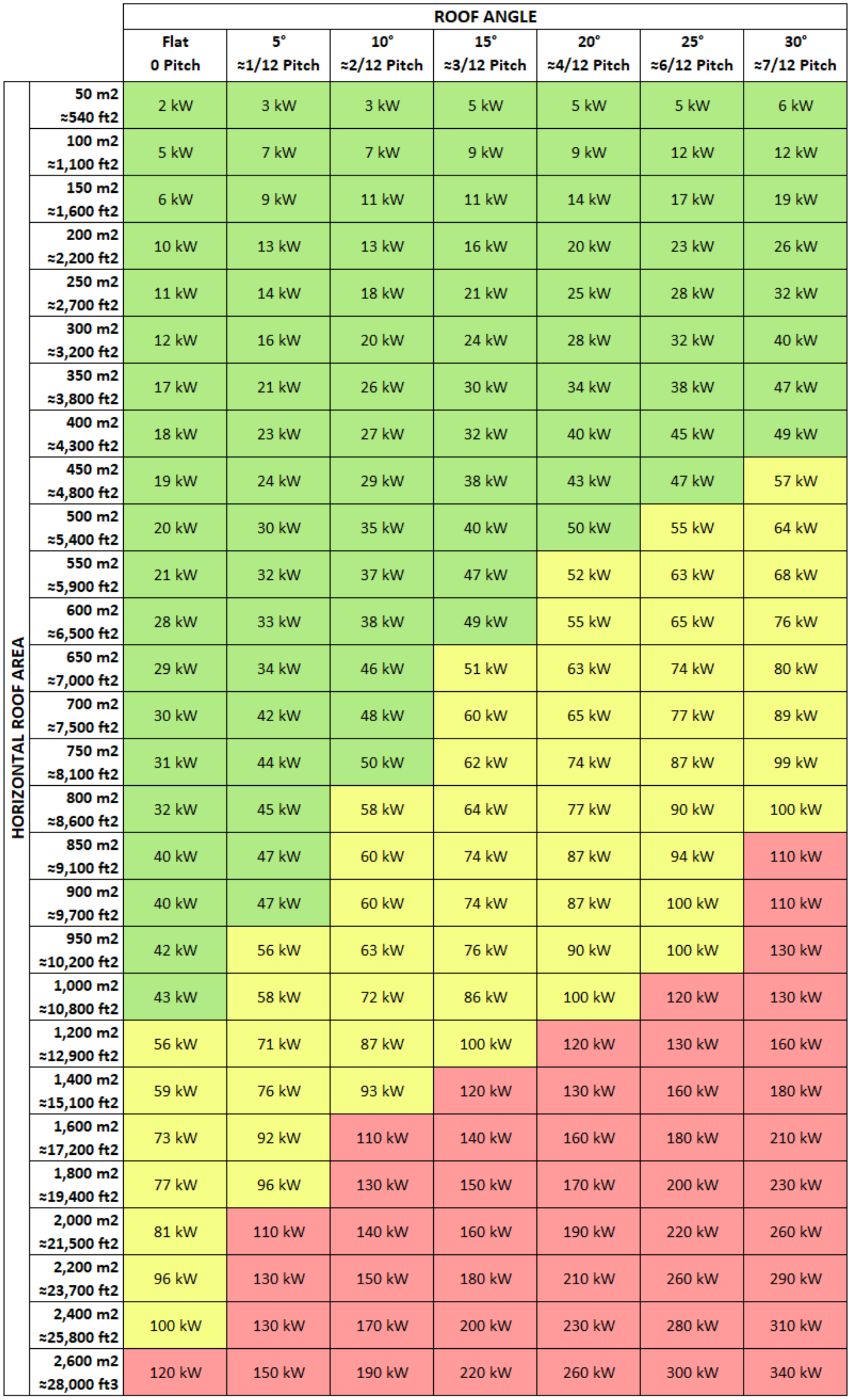
[82] United States Energy Information Administration (EIA) "Electric Power Annual 2016" 2017 Table 8.2. Link

[83] United States Environmental Protection Agency (EPA) "Emission Factors for Greenhouse Gas Inventories" 2014 Link

Appendix B: High-Resolution Matrices

High-Resolution Solar Capacity Matrix



		ROOF ANGLE						
		Flat 0 Pitch	5° ≈1/12 Pitch	10° ≈2/12 Pitch	15° ≈3/12 Pitch	20° ≈4/12 Pitch	25° ≈6/12 Pitch	30° ≈7/12 Pitch
HORIZONTAL ROOF AREA	50 m2 ≈540 ft2	2 kW	3 kW	3 kW	5 kW	5 kW	5 kW	6 kW
	100 m2 ≈1,100 ft2	5 kW	7 kW	7 kW	9 kW	9 kW	12 kW	12 kW
	150 m2 ≈1,600 ft2	6 kW	9 kW	11 kW	11 kW	14 kW	17 kW	19 kW
	200 m2 ≈2,200 ft2	10 kW	13 kW	13 kW	16 kW	20 kW	23 kW	26 kW
	250 m2 ≈2,700 ft2	11 kW	14 kW	18 kW	21 kW	25 kW	28 kW	32 kW
	300 m2 ≈3,200 ft2	12 kW	16 kW	20 kW	24 kW	28 kW	32 kW	40 kW
	350 m2 ≈3,800 ft2	17 kW	21 kW	26 kW	30 kW	34 kW	38 kW	47 kW
	400 m2 ≈4,300 ft2	18 kW	23 kW	27 kW	32 kW	40 kW	45 kW	49 kW
	450 m2 ≈4,800 ft2	19 kW	24 kW	29 kW	38 kW	43 kW	47 kW	57 kW
	500 m2 ≈5,400 ft2	20 kW	30 kW	35 kW	40 kW	50 kW	55 kW	64 kW
	550 m2 ≈5,900 ft2	21 kW	32 kW	37 kW	47 kW	52 kW	63 kW	68 kW
	600 m2 ≈6,500 ft2	28 kW	33 kW	38 kW	49 kW	55 kW	65 kW	76 kW
	650 m2 ≈7,000 ft2	29 kW	34 kW	46 kW	51 kW	63 kW	74 kW	80 kW
	700 m2 ≈7,500 ft2	30 kW	42 kW	48 kW	60 kW	65 kW	77 kW	89 kW
	750 m2 ≈8,100 ft2	31 kW	44 kW	50 kW	62 kW	74 kW	87 kW	99 kW
	800 m2 ≈8,600 ft2	32 kW	45 kW	58 kW	64 kW	77 kW	90 kW	100 kW
	850 m2 ≈9,100 ft2	40 kW	47 kW	60 kW	74 kW	87 kW	94 kW	110 kW
	900 m2 ≈9,700 ft2	40 kW	47 kW	60 kW	74 kW	87 kW	100 kW	110 kW
	950 m2 ≈10,200 ft2	42 kW	56 kW	63 kW	76 kW	90 kW	100 kW	130 kW
	1,000 m2 ≈10,800 ft2	43 kW	58 kW	72 kW	86 kW	100 kW	120 kW	130 kW
	1,200 m2 ≈12,900 ft2	56 kW	71 kW	87 kW	100 kW	120 kW	130 kW	160 kW
	1,400 m2 ≈15,100 ft2	59 kW	76 kW	93 kW	120 kW	130 kW	160 kW	180 kW
	1,600 m2 ≈17,200 ft2	73 kW	92 kW	110 kW	140 kW	160 kW	180 kW	210 kW
	1,800 m2 ≈19,400 ft2	77 kW	96 kW	130 kW	150 kW	170 kW	200 kW	230 kW
	2,000 m2 ≈21,500 ft2	81 kW	110 kW	140 kW	160 kW	190 kW	220 kW	260 kW
	2,200 m2 ≈23,700 ft2	96 kW	130 kW	150 kW	180 kW	210 kW	260 kW	290 kW
	2,400 m2 ≈25,800 ft2	100 kW	130 kW	170 kW	200 kW	230 kW	280 kW	310 kW
	2,600 m2 ≈28,000 ft3	120 kW	150 kW	190 kW	220 kW	260 kW	300 kW	340 kW

High-Resolution Electricity Production Matrix

		SOLAR CAPACITY									
		5 kW	10 kW	15 kW	20 kW	25 kW	30 kW	35 kW	40 kW	45 kW	50 kW
LOCATION	Okanagan	8,800 kWh	18,000 kWh	27,000 kWh	36,000 kWh	45,000 kWh	54,000 kWh	63,000 kWh	72,000 kWh	82,000 kWh	91,000 kWh
	Fraser Valley	8,100 kWh	16,000 kWh	25,000 kWh	33,000 kWh	42,000 kWh	50,000 kWh	58,000 kWh	67,000 kWh	75,000 kWh	84,000 kWh
	Vancouver Island	8,300 kWh	17,000 kWh	25,000 kWh	34,000 kWh	42,000 kWh	51,000 kWh	60,000 kWh	68,000 kWh	77,000 kWh	86,000 kWh

		SOLAR CAPACITY									
		55 kW	60 kW	65 kW	70 kW	75 kW	80 kW	85 kW	90 kW	95 kW	100 kW
LOCATION	Okanagan	100,000 kWh	110,000 kWh	120,000 kWh	130,000 kWh	140,000 kWh	150,000 kWh	160,000 kWh	160,000 kWh	170,000 kWh	180,000 kWh
	Fraser Valley	92,000 kWh	100,000 kWh	110,000 kWh	120,000 kWh	130,000 kWh	130,000 kWh	140,000 kWh	150,000 kWh	160,000 kWh	170,000 kWh
	Vancouver Island	94,000 kWh	100,000 kWh	110,000 kWh	120,000 kWh	130,000 kWh	140,000 kWh	150,000 kWh	160,000 kWh	160,000 kWh	170,000 kWh

High-Resolution Economic Analysis Matrix - #1 / 2

				SOLAR CAPACITY									
				[ALL-IN COST]									
				5 kW	**10 kW**	**15 kW**	**20 kW**	**25 kW**	**30 kW**	**35 kW**	**40 kW**	**45 kW**	**50 kW**
				[$22,000]	*[$43,000]*	*[$64,000]*	*[$84,000]*	*[$100,000]*	*[$120,000]*	*[$140,000]*	*[$160,000]*	*[$170,000]*	*[$190,000]*
LOCATION	**Okanagan**	***Price = 9¢ / kWh***	**Average Savings**	$800 / Yr	$1,500 / Yr	$2,300 / Yr	$3,100 / Yr	$3,900 / Yr	$4,600 / Yr	$5,400 / Yr	$6,200 / Yr	$7,000 / Yr	$7,800 / Yr
			Payback Period	30 Years	29 Years	28 Years	28 Years	27 Years	27 Years	26 Years	26 Years	25 Years	25 Years
		Price = 10¢ / kWh	**Average Savings**	$800 / Yr	$1,700 / Yr	$2,600 / Yr	$3,400 / Yr	$4,300 / Yr	$5,200 / Yr	$6,000 / Yr	$6,900 / Yr	$7,800 / Yr	$8,600 / Yr
			Payback Period	27 Years	26 Years	25 Years	25 Years	24 Years	24 Years	23 Years	23 Years	22 Years	22 Years
		Price = 11¢ / kWh	**Average Savings**	$900 / Yr	$1,900 / Yr	$2,800 / Yr	$3,800 / Yr	$4,700 / Yr	$5,700 / Yr	$6,600 / Yr	$7,600 / Yr	$8,500 / Yr	$9,500 / Yr
			Payback Period	24 Years	23 Years	23 Years	22 Years	22 Years	22 Years	21 Years	21 Years	20 Years	20 Years
		Price = 12¢ / kWh	**Average Savings**	$1,000 / Yr	$2,000 / Yr	$3,100 / Yr	$4,100 / Yr	$5,100 / Yr	$6,200 / Yr	$7,200 / Yr	$8,300 / Yr	$9,300 / Yr	$10,000 / Yr
			Payback Period	22 Years	21 Years	21 Years	20 Years	20 Years	20 Years	19 Years	19 Years	19 Years	18 Years
		Price = 13¢ / kWh	**Average Savings**	$1,100 / Yr	$2,200 / Yr	$3,300 / Yr	$4,400 / Yr	$5,600 / Yr	$6,700 / Yr	$7,800 / Yr	$9,000 / Yr	$10,000 / Yr	$11,000 / Yr
			Payback Period	20 Years	20 Years	19 Years	19 Years	18 Years	18 Years	18 Years	17 Years	17 Years	17 Years
	Fraser Valley	***Price = 9¢ / kWh***	**Average Savings**	$700 / Yr	$1,400 / Yr	$2,100 / Yr	$2,800 / Yr	$3,600 / Yr	$4,300 / Yr	$5,000 / Yr	$5,700 / Yr	$6,500 / Yr	$7,200 / Yr
			Payback Period	>30 Years	>30 Years	>30 Years	>30 Years	30 Years	29 Years	29 Years	28 Years	27 Years	27 Years
		Price = 10¢ / kWh	**Average Savings**	$800 / Yr	$1,600 / Yr	$2,400 / Yr	$3,200 / Yr	$4,000 / Yr	$4,800 / Yr	$5,600 / Yr	$6,400 / Yr	$7,200 / Yr	$8,000 / Yr
			Payback Period	29 Years	28 Years	28 Years	27 Years	27 Years	26 Years	25 Years	25 Years	24 Years	24 Years
		Price = 11¢ / kWh	**Average Savings**	$900 / Yr	$1,700 / Yr	$2,600 / Yr	$3,500 / Yr	$4,400 / Yr	$5,200 / Yr	$6,100 / Yr	$7,000 / Yr	$7,900 / Yr	$8,800 / Yr
			Payback Period	26 Years	26 Years	25 Years	24 Years	24 Years	23 Years	23 Years	23 Years	22 Years	22 Years
		Price = 12¢ / kWh	**Average Savings**	$900 / Yr	$1,900 / Yr	$2,800 / Yr	$3,800 / Yr	$4,700 / Yr	$5,700 / Yr	$6,700 / Yr	$7,600 / Yr	$8,600 / Yr	$9,600 / Yr
			Payback Period	24 Years	23 Years	23 Years	22 Years	22 Years	21 Years	21 Years	21 Years	20 Years	20 Years
		Price = 13¢ / kWh	**Average Savings**	$1,000 / Yr	$2,000 / Yr	$3,100 / Yr	$4,100 / Yr	$5,100 / Yr	$6,200 / Yr	$7,200 / Yr	$8,300 / Yr	$9,300 / Yr	$10,000 / Yr
			Payback Period	22 Years	21 Years	21 Years	20 Years	20 Years	20 Years	19 Years	19 Years	19 Years	18 Years
	Vancouver Island	***Price = 9¢ / kWh***	**Average Savings**	$700 / Yr	$1,400 / Yr	$2,200 / Yr	$2,900 / Yr	$3,600 / Yr	$4,400 / Yr	$5,100 / Yr	$5,800 / Yr	$6,600 / Yr	$7,300 / Yr
			Payback Period	>30 Years	>30 Years	>30 Years	30 Years	29 Years	29 Years	28 Years	27 Years	27 Years	26 Years
		Price = 10¢ / kWh	**Average Savings**	$800 / Yr	$1,600 / Yr	$2,400 / Yr	$3,200 / Yr	$4,000 / Yr	$4,900 / Yr	$5,700 / Yr	$6,500 / Yr	$7,300 / Yr	$8,100 / Yr
			Payback Period	28 Years	28 Years	27 Years	26 Years	26 Years	25 Years	25 Years	24 Years	24 Years	23 Years
		Price = 11¢ / kWh	**Average Savings**	$900 / Yr	$1,800 / Yr	$2,600 / Yr	$3,500 / Yr	$4,400 / Yr	$5,300 / Yr	$6,200 / Yr	$7,100 / Yr	$8,100 / Yr	$9,000 / Yr
			Payback Period	26 Years	25 Years	24 Years	24 Years	23 Years	23 Years	23 Years	22 Years	22 Years	21 Years
		Price = 12¢ / kWh	**Average Savings**	$1,000 / Yr	$1,900 / Yr	$2,900 / Yr	$3,900 / Yr	$4,800 / Yr	$5,800 / Yr	$6,800 / Yr	$7,800 / Yr	$8,800 / Yr	$9,800 / Yr
			Payback Period	23 Years	23 Years	22 Years	22 Years	21 Years	21 Years	21 Years	20 Years	20 Years	19 Years
		Price = 13¢ / kWh	**Average Savings**	$1,000 / Yr	$2,100 / Yr	$3,100 / Yr	$4,200 / Yr	$5,300 / Yr	$6,300 / Yr	$7,400 / Yr	$8,400 / Yr	$9,500 / Yr	$11,000 / Yr
			Payback Period	21 Years	21 Years	20 Years	20 Years	20 Years	19 Years	19 Years	19 Years	18 Years	18 Years

High-Resolution Economic Analysis Matrix - #2 / 2

				SOLAR CAPACITY									
				[ALL-IN COST]									
				55 kW	**60 kW**	**65 kW**	**70 kW**	**75 kW**	**80 kW**	**85 kW**	**90 kW**	**95 kW**	**100 kW**
				[$210,000]	*[$220,000]*	*[$230,000]*	*[$250,000]*	*[$260,000]*	*[$270,000]*	*[$290,000]*	*[$300,000]*	*[$320,000]*	*[$330,000]*
LOCATION	**Okanagan**	*Price = 9¢ / kWh*	**Average Savings**	$8,600 / Yr	$9,400 / Yr	$10,000 / Yr	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr
			Payback Period	24 Years	24 Years	23 Years	23 Years	22 Years	22 Years	22 Years	22 Years	21 Years	21 Years
		Price = 10¢ / kWh	**Average Savings**	$9,500 / Yr	$10,000 / Yr	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr
			Payback Period	22 Years	21 Years	21 Years	20 Years	20 Years	20 Years	19 Years	19 Years	19 Years	19 Years
		Price = 11¢ / kWh	**Average Savings**	$11,000 / Yr	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr	$19,000 / Yr
			Payback Period	20 Years	19 Years	19 Years	18 Years	18 Years	18 Years	18 Years	17 Years	17 Years	17 Years
		Price = 12¢ / kWh	**Average Savings**	$11,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr	$19,000 / Yr	$20,000 / Yr	$21,000 / Yr
			Payback Period	18 Years	17 Years	17 Years	17 Years	16 Years	16 Years	16 Years	16 Years	16 Years	16 Years
		Price = 13¢ / kWh	**Average Savings**	$12,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr	$19,000 / Yr	$20,000 / Yr	$22,000 / Yr	$23,000 / Yr
			Payback Period	16 Years	16 Years	16 Years	15 Years	15 Years	15 Years	15 Years	15 Years	15 Years	14 Years
	Fraser Valley	*Price = 9¢ / kWh*	**Average Savings**	$7,900 / Yr	$8,600 / Yr	$9,400 / Yr	$10,000 / Yr	$11,000 / Yr	$12,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr
			Payback Period	26 Years	26 Years	25 Years	25 Years	24 Years	24 Years	24 Years	24 Years	23 Years	23 Years
		Price = 10¢ / kWh	**Average Savings**	$8,800 / Yr	$9,600 / Yr	$10,000 / Yr	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$15,000 / Yr	$16,000 / Yr
			Payback Period	24 Years	23 Years	23 Years	22 Years	22 Years	21 Years	21 Years	21 Years	21 Years	21 Years
		Price = 11¢ / kWh	**Average Savings**	$9,700 / Yr	$11,000 / Yr	$12,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr
			Payback Period	21 Years	21 Years	20 Years	20 Years	20 Years	19 Years	19 Years	19 Years	19 Years	19 Years
		Price = 12¢ / kWh	**Average Savings**	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr	$19,000 / Yr
			Payback Period	19 Years	19 Years	19 Years	18 Years	18 Years	18 Years	17 Years	17 Years	17 Years	17 Years
		Price = 13¢ / kWh	**Average Savings**	$11,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr	$19,000 / Yr	$20,000 / Yr	$21,000 / Yr
			Payback Period	18 Years	17 Years	17 Years	17 Years	16 Years	16 Years	16 Years	16 Years	16 Years	16 Years
	Vancouver Island	*Price = 9¢ / kWh*	**Average Savings**	$8,100 / Yr	$8,800 / Yr	$9,600 / Yr	$10,000 / Yr	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr
			Payback Period	26 Years	25 Years	25 Years	24 Years	24 Years	23 Years	23 Years	23 Years	23 Years	23 Years
		Price = 10¢ / kWh	**Average Savings**	$9,000 / Yr	$9,800 / Yr	$11,000 / Yr	$12,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$16,000 / Yr
			Payback Period	23 Years	23 Years	22 Years	22 Years	21 Years	21 Years	21 Years	21 Years	20 Years	20 Years
		Price = 11¢ / kWh	**Average Savings**	$9,900 / Yr	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr
			Payback Period	21 Years	20 Years	20 Years	20 Years	19 Years	19 Years	19 Years	19 Years	19 Years	18 Years
		Price = 12¢ / kWh	**Average Savings**	$11,000 / Yr	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr	$19,000 / Yr	$20,000 / Yr
			Payback Period	19 Years	19 Years	18 Years	18 Years	17 Years	17 Years	17 Years	17 Years	17 Years	17 Years
		Price = 13¢ / kWh	**Average Savings**	$12,000 / Yr	$13,000 / Yr	$14,000 / Yr	$15,000 / Yr	$16,000 / Yr	$17,000 / Yr	$18,000 / Yr	$19,000 / Yr	$20,000 / Yr	$21,000 / Yr
			Payback Period	17 Years	17 Years	17 Years	16 Years	16 Years	16 Years	16 Years	16 Years	16 Years	15 Years

High-Resolution GHG Emissions Matrix

		SOLAR CAPACITY									
		5 kW	10 kW	15 kW	20 kW	25 kW	30 kW	35 kW	40 kW	45 kW	50 kW
LOCATION	Okanagan	5 Tonnes of CO2 eq. / Yr	11 Tonnes of CO2 eq. / Yr	16 Tonnes of CO2 eq. / Yr	21 Tonnes of CO2 eq. / Yr	27 Tonnes of CO2 eq. / Yr	32 Tonnes of CO2 eq. / Yr	38 Tonnes of CO2 eq. / Yr	43 Tonnes of CO2 eq. / Yr	49 Tonnes of CO2 eq. / Yr	54 Tonnes of CO2 eq. / Yr
	Fraser Valley	5 Tonnes of CO2 eq. / Yr	10 Tonnes of CO2 eq. / Yr	15 Tonnes of CO2 eq. / Yr	20 Tonnes of CO2 eq. / Yr	25 Tonnes of CO2 eq. / Yr	30 Tonnes of CO2 eq. / Yr	35 Tonnes of CO2 eq. / Yr	40 Tonnes of CO2 eq. / Yr	45 Tonnes of CO2 eq. / Yr	50 Tonnes of CO2 eq. / Yr
	Vancouver Island	5 Tonnes of CO2 eq. / Yr	10 Tonnes of CO2 eq. / Yr	15 Tonnes of CO2 eq. / Yr	20 Tonnes of CO2 eq. / Yr	25 Tonnes of CO2 eq. / Yr	30 Tonnes of CO2 eq. / Yr	35 Tonnes of CO2 eq. / Yr	41 Tonnes of CO2 eq. / Yr	46 Tonnes of CO2 eq. / Yr	51 Tonnes of CO2 eq. / Yr

		SOLAR CAPACITY									
		55 kW	60 kW	65 kW	70 kW	75 kW	80 kW	85 kW	90 kW	95 kW	100 kW
LOCATION	Okanagan	60 Tonnes of CO2 eq. / Yr	65 Tonnes of CO2 eq. / Yr	71 Tonnes of CO2 eq. / Yr	76 Tonnes of CO2 eq. / Yr	82 Tonnes of CO2 eq. / Yr	87 Tonnes of CO2 eq. / Yr	93 Tonnes of CO2 eq. / Yr	98 Tonnes of CO2 eq. / Yr	100 Tonnes of CO2 eq. / Yr	110 Tonnes of CO2 eq. / Yr
	Fraser Valley	55 Tonnes of CO2 eq. / Yr	60 Tonnes of CO2 eq. / Yr	65 Tonnes of CO2 eq. / Yr	70 Tonnes of CO2 eq. / Yr	75 Tonnes of CO2 eq. / Yr	80 Tonnes of CO2 eq. / Yr	85 Tonnes of CO2 eq. / Yr	91 Tonnes of CO2 eq. / Yr	96 Tonnes of CO2 eq. / Yr	100 Tonnes of CO2 eq. / Yr
	Vancouver Island	56 Tonnes of CO2 eq. / Yr	61 Tonnes of CO2 eq. / Yr	66 Tonnes of CO2 eq. / Yr	72 Tonnes of CO2 eq. / Yr	77 Tonnes of CO2 eq. / Yr	82 Tonnes of CO2 eq. / Yr	87 Tonnes of CO2 eq. / Yr	92 Tonnes of CO2 eq. / Yr	98 Tonnes of CO2 eq. / Yr	100 Tonnes of CO2 eq. / Yr

Appendix C: Socio-Environmental Analysis of Implementing Solar Electricity On-Farm

ENVIRONMENTAL DYNAMICS INC.

Down to Earth Biology

Socio-Environmental Impact Analysis of Implementing Solar Electricity On-Farm

Prepared For

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17V0359
February 2018

ENVIRONMENTAL DYNAMICS INC.
Down to Earth Biology

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1 Introduction

The Government of Canada has committed to reduce Canada's total greenhouse gas (GHG) emissions by 17% from 2005 levels by 2020 (Environment Canada 2012). This strategy is then impressed on each province. To achieve this goal, British Columbia has developed provincial GHG reduction targets, a Carbon Tax, emission control measures, renewable energy initiatives, and building practice amendments. Under the BC *Greenhouse Gas Reduction Targets Act*, GHG emissions are to be reduced by at least 33% below 2007 levels by 2020, with interim measures to guide this goal. More aggressively, a further reduction by 80% is targeted for 2050. To these ends provincial ministries are developing initiatives to reduce GHG emissions, conserve energy and implement sustainable practices within their own mandates.

1.1 Scope of Work and Background

The Ministry of Agriculture is evaluating the viability of installing solar power on farms in British Columbia. Considerations for the impacts to economic, social and environmental values, along with distinctions based on farm type, size and geographical location need to be examined. Midgard Consulting Inc. requested input from EDI Environmental Dynamics to assess the social and environmental aspects of this undertaking.

The social impacts resulting for the installation of solar power are generally perception based, both positive and negative. Farmers are interested in the concept and surrounding neighbors are receptive to the esthetics. Interest is based on the potential for cost savings, public environmental consciousness, and alignment with market branding.

The environmental impacts associated with solar power typically include land use and habitat loss, water use, and the use of hazardous materials in the cell manufacturing process. The types of impacts vary greatly depending on the scale of the system and the technology used, such as photovoltaic (PV) solar cells or concentrating solar thermal plants (CSP).

For the purposes of this analysis of impacts, the following conditions and circumstances apply:

- The solar technology being considered is photovoltaic (PV), since it's more conducive to small applications and readily available throughout BC;
- Rooftop only installations are being reviewed. A review of on-ground solar would potentially have more localized environmental effects, however to reduce that, only rooftop options are being considered;
- Installation is south, east or west facing with a slope approximately to the latitude of the area.
- Various farms types being reviewed, primarily poultry, dairy, and winery/vineyard; and
- Various regions of the province being reviewed, Fraser Valley, Okanagan and Vancouver Island.

1.1.1 Relevant Legislation and Guidance

When considering the social and environmental effects of installing solar on farms, it's not unlike considering impacts from any kind of land development or renovation. The same legislation, policies, regulations, guidelines and best practices that protect aquatic and terrestrial species are applicable. The following list of documents is applicable and how they relate to this project is described.

- ***Wildlife Act***: This Act states that all wildlife in the province of BC is the property of the government. During installation and maintenance of solar projects, any damage or destruction of wildlife and wildlife habitat may result in action taken against the developers. Birds, eggs, occupied nests or any nests belonging to eagles, peregrine falcons, gyrfalcons, osprey, heron or burrowing owl cannot be displaced or harmed. Any wildlife harmed by accident must be immediately reported.
- ***Migratory Bird Conventions Act***: This Act states that any migratory bird or nest cannot be moved, destroyed, damaged or disturbed during the installation and maintenance of solar projects. Before clearing land, a pre-clearing survey must be conducted to determine the existence and location of any migratory bird nest.
- ***Species at Risk Act***: This legislation states that on private land, it is prohibited to damage, destroy, move or disturb any aquatic species or migratory birds that are listed in Schedule 1 of SARA during the installation and maintenance of solar projects.
- **National Farm Building Code of Canada:** This document provides adaptations on the National Building Code of Canada to accommodate the needs of farmers. Included are regulations on rooftop loads, roof slope and roof materials for farm buildings that would need to be followed during the installation of rooftop solar panels.
- **Develop with Care 2014:** This document provides guidelines to land developers to promote environmental sustainability and stewardship. If followed, these science-based best practices can help developers decrease the environmental impact of their project and establish due diligence if any environmental problems arise. This document promotes the use of non-carbon emitting power sources such as solar power.

1.1.2 Net Metering Program

This project is only assessing power grid connected systems since BC Hydro only allows for net metering for those who generate electricity for their own use. Net metering simply outlined is when farmers generate more power than needed; the excess is sold to BC Hydro. In the event that not enough power is generated for farm needs, the deficit is purchased from BC Hydro. The sale of excess power to BC Hydro produces a credit towards future electricity needs. As of March 2016, there were almost 650 customers in BC on the Net

Metering program generating 3.8 MW of power (BC Hydro 2017) (more recent data (2017) from the BC Hydro website indicates over 900 customers participate in net metering (https://www.bchydro.com/work-with-us/selling-clean-energy/net-metering.html)). The composition of the power generated is over 95% solar PV systems (BC Hydro 2017). Under the Net Metering program, customers have the option to own or lease the electricity generating equipment and cannot exceed 100 kW generated. Table 1 details the number and type of power generation under the Net Metering program and the regional distribution.

Table 35. Net Metering Projects by Region

Location	Generation Type	Number of Projects	Capacity (kW)
Central Interior	PV	24	111
	Wind	1	2
	Wind & PV	1	8
East Kootenay	Hydro	1	25
	PV	26	129
Kelly/Nicola	Hydro	2	8
	PV	28	128
	Wind	1	2
Lower Mainland	Biogas	1	20
	Hydro	4	177
	Hydro & PV	1	4
	PV	173	1,036
	Wind	1	5
	Wind & PV	1	5
North Coast	PV	20	92

	Wind	1	3
Peace River	Hydro	1	100
	PV	17	77
South Interior	Hydro	3	112
	PV	54	286
	Wind	3	15
Vancouver Island	Hydro	2	56
	PV	271	1,381
	Wind	1	3
	Wind & PV	2	7
	Total	**640**	**3,794**

Source: BC Hydro 2017

1.1.3 Project Areas and Farming Types

The intent of this assessment considered three broad areas of the province representing the type and extent of impacts associated with PV installations. These areas economically also represent the most intense and diverse farming regions of the province; the Fraser Valley, the Okanagan and Vancouver Island.

When considering on-roof PV installations, farm type may influence implementation; properties that involve more grazing type activities may see less benefit since they may have fewer buildings to use for installation structures. Farm sizes may also drive electricity needs; they can range from larger farms with production quotas down to smaller artisan and hobby farms which typically have smaller property sizes with fewer and smaller buildings. Other factors affecting why farmers may consider on-farm solar installation could include alignment with marketing plans and other “green” initiatives.

Table 2 discusses a general categorization of farm diversity, the type of farms that might be included and a broad description of their attributes from the solar perspective of land needs (e.g. available buildings), how the power might be used and level of endorsement (e.g. could solar support current marketing or branding initiatives or sustainability beliefs; public relations). Not all farms will fall into these categories, but a preponderance of them will.

Table 36. Farm diversity

Farm Type	Size/Scale	Description
Dairy	Hobby to quota in scale	• grazing and/or pasture land • larger operations may have substantial building footprint • some kind of processing/holding of milk. • general electrical needs (i.e. lights, pumps, barns, storage, fences, etc.) • hobby level may be open to the public for tours, store
Poultry	Hobby to quota in scale	• smaller defined footprint • buildings dominate the footprint for egg and meat processing, incubators • general electrical needs (i.e. lights, pumps, barns, storage, fences, temperature/humidity, etc.) • hobby level may be open to the public for tours, store
Wineries/Vineyards	Hobby to large in scale	• primarily land needs, some buildings • grape and wine processing • general electrical needs (i.e. lights, temperature/humidity, pumps, barns, storage, etc.) • likely open to the public for tours, store

1.2 Project Scenario

To assess the possible impacts of installing and operating solar on-farm a depiction of what that scenario might look like needs to be defined (Table 37). For this assessment we are considering that procurement of the PV cells will be from a Canadian vendor and that the installation of PV cells on a variety of farms will be on the available existing roof structures. The installation is typically done by an experienced solar installer or the farm producer (e.g. do-it-yourself), both options require a licenced electrician to connect the system to the electrical grid and to ensure that electrically the installation is safe. Farm buildings by definition fall under the National Farm Building Code of Canada and do not need a regular building permit. The British Columbia Building Code requires all farm buildings within municipal or regional district boundaries to conform to the national code. Once installed, the routine maintenance is minimal, aside from replacement of failed or faulty cells and snow and debris removal if necessary. The general life of PV cells is 25 years. Once the cells reach the end of their lifespan, producing less energy, they need to be disposed.

Table 37. On-farm solar activities

Installation Activities	
Area for installation	on-roof, no on-ground option

Aspect of installation	south facing
Type of installation	flat or sloped roofs
Installation method	do-it-yourself or solar installer, with electrician
Procurement	on-line or brick and mortar Canadian retailer
Operation Activities	
Operation	on-grid power generation
Maintenance	possible replacement of faulty or damage cells
Maintenance	cleaning, removal of snow, debris
Decommissioning Activities	
Removal	removal of the cells
Disposal	disposal of cells
Refurbishment/Reuse	individual components can be used in other products and the cells themselves can be reused in other solar applications

2 Methodology

The impact analysis is qualitative in scope and considers the implications of installation of PV systems on farms to both environmental and social resources. A desktop analysis of the potential impacts was conducted by reviewing available literature in regions where on-farm installations have been instituted, such as in Alberta, Europe and the United States of America. Other grey literature sourced included PV cell manufacturers, BC Hydro, lobby groups, associations and solar installers. Perception information was gleaned from grey literature, a survey sent to a subset of farmers in British Columbia asking for their opinions on solar power and a BC Hydro survey provided to their Net Metering Program participants on their satisfaction with the program.

The potential impacts were categorized based on the following severity ranking:

- High = impact is substantial and could be considered a "showstopper" as far as feasibility, delivery or success of the project. It would be very difficult to mitigate.
- Medium = impact is present and can be partially mitigated; other factors such as duration, frequency, geographical extent may influence this impact.
- Low = there is an impact, but it can be fully mitigated.
- None = there is no impact perceived.

Furthermore, impacts on air quality were reviewed in the context of the greenhouse gases produced during the life-cycle of PV cells from obtaining the raw materials to installation on the farm and disposal. An assessment of the energy production is separate from this examination.

3 Air Quality

Greenhouse gases (GHGs) are those gaseous components of the atmosphere, both natural and anthropogenic, that absorb and emit the sun's radiation (the greenhouse effect). As a result of human activities, global atmospheric concentrations of GHGs have increased markedly since 1750 and climate warming is increasing (IPCC 2007). The GHGs of concern include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases (F-gases) (Environment Canada 2010b).

Solar power is one of, if not the cleanest, source of power, compared to other types of power generation, in that it:

- generates no carbon dioxide (CO_2) or other greenhouse gases (GHGs) that contribute to climate change during normal operation (Dell et al. 2014);
- produces no harmful emissions or wastes associated with coal power, such as mercury, sulfur dioxide, nitrogen oxides, lead, and arsenic (Freese et al. 2008); and
- has low life-cycle CO_2 emissions compared with traditional fossil fuel-based electricity production, as most of the emissions are associated with the refinement and processing of the semiconductor materials required to manufacture the panels (Environment Canada 2012).

3.1 Life-Cycle Analysis

An examination of the emissions savings of the PV system considers all aspects from the raw materials and energy required to make the infrastructure and all the components, sales and marketing and distribution, site preparation, installation, operation and maintenance, to final decommissioning and disposal. In this assessment we are only considering silicone and thin-film PV technologies since they make up over 90% of the commercially available products.

Fabrication of the PV module – the bulk of the energy for crystalline silicon units is spent on refining and purifying metallurgical-grade silicon into solar-grade silicon (>99.999999% pure). Thin-film technologies such as cadmium telluride (CdTe) and copper indium gallium selenide (CIGS) require less energy, as the thickness of active materials required to convert sunlight into electricity is about 100 times less than the thickness for conventional technologies based on crystalline silicon. Metal-grade cadmium, zinc, selenium and tellurium for CdTe and CIGS PV modules are obtained primarily as by-products of zinc and copper smelting, respectively, and further purification is required to obtain solar-grade purity (>99.999999%).

Fabrication of the balance of system (BOS) – this includes the raw materials and energy required for the encapsulation and BOS components, for example, aluminum for module frames, silica for glass, copper ore for cables, and iron and zinc ores for mounting structures.

Procurement and installation – includes the supply chain components such as distribution, shipping and marketing. The installation stage incorporates all the labour needs such as engineers and architects reviewing structural integrity, contractors for building support, installers of PV systems and modules, cables, and power conditioning equipment, electricians and inspectors.

Operations and Maintenance – the life of operation, power generation and overall emission savings. The economics of operation, including the energy payback and GHG offsets, will not be included here.

Decommissioning – this includes the efforts to remove the parts and recycle/reuse/dispose of the components. The most widely used PV cells contain, in small amounts, lead and cadmium, both considered toxic (*Canadian Environmental Protection Act* 1999) as well as tellurium and selenium, which are considered hazardous. Cadmium compounds are regulated in many countries because of their toxicity in fish and wildlife and because they can pass to humans through the food chain (McDonald and Pearce 2010). Cadmium can also accumulate in the environment as a result of PV cell disposal in landfills by leaching into groundwater, surface water contamination and can enter the atmosphere through incinerator emissions (Table 4). Incinerators use pollution controls that trap cadmium, but the resulting ash contains cadmium that can escape into the environment through ashfill leachate (McDonald and Pearce 2010).

Table 38. Substances of concern in PV manufacturing.

Substance	Use	Concern
cadmium sulphate	Thin-film semiconductor layer	Adverse effects on human health and the environment; persistent and bioaccumulative.
cadmium telluride	Thin-film semiconductor	Persistent because it is a metal but has not been found to be bioaccumulative; recent studies have shown that CdTe has a low acute inhalation, oral and aquatic toxicity
tellurium dioxide.	Produces the CdTe thin-film layer	Persistent to the environment

Source: SVTC, 2009; EPRI, 2003; Kaczmar, 2011; Fthenakis and Kim, 2011a; Government of Canada, 2012

Cadmium is a natural by-product of zinc mining (Wolden et al. 2011), which could be considered a beneficial consequence. Some further postulate that CdTe PV manufacturing is a means to sequester elemental cadmium in an environmentally beneficial manner (Wolden et al. 2011, Raugei and Fthenakis, 2010). Life-cycle analysis of cadmium use in PV cells has the potential to reduce overall global cadmium-related environmental pollution from mining as the PV industry grows (Raugei and Fthenakis 2010). Further as the PV market evolves with the adoption of end-of-life take-back and recycling programs, cadmium emissions will continue to decline (Sinha et al. 2008; Raugei and Fthenakis 2010). When CdTe PV technology replaces coal-based power generation, overall cadmium emissions will be reduced since coal power emits 100 to 360 times more cadmium into the atmosphere.

Analysis of GHG Emissions per kW h of Panel Installed

Photovoltaic systems emit no GHGs or air pollutants during normal operation (EPIA/Greenpeace International, 2011; Kaygusuz, 2009), however the material extraction and production stages account for almost all emissions in the PV cell life-cycle. There is no definitive published data on GHG and air pollutant emissions in the recycling and decommissioning stages of the PV life-cycle, data reviewed is inconsistent as disposal methods, modes of transportation and recycling stages are limited given this is an emerging facet of the industry with no standardization or regulation, so estimates are highly assumptive. Most of the current literature does not provide guidance on how to model end-of-life issues into life-cycle analysis (Fthenakis et. al. 2011a), therefore, results vary.

Total life-cycle emissions of GHGs (in carbon dioxide equivalence, CO_2 eq) have been reported to be 28 to 72 g CO_2 eq/kW h for crystalline silicon and 18 to 20 g CO_2 eq/kW h for CdTe (Jazayeri at al. 2008; Fthenakis et al. 2011b; Environment Canada 2010a). A comprehensive review by the US National Renewable Energy Laboratory (US NERL) of 400 of studies, summarized 46 life-cycle estimates into a single assessment. They found GHG emissions of 26 to 36 g CO_2 eq/kW h of panel installed combining both types of panels. The range in values is an artifact of the energy type and mix used to produce the PV modules around the world, wafer thickness, silicon type and disposal/recycling/reuse options. Compared to other types of power generation, the life-cycle analysis of GHG emission of PV modules is markedly less (Table 5).

Table 39. Total life cycle emissions for various sources of power generation.

Pollutant	**CO_2 eq/ TW h**			
	Nuclear	Coal	Natural Gas	PV
GHG Emissions US	1,837	1,051,215	540,391	26,000 – 36,000[1]
GHG Emissions CDN	-	853,032	460,674	18,000 - 72,000[2]

Source: Jazayeri at al. 2008; Fthenakis et al. 2011b; US NREL 2012[1] Environment Canada 2010a[2]

4 Vegetation, Wildlife and Aquatic Resources

The environmental assessment is qualitative in scope and considers the potential effects of implementing rooftop solar electricity on farms on vegetation, wildlife and aquatic resources (water). Implementation of on-farm rooftop solar electricity as described in Section 1.2, can be categorized into the following project phases:

- Initiation (installation of PV systems on rooftops);
- Operations and maintenance; and
- Decommissioning.

This environmental assessment does not include evaluation of the potential effects associated with procurement, manufacturing and transportation of the PV panels to the farm, as these project phases are not anticipated to result in measurable changes to baseline conditions for environmental resources. Environmental effects associated with air quality or GHG emissions is discussed for these three phases in Section 3.

The interaction of environmental resources with project activities, by project phase, was evaluated (Table 6). PV systems are to be installed on existing farm infrastructure (e.g. barn, house, outbuildings, etc.) and therefore, vegetation removal associated with land clearing will not be required. Some pruning of trees adjacent to buildings with rooftop solar systems installed may be required to reduce shading and increase the amount of sunlight hitting the panels.

Table 40. Table of interactions by Project phase

Activity by Project Phase	Environmental Resource		
	Vegetation	Wildlife	Water
Initiation			
Installation of PV system on rooftop		✓	
Pruning of trees adjacent to building to reduce shading	✓	✓	
Operations & Maintenance			
Passive generation of electricity through solar absorption			
Pruning of trees adjacent to building to prevent shading	✓	✓	
Cleaning of PV panels to maintain efficiency			✓
Decommissioning			
Removal of PV system from rooftop		✓	

As the PV systems evaluated here are restricted to rooftop, wildlife resources affected will be restricted to species which use the rooftop of farm buildings for perching, roosting, and / or nesting, which is essentially avian species, primarily birds.

Water use in the life cycle of PV technologies is mainly from upstream usage related to manufacturing and is considered to be minimal. No water is used during the operation of PV systems, except for when modules are cleaned. In addition, the impacts on water quality are considered to be minimal (Environment Canada 2012).

The potential effects associated with the initiation, operations and decommissioning are anticipated to be the same across all regions in BC, as those identified are site-specific and not generally affected by differences in climate or landscape. The bird species primarily affected in each region may vary, but the overall effect on birds is the same.

4.1 Current Conditions

Solar power is generally associated with large amounts of land disturbance (Kammen et al. 2011; Environment Canada 2012); however, this effect results from large arrays associated with ground-mounted PV systems. As described in Section 1.2, this assessment is restricted to rooftop PV installations only. Rooftop PV systems do not result in additional land disturbance as they are installed on existing buildings, and a study by Fthenakis and Kim (2009) has shown that rooftop PV installations have the least land use of all technologies considered, including nuclear, natural gas, mining, hydroelectric, wind and ground-mounted solar.

Given that the power generated by solar cells is generally proportional to the amount of sunlight received (Environment Canada 2012), and as such, the efficiency of rooftop PV systems would be affected by shading or any reduction in sunlight reaching the panels. In addition, dirt and dust can reduce solar cell efficiency (Kammen et al. 2011), and therefore maintenance of PV systems includes washing off the panels regularly.

Many bird species nest on farm infrastructure, including under the eaves of buildings (e.g. barn swallow, American robin). Migratory bird nests are protected by the federal *Migratory Bird Convention Act*, which prohibits the disturbance or destruction of a migratory bird nest and its eggs. In addition, birds of prey (e.g. red-tailed hawk, barn owl) will perch on rooftops while surveying farm fields for potential prey or to roost.

4.2 Impact Assessment

Environmental effects typically associated with land development include habitat loss, change in habitat, sensory disturbance and direct mortality. The effects associated with installation, operation and decommissioning of the rooftop PV panels can change as the project moves through the phases. Effects on water use and quality are not anticipated, as using water for cleaning solar panels is akin to regular window washing (Environment Canada 2012).

4.2.1 Habitat Loss

Habitat loss refers to the long-term or permanent removal of wildlife habitat (e.g. vegetation clearing). As discussed above, rooftop PV systems are placed on land already disturbed by the buildings upon which they are installed, and therefore no additional clearing is required. However, where rooftop PV systems are installed, exposure to sunlight should be maximized and it may be necessary to prune or cut back trees and tall shrubs in the immediate vicinity of the building with the installation. Pruning of vegetation adjacent to farm infrastructure where PV systems are installed is expected to be required for the life of the project. The amount of vegetation to be pruned or cut back is expected be minimal, and vegetation will be allowed to grow back if / when PV panels are removed. The impact associated with habitat loss and vegetation removal is expected to be none.

4.2.2 Change in Habitat

Changes in habitat would include any changes to the area that do not necessarily render the habitat unusable or unsuitable but may decrease the quality of the habitat or result in a permanent or temporary change in use. Where vegetation is cleared, or pruned, area formerly shaded may become subjected to increased light and wind. Nests of breeding birds (i.e. under the eaves of buildings) may be vulnerable to the increased exposure of wind, which may lead to compromised nest structures, and susceptible to predation due to increased exposure.

Effects associated with increased exposure to wind and predators from pruning of vegetation to maximize the southern exposure of PV panels to sunlight can be mitigated by planting and maintaining similar vegetation on the opposite sides of the building or by erecting alternate nesting structures in suitable habitat away from rooftop PV system. While birds may potentially avoid rooftops with PV panels, it is likely that species will become accustomed to their presence, similar to satellite dishes and other rooftop infrastructure, and continue to nest and roost in the vicinity. The impact associated with change in habitat is expected to be low.

4.2.3 Sensory Disturbance

An individual / species response to potential disturbance stimuli includes undetected metabolic changes, vocalizations, and dispersion away from the source of disturbance. Elevated noise levels (e.g. from people or machinery), olfactory stimuli, and visual stimuli constitute various types of disturbance stimuli. Breeding birds may respond to disturbance stimuli by vocalization and dispersion, which may lead to nest abandonment and/or nest predation.

During installation, birds nesting under the eaves of the building rooftop, or in surrounding vegetation, may be disturbed. This effect can be mitigated by installing PV systems outside of the regional bird nesting window (e.g. March 15 to August 31 in the Lower Mainland region). Where installation must occur during the active nesting window, a qualified environmental professional (QEP) can be engaged to conduct a passive pre-clearing nest survey to identify potential nesting activity in the vicinity of the building rooftop proposed for installation. Maintenance of the PV panels, including washing, should be conducted outside the nesting window where possible. Similar effects associated with decommissioning of the PV system can also be mitigated by conducted works outside of the nesting window, or conducting a pre-clearing nest survey in advance.

The AC inverter and grid tie-in wiring will produce low frequency electromagnetic frequency (EMF), however EMF emitted is likely not harmful to birds, as they quickly diminish with distance and are indistinguishable from normal background levels within several yards (ODT 2010). Effects to human health and safety associated with EMF are discussed in detail in Section 5.2.6.

Effects associated with sensory disturbance are expected to be restricted to the initiation and decommissioning phase, with the exception of routine vegetation pruning during the operations and maintenance phase. These effects can be mitigated through the timing of works. The impact associated with sensory disturbance is expected to be low.

4.2.4 Direct Mortality

Project-related activities may have potential for injury / mortality to wildlife species. Nesting birds are particularly vulnerable to mortality and injury during vegetation pruning. Collision with solar panel arrays, known as the "lake effect", whereby migrating birds perceive the reflective surfaces of PV panels as bodies of water and attempt to land on them (Walston et al. 2015) is an effect associated with larger-scale, typically ground-mounted, solar facilities. Rooftop PV systems are likely not large enough to mimic a body of water. Incineration / burning by concentrated rays are another effect associated with solar facilities, however, it results from thermal solar, also known as concentrating solar, where a huge number of mirrors point to a central tower, creating an incredibly high-heat area that is transforms fluid into steam which turns a turbine to power a generator (Smithson-Stanley and Bergstrom 2017). Rooftop PV panels absorb sunlight and convert directly to electricity (Section 1.1.2), and do not generate concentrated rays nor emit heat.

Direct mortality resulting from vegetation pruning can be mitigated by conducting works outside the regional bird nesting season, as discussed in Section 3.2.3. Where vegetation pruning must occur within the active nesting window, a QEP should be engaged to conduct a passive pre-clearing nest survey to identify potential nesting activity in the vicinity of the project. The impact associated with direct mortality is expected to be low.

5 Social Resources

The social assessment is qualitative in scope and considers the implications of installation on farms to the following social resources:

- employment and skilled labour / training related to installation and maintenance;
- procurement of infrastructure and the preparation of the structure;
- disposal of faulty units or end of life;
- aesthetics and visual appeal;
- perceptions and barriers; and
- health and safety.

The typical life of a solar project involves planning, the installation, operations and maintenance and removal. Planning is related to scoping the effort, budget and financing, energy savings, procurement of the hardware and other needs/logistics required to install. Installation would be any site preparations needed, the mounting of the panels on roof and initiation of the power; operations is the function of the panels and including any maintenance, and removal is the decommissioning of the panels. When assessing the impacts of the life of a solar project, the various activities involved from two perspectives were considered: that of the farmer/producer and that of the government.

This report does not include economics to purchase or operate the panels, that is provided separately.

5.1 Current Conditions

Currently in British Columbia there are 613 projects using PV under the Net Metering Program (BC Hydro 2017) for a combined 3,240 kW of power being generated. Most of the projects are 10 kW or less in size. Since inception in 2005, interest in the program continues to increase with 89, 156 and 271 applications submitted in 2014, 2015 and 2016 respectively (BC Hydro 2017). Nationally there is an expectation that solar investment will continue to increase as more programs and initiatives become available, pricing continues to decrease and more resources become available.

5.1.1 Employment and Training

The solar industry is undergoing a boom. In 2016 the US solar industry employed more than 260,000 people (Solar Foundation 2016) and in 2014 there were more than 6,000 solar companies, investing approximately $15 billion in the US economy annually (GMT and SEIA 2014a). The solar industry in the US has a longer history than in Canada however the industry here is poised for a boom in the next decade. In 2015 Canada was home to an estimated 8,100 jobs in solar PV (Clean Energy Canada, 2017) with market growth of more than 22% of installed capacity annually between 1993 and 2009 (IEA, 2009). At the end of 2015 Canada had more than 2,500 MW of solar generation capacity installed (CanSIA, 2018) and it is projected that by 2020 there will be more than 10,000 jobs attributed to the solar industry alone with the majority in construction and manufacturing, followed by operations and maintenance jobs (CanSIA 2014).

In BC there are approximately 24 solar installers, most located in the lower half of the province (BCSEA 2018). Therefore, residential level rooftop solar can be installed more readily in cities and towns, as opposed to remote locations, thus the need offers job possibilities for local rural workers. However installations at the farm level allow for rural engagement where few installers are available. This regional disparity is likely a result of incentives to date that focus on hot water solar heating. Training available in BC includes graduate level courses and courses that are energy management and sustainable energy in nature available at the larger universities (Simon Fraser University, University of Victoria, University of British Columbia, BC Institute of Technology and Selkirk College). Specific training related to solar installation is not available in BC. A review of available training specific to solar power is provided (Table 7).

Table 41. Solar education review

Education Provider	Course/Program	Location
Canadian Solar Institute	5-Day Solar PV Design and Installation Workshop	Travels throughout Canada
Solar Living Institute	Online solar training, hands-on North American Board of Certified Energy Practitioners (NABCEP) and year-round	Hopland, California
Solar Instructor Training Network	Various courses	Various location throughout the US
Solar Energy International	Introduction to Renewable Energy - free Online Course	-
Renewable Energy World	Solar Training NABCEP approved courses (most online)	-
National Board of Certified Energy Practitioners	NABCEP PV Installation Professional and Solar Heating Installer Certifications	Travels throughout US
Clean Energy Institute at the University of Washington	Various courses on PV project development, design, urban uses, cell manufacturing, etc.	Bothell, Seattle, Tacoma
Seneca College	Photovoltaic Clerk and Admin, Electrician, Design, and Installation	Toronto

Source: BCSEA

5.1.2 Site Preparations and Procurement

In this scenario we are only considering on-roof installation. Site preparation is dependent upon the roof area available, aspect for optimal electricity generation (e.g. solar orientation), structural integrity for anchoring the cells and distance to grid interconnection (e.g. distance to panel location and space for inverter installation). An on-ground installation would require more civil activities such as possible leveling, grading, gravel, ground anchors, vegetation removal and possible drainage management for runoff.

The on-roof scenario is less onerous for producers because it requires no loss of production area, it uses the existing footprint.

Procurement involves the availability of the cells in the marketplace (including manufacturing); distribution, shipping, marketing and access to local system installers. Canadian PV manufacturers are involved in different stages of the PV life cycle, producing solar-grade semiconductor materials (for example companies such as Calisolar and 5N Plus), module and PV cells (for example, Centennial Solar, Day4 Energy, Heliene, Photowatt Canada, Celestica and Canadian Solar), and many other products along the PV value chain. Recently, the Ontario government's Feed-In-Tariff (FIT) program requirement for domestic content attracted a large number of new companies to Ontario, resulting in a dynamic and rapidly changing industry. The installation stage includes labour for technical support and labour for the support structures being erected, PV systems mounting, and PV modules, cables, and power conditioning equipment.

Often installers retail cells from various manufacturers, offering the installation, maintenance and performance warranties. There are nine companies in Canada that produce 75% of PV cells sold in Canada the remainder of the market is sourced by foreign manufacturers (IEA 2015).In BC there's approximately two dozen companies specializing in solar installations (BCSEA 2018).

5.1.3 Disposal

Manufacturing PV cells involves a range of hazardous materials such as, hydrochloric acid, sulfuric acid, nitric acid, and hydrogen fluoride. Solar cells manufactured from non-silicon material are made from gallium arsenide, copper-indium-gallium-diselenide, and cadmium telluride, and contain more hazardous materials than those used in traditional silicon cells (Hand et al. 2012). The most common solar cells are made from crystalline silicon, representing more than 85% of world solar market in 2011 (DOE 2018). They are produced from thin wafers cut from silicon ingots. The wafers are coated in an antireflective coating, often titanium dioxide or silicon nitride and the electrical current is captured by the addition of phosphorus and aluminum. Lastly a silver backing is added (DOW 2018). The best disposal options have employed separation of the layers and reuse or recycling of the components into new cells or other technology products.

This end-of-life recycling keeps solar materials out of landfills. European PV manufacturers have a region-wide program and some manufacturers in the United States have their own programs (SEIA 2014b). PV CYCLE, an international non-profit PV industry program is addressing the recycling challenge in Europe.

The first large-scale dismantling facility for end-of-life modules was introduced in Europe in 2009 (Environment Canada, 2012) and in 2015 all of the European Union Member States adopted PV recycling legislation, supported by PV CYCLE (PV CYCLE 2015). PV CYCLE has also branched out to the US to support sustainable lifecycle management in the PV industry with education and options for disposal.

Currently in the US there is a National PV Recycling Program developed by the Solar Energy Industries Association (SEIA) where PV waste and end-of-life PV panels can be disposed of in a cost-effective manner (SEIA 2018). Another viable option gaining support is re-selling of PV cells instead of recycling. PV cells are electrically rated for specific power efficiency and at the end-of-life that efficiency is no longer attainable for the purpose there were installed for. Reuse for some other lower power need give them a second life (IRENA and IEA 2016). Recycling of cells in Canada is an emerging industry as panels installed in the 1980s are now being disposed of now, yet there exists limited regulation around this and as the market matures the demand for options will only increase. The potential for value creation is present; end-of-life PV management could spawn new industries and create economic value and support sustainable initiatives (IRENA and IEA 2016).

5.1.4 Aesthetics

Perceptions about the visual aesthetics of solar panels is subjective. With that said, the solar panel visual appeal has improved significantly in the last couple years. Traditionally, the only option was bright blue cells, with a white back-sheet, and a silver frame – the "typical" solar module. Today you can get versions that blend in with darker shingles having all black solar panels with black back-sheets and black frames.

Furthermore, cabling technologies no longer needs to be visible thus creating a much cleaner finish. Similarly, anchoring and racking innovations provide numerous color and stand-off (height from your roof plane) options as well. Low-profile racking is becoming more available, and as touted by Tesla solar panels can be part the roof itself. No additional solar panels are required since the shingle itself is the PV cell. This technology is expected to reach market in 1 to 3 years, although some installations are now occurring in the US.

In an on-farm scenario generally aesthetics is not a primary issue for a producer however there are some situations where the visual appeal of the panels may play a bigger role. These might be situations where there's a public aspect such as restaurant or store or vista that is part of the "charm" of the farm type. This would likely be more germane to artisanal or winery farm types.

5.1.5 Perceptions and Barriers

Producer opinions of solar power and its applicability to an on-farm scenario is dependent upon their perceptions. Willingness to install is driven by many motivators including:

- Energy self-sufficiency is appealing to some;

- The addition of a storage unit (e.g. some kind of battery) also allows for generation of power when the grid has a power failure, which could be used to maintain operation critical systems, like pumps, fences, etc.;
- Space-savings by using already existing roofed structures, no loss of production land;
- Increased property value;
- The contribution to decentralized power; less reliance on the energy distribution infrastructure;
- Supporting "green" and sustainable initiatives;
- Aligns with commercial branding strategy or marketing; and
- Cost and return on investment period.

As part of this review a subset of producers was surveyed in the three target areas (Fraser Valley, Okanagan and Vancouver Island) for their option on solar power: four dairy producers, three poultry producers, and four vineyard and winery producers. Additional perceptions about solar power as a result of the survey included:

- Concerns over the maturity of the technology in Canada;
- Lack of information/knowledge about solar energy and maintenance;
- Supporting climate change initiatives is appealing;
- Importance of being a responsible "citizen";
- Solar life-cycle emissions should be less than BC Hydro electricity;
- Concern over feasibility with our climate;
- Importance of environmentally friendly and ethically sourced supply chain of panels (full life cycle);
- Funding sources to support installation costs;
- Panels provide added benefit of cooling roofs in summer; and
- Concerns over the potential for roof damage

Further, in February 2017, BC Hydro surveyed 1,800 customers about their perceptions of the Net metering Program (BC Hydro 2017). This encompassed all participants to the program including on-farm, residential and commercial installations. Of the 232 respondents the following feedback was gained:

- 52% felt the largest barrier to being part of the program was the cost of infrastructure;
- 40% felt the price that BC Hydro paid for surplus energy was too low;
- 25% said there were no barriers to participation;
- 20% felt that municipal bylaws and permitting were an obstacle (applicable to residential and commercial installation only);
- 10% felt that the 100 kW system limitation on generation was a barrier; and
- 9% felt that interconnection issues to the grid were an obstacle.

Consideration of barriers that may challenge on-farm solar development include:

- Roof area or aspect could be a limitation in some situations;
- Structural limitations to existing roofs resulting in the need for additional support or reconstruction, thus adding to the cost;
- Will there be a cap on the power on-farm producers can produce? Under net metering 0-50 kW energy production scenarios that require system upgrades are paid by BC Hydro; 50-100 kW system upgrades are paid by consumer, will the same apply for the on-farm program? If there was a flood of applications in the smaller scenario would BC Hydro change their practice and would the entire Net Metering program be overwhelmed?
- BC Hydro is currently reviewing their energy pricing under the Net Metering program, it may be advantageous to have some early conversations with BC Hydro about what the ramifications of on-farm interest might mean to pricing;

5.1.6 Safety and Health

The semiconductor components of photovoltaic cells are hazardous elements. Mining practices in some countries can be inherently dangerous to workers, while manufacturing practices; refinement, processing and assembly also be hazardous to workers as discussed in Section 5.1.3 Disposal. Ethical and safe sourcing and manufacturing practices are becoming more important to consumers and marketable for manufacturers.

As a device generating electricity, safety of installers and electricians is paramount and as such they should be appropriately trained and qualified. Correct installation also eliminates the risk of fire. However, in the event of a building fire there is a risk of electrocution or shock to first responders if they were to come into contact with a high voltage conductor.

All devices that generate, transmit or use electricity generate some level of electromagnetic field (EMF). The strength of the field varies with distance, power consumption, voltage, and how fast the electric current is moving. Electromagnetic fields are characterized by their frequency and wavelength and it’s these factors that interact with living things. Solar panels themselves do note generate EMF as they produce DC current, however the AC inverter and grid tie-in wiring do generate extremely low frequency (ELF) fields.

5.2 Impacts Assessment

5.2.1 Employment and Training

If on-farm solar interest was to increase the limited number of installers in rural areas may cause an impact to both producers and the government. Mitigation might include working with lobby and industry groups to develop training programs to meet potential demand. Alternatively or additionally, limiting the number of farms each year that could install solar might allow time for training or more installers to flood the market or develop businesses in rural communities.

5.2.2 Site Preparations and Procurement

Civil needs (e.g. structural reinforcement) can be provided by typically any general contractor, engineer or architect and they are widely distributed across the province. Purchasing of cells is generally easy however if there was a requirement for locally produced cells this would be a limitation; national sourcing would be feasible. There may be some considerations related to experienced installers, especially in more rural areas of the province. The cost of installation may be increased due to travel of installers.

If solar could be installed on-farm and there's was an influx of Net Metering program applications, there might be a demand/shortage of installers or a rush to install with undertrained staff and thus the quality of the installation may not be consistent (especially in rural areas). Consideration for an installer registry or certification program similar to what is done in Alberta (Pers. comm. D. Bingham 2018) would support the higher demand.

5.2.3 Disposal

Current disposal options in British Columbia along with the rest of Canada are limited. The viability of recycling the PV cell components exists because all of the parts are reusable, however there isn't many options available. Another opportunity gaining acceptance is the re-selling of used modules. PV cells have a 25+ year lifespan however once decommissioned they can continue to produce power just not at the efficiency needed to generate cost effective power for on-farm demands. As the PV market in BC matures this will become a real growth opportunity. From a producer perspective this will not be an impact for over two decades however, for the government this might be a consideration worth developing with industry and/or non-profit groups as part of the longer supply chain management cycle. Options exist for a pilot program, test case or business proposal.

5.2.4 Aesthetics

The visual appeal of solar on-farm is likely not a consideration for the majority of farms. In applications such as some wineries or artisanal farms there may be a substantial public aspect such as hosting weddings, restaurants or tours in which visible PV cells would be unsightly. This is likely a very small number and strategic placement of the panels may resolve any concerns.

5.2.5 Perceptions and Barriers

Many of the documented and surveyed perceptions associated with the feasibility of on-farm solar are related to education. Producers and the general public are subjected to media information and mis-information or lack of information in which assumptions arise. Interest in solar energy as a whole is really driven by a strong educational component. Mitigation could include educating the farming community including: accurate and consistent calculation of costs, financing and funding sources, return on investment/energy savings, supply chain criteria, a roster of quality installers, maintenance, and end-of-life options. When considering on-farm installations and the perceptions from the BC Hydro Net Metering program survey if there was financial support for infrastructure and installation, there would be very few barriers to overcome, only the BC Hydro energy rate and interconnection to the grid.

As part of the on-farm solar development it is recommended that a stakeholder working group(s) be developed so that current and future on-farm participants all receive the same information and all issues can be raised. The working group(s) should consist of, but not limited to, BC Hydro, Ministry of Agriculture, industry groups/associations, educational institutions, Clean Energy BC, BC Sustainable Energy Association and others, such as representatives from the federal government and national associations.

5.2.6 Safety and Health

Photovoltaic cells are very safe compared to other types of power generation, however the raw materials sourced during the manufacture can be dangerous to workers and the environment as discussed in Section 5.1.3 Disposal. When these elemental semiconductor materials are encapsulated in the glass panels the risk to the end user is mitigated. Additionally, some provinces are requiring the components to be CSA approved so that they have been tested to meet applicable standards for safety and/or performance in Canada (Pers. comm. D. Bingham 2018).

As an electricity generating device there could be risk first responders in an emergency situation as a result building codes in some states in the US are being revised to increase public safety related to buildings requesting installation of PV cells (ODT 2010).

The strength of ELF EMF produced by PV systems does not approach levels considered harmful to human health. Furthermore, the small EMF produced quickly diminishes with distance and are indistinguishable from normal background levels within several yards (ODT 2010). Health Canada acknowledges that there has been much research on the possible health effects of ELF EMF and attests “some studies have suggested a possible link between exposure to ELF magnetic fields and certain types of childhood cancer, but at present this association is not established.” They do not believe that any precautionary measures are required regarding daily exposures to EMFs at ELFs (Health Canada 2018).

6 Summary of Impacts and MItigation

Resource	Impact	Severity	Mitigation	Comments
Environmental				
Vegetation	Habitat Loss	none	-	Pruning of trees associated with installation and operations is likely minimal and will grow back after the panels are decommissioned.
Wildlife	Change in Habitat	low	Plant alternate vegetation / nest structures to help mitigate increased exposure	Ranked low as birds will likely adapt to the presence of solar panels and changes in microsite conditions.
	Sensory Disturbance	low	Conduct works outside the regional bird nesting window; or conduct a passive pre-clearing nest survey in advance of works.	Ranked low as disturbance to birds can be minimized through the timing of works.
	Direct Mortality	low	Conduct works outside the regional bird nesting window; or conduct a passive pre-clearing nest survey in advance of works.	Injury or taking of birds can be mitigated through the timing of works.
Water	Change in water quantity / quality	none	-	Using water for cleaning solar panels is akin to regular window washing (Environment Canada 2012)

Resource	Impact	Severity	Mitigation	Comments
Social				
Employment and Training	Limited training programs available to support market need and limited distribution of installers, especially in rural areas.	medium	Increased education options within BC; phased or limited update of solar development to manage demand.	
Site Preparations and Procurement	Limited rurally-based installers or sub-par installations	low	Additional cost to travel to rural areas borne by producer; installer registry.	
Disposal	Limited options exist for recycling or reuse	low	Consider in the long-term options for recycling or reuse as the market matures; opportunities exist for pilot program or start-up.	Ranked low as it not an imminent issue and could be resolved once solar installed.
Aesthetics	Small number of "speciality" farms may consider PV cells unsightly	low	Very small number of farms may find this an issue; strategic placement of the panels may resolve any issues.	
Perceptions and Barriers	Various perceptions around calculation of costs, financing/funding, ROI, energy savings, supply chain criteria, quality installers roster, maintenance, and end-of-life options. Success could lead to administration challenges and overwhelming of the Net Metering program.	medium	As part of on-farm solar development consider stakeholder working group(s); education programs to address issues, concerns and misconceptions.	

Resource	**Impact**	**Severity**	**Mitigation**	**Comments**
Safety and Health	Possible risk of electrical exposure of first responders and extremely low frequency EMF	none	Panels installed to building code address risks and current literature on EMF indicates health risk are negligible.	

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Appendix D: Blank Producer Surveys

Questionnaire for Dairy Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): ____

2. Address of farm: ____

3. Name of person completing this survey: ____

4. Contact phone: ____

5. Contact email: ____

6. Farm type: Dairy

7. Please circle your type of operation:

a. *Pasture-Based Dairy Farm* *Housed Dairy Farm* *Other*

If Other, please specify:____

b. *Raw milk production* *Pasteurized milk production* *Other on-site processing*

If Other on-site processing, please specify:____

8. Please estimate quantities of the farm's production:

Total Number of Cows	Annual Milk Production (Specify if Raw or Pasteurized Milk)	Annual Quantity of Other Dairy Products (Please Specify)

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? ______________________________

11. Of these buildings, how many have electrical breaker panels in them? __________________

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (e.g. that would be suitable for rooftop solar PV)?

____

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. ____
2. ____
3. ____

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No Yes (please specify) ____

____

15. Have you considered solar energy options on your farm in the past?

No Yes (please specify) ____

____

____

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
b. Yes – I think it's the way of the future, we have to do our part for climate change
c. Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
k. Other (Please specify) ____

____

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of _________ years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (e.g. clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

____

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g. being 'green' or 'carbon neutral')? Yes or No and Why?

____

____

____

20. What is your general perception of solar power?

____

____

____

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Poultry Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write ‘unsure’ next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): ____

2. Address of farm: ____

3. Name of person completing this survey: ____

4. Contact phone: ____

5. Contact email: ____

6. Farm type: Poultry

7. Please circle your type of operation:

a. *Chickens only* *Chickens + Turkey* *Turkey only*

If other, please specify: ____

b. *Meat Only* *Meat + Eggs* *Eggs only*

If other, please specify: ____

8. Please estimate quantities of the farm’s production:

	Number of Broilers (raised for meat)	**Number of Layers (raised for eggs)**	**Annual Meat Production**	**Annual Egg Production**	**Other (please specify)**
Chicken Farms					
Turkey Farms					
Other (please specify)					

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	**Account Number (s)**	**Area or buildings served by account (s)**

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? ________________________________

11. Of these buildings, how many have electrical breaker panels in them?

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (e.g. that would be suitable for rooftop solar PV)?

____

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. ____
2. ____
3. ____

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No Yes (please specify) ____

____

____

15. Have you considered solar energy options on your farm in the past?

No Yes (please specify) ______________________________________

____

____

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

I. Yes – Because it fits or aligns with our marketing strategy

m. Yes – I think it's the way of the future, we have to do our part for climate change
n. Yes – Because I'm in favor of alternative energy sources
o. No – Because it's too costly or the cost is unknown
p. No – Because there is not enough space available on my farm to install solar panels
q. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
r. No – Electrical equipment will create risk of fire
s. No – Because I don't see the value
t. No – Solar PV panels are not aesthetically pleasing
u. No – Lack of sunshine (solar resource)
v. Other (Please specify) ____

____

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of _________ years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (e.g. clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

____

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g. being 'green' or 'carbon neutral')?   Yes or No and Why?

____

____

____

20. What is your general perception of solar power?

____

____

____

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Vineyards and Wineries

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write ‘unsure’ next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): ____

2. Address of farm: ____

3. Name of person completing this survey: ____

4. Contact phone: ____

5. Contact email: ____

6. Farm type: Vineyards and Wineries

7. Please circle your type of operation:

Vineyard only *Vineyard + Winery* *Winery only*

8. Please estimate quantities of the farm’s production:

	Vineyard (s) owned and operated by your company	**Vineyard (s) owned and operated separately, but grapes purchased from your company**	**Please circle best choice below**
Size of vineyard (s)			Acres / ha
Annual fruit production			Tonnes
Annual wine production			Litres / bottles / cases

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	**Account Number (s)**	**Area or buildings served by account (s)**

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? ________________________________

11. Of these buildings, how many have electrical breaker panels in them?

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (e.g. that would be suitable for rooftop solar PV)?

____

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. ____
2. ____
3. ____

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No Yes (please specify) ____

____

____

15. Have you considered solar energy options on your farm in the past?

No Yes (please specify) ____

____

____

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
b. Yes – I think it's the way of the future, we have to do our part for climate change
c. Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels

f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
k. Other (Please specify) ____

____

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of _________ years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (e.g. clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

____

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g. being 'green' or 'carbon neutral')? Yes or No and Why?

____

____

____

20. What is your general perception of solar power?

____

____

____

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Appendix E: Consent Forms

BC Hydro
Power smart

Page 1 of 2

Customer Account Information Request Form

Complete and return to:

BC Hydro
E-mail: scan@bchydro.com
6911 Southpoint Drive, C02
Burnaby, BC V3N 4X8

If you require assistance completing this form, please call 604 224-9376 (Toll Free: 1-800-224-9376).
NOTE: Responses to requests for customer account information may take up to 30 days to process.

APPLICATION INFORMATION (please print)

Name of applicant

Last name First name Middle Name

Current mailing address

Address City/town Province Postal code

Contact Information

Telephone (work) Telephone (home) Fax Email address

DETAILS OF REQUESTED INFORMATION (please print)

NOTE: The more information you provide regarding the details of your request, the faster we can locate your information and provide a response.

Name of account holder

Last name First name Middle name

Account address(es)

Address City/town Province Postal code

Account number(s) **Time period for information being requested**

From: Month/year **To:** Month/year

Exact nature of the information you require: (Example: billed amounts, consumption amounts, payment amounts)

Requester's signature **Date**

Page 1
Last revised: 16 July, 2003

Day/month/year

If this request is for an account other than your own, have the third party complete the following section:

THIRD PARTY INFORMATION (please print)

I,______________________________authorize BC Hydro to disclose the following information to:
(name of person authorizing release of their personal information)

____
(name and address of person to whom BC Hydro may disclose the specific information indicated below)

Exact time period for disclosure

From: __________________ To: __________________
Month/year Month/year

Exact type of information to be disclosed (Example: billed amounts, consumption amounts, payment amounts)

____

For the purpose of (Example: audit, energy analysis)

____

Signature of authorizing person **Date of signature**

____________________ ____________________
Day/month/year

ADDITIONAL DOCUMENTATION

If the request is not for your current account:
You are required to provide proof of residency, such as an old bill or a post-marked letter from legal or government source, linking you with your old address during the period of interest to you.

If the request is for a business entity:
You are required to provide:

- A copy of an old bill; and
- Your business card or a letter requesting the information (on company letterhead, signed by a person of authority, i.e., CEO, President, CFO)

If the account holder is deceased or lacks legal capacity:
You are required to provide proof of designation as an executor, an administrator or a guardian. This documentation must indicate that you have the authority to access the account holder's records.

If your name has changed since you were responsible for the account:
You are required to provide legal documents substantiating the name change.

Consent Form

Feasibility of Solar Electricity on Farms in BC

Cover Letter

To enable Midgard Consulting Inc. ("Midgard") to create average electricity consumption scenarios for different types of farms (e.g., dairy, poultry, or wineries), Midgard requires that the attached Consent Form to be completed and returned to us. Please ensure this is returned in a timely fashion.

The purpose of the Consent Form is to allow Midgard to obtain electricity consumption data from utility providers such as BC Hydro or FortisBC. **Note that all of the information provided on this form remains confidential between Midgard and your company.**

For your ease, we recommend you print the following page to fill out. Once completed, please scan and email the document back to Midgard Consulting at the address below.

If you have any questions or need clarification, please do not hesitate to contact us.

Lindsay Thompson
Midgard Consulting Incorporated
#828 - 1130 West Pender St. Vancouver, BC, V6E 4A4
Office: +1 604-298-4997 | Mobile: +1 778-847-1703
Email: lthompson@midgard-consulting.com

Yours sincerely,

Lindsay Thompson

Engineering Consultant, Midgard Consulting Inc.

Producer Consent Form

I, ____hereby agree to let Lindsay Thompson of Midgard Consulting Inc. to access electricity consumption data from my farm known as ______________________________________ located at ____.

I hereby authorize FortisBC, my Electricity Utility Provider, to release electricity consumption data for a 60 month period (from November, 2012 to November, 2017) to Lindsay Thompson of Midgard Consulting Inc. for the purposes of this study. Details of my farm's electricity account(s) are included in the table below:

Electricity Utility Provider	Name of Account Holder	Account Number (s)	Account Address

All personal information will remain confidential, however, electricity consumption data will be used to create average electricity consumption scenarios for different types of farms (i.e. dairy, poultry, or wineries) and compiled into a final report.

Date: ______________________________

Signature: ____

Appendix F: Survey Results

For confidentiality reasons, all identifying information has been removed from the following survey results.

Questionnaire for Dairy Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 1

2. Address of farm: Okanagan

3. Name of person completing this survey: ______

4. Contact phone: ______

5. Contact email: ______

6. Farm type: Dairy

7. Please circle your type of operation:

c. *Pasture-Based Dairy Farm* [✓ *Housed Dairy Farm*] *Other*

If Other, please specify: ______

d. [✓ *Raw milk production*] *Pasteurized milk production* *Other on-site processing*

If Other on-site processing, please specify: ______

8. Please estimate quantities of the farm's production:

Total Number of Cows	**Annual Milk Production (Specify if Raw or Pasteurized Milk)**	**Annual Quantity of Other Dairy Products (Please Specify)**
Approximately 100 cows	Approximately 1,300,000 liters (3,600 liters per day)	-

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)
BC Hydro	-	Barn

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? One building. The barn is most feasible for solar.

11. Of these buildings, how many have electrical breaker panels in them? The barn is electrified.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

The barn has a south-facing roof and the buildings dimensions are: 93 x 21 meters + 24 x 21 meters.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Milk Tank Cooling Compressor
2. Hot Water Tank
3. Robotic Milker

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

[✓ *No*] *Yes (please specify)* ____________________

15. Have you considered solar energy options on your farm in the past?

[✓ *No*] *Yes (please specify)* Because the technology is not yet feasible for Canada.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

[✓ a.] Yes – Because it fits or aligns with our marketing strategy
b. Yes – I think it's the way of the future, we have to do our part for climate change
[✓ c.] Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
[✓ k.] Other (Please specify) Yes, but only if it makes economic sense.

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of 5 years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Unsure.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Positive that there would be a benefit and that customers would love it.

20. What is your general perception of solar power?

Not skeptical to the technology and it's clear that a lot of improvements are happening. Would only invest if it makes economic sense.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Dairy Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 2

2. Address of farm: Okanagan

3. Name of person completing this survey: ______

4. Contact phone: ______

5. Contact email: ______

6. Farm type: Dairy

7. Please circle your type of operation:

e. *Pasture-Based Dairy Farm* [✓ *Housed Dairy Farm*] *Other*

If Other, please specify:______

f. [✓ *Raw milk production*] *Pasteurized milk production* *Other on-site processing*

If Other on-site processing, please specify:______

8. Please estimate quantities of the farm's production:

Total Number of Cows	**Annual Milk Production (Specify if Raw or Pasteurized Milk)**	**Annual Quantity of Other Dairy Products (Please Specify)**
Approximately 230 cows	Approximately 2,500,000 liters (7,000 liters per day)	-

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	**Account Number (s)**	**Area or buildings served by account (s)**
BC Hydro	-	Barn

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? One building. The barn is most feasible for solar.

11. Of these buildings, how many have electrical breaker panels in them? The barn is electrified.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

Barn has a south-facing roof with dimensions: 100 x 30 meters.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Vacuum Pump [load during 12h/day]
2. Milk Cooling
3. Lighting [Usually 1/3 of the bill]

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

[✓ No] *Yes (please specify)* ____________________

15. Have you considered solar energy options on your farm in the past?

No *[✓ Yes]* *(please specify)* Yes because the barn roof is large and south facing, however, no thorough study has been completed on the subject to date.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
b. Yes – I think it's the way of the future, we have to do our part for climate change
c. Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
[✓ k.] Other (Please specify) Only if it makes economic sense.

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of 10 years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Would do it himself.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

It could potentially benefit but it is not a common thing to proceed for dairy farmers

20. What is your general perception of solar power?

Not skeptical to the technology, but would only invest if it makes economic sense.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Dairy Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 3

2. Address of farm: Okanagan

3. Name of person completing this survey: ______

4. Contact phone: ______

5. Contact email: ______

6. Farm type: Dairy

7. Please circle your type of operation:

g. *Pasture-Based Dairy Farm* [✓ *Housed Dairy Farm*] *Other*

If Other, please specify:______

h. [✓ *Raw milk production*] *Pasteurized milk production* *Other on-site processing*

If Other on-site processing, please specify:______

8. Please estimate quantities of the farm's production:

Total Number of Cows	Annual Milk Production (Specify if Raw or Pasteurized Milk)	Annual Quantity of Other Dairy Products (Please Specify)
80 cows	752,000 liters (2,060 liters per day)	-

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)
BC Hydro	-	Three buildings

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Three buildings.

11. Of these buildings, how many have electrical breaker panels in them? All three buildings.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?
Barn roof is currently 2,200 m^2, but will be expanded to approximately 3,700 m^2 in summer 2018.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Milk Cooling
2. Hot Water Tank
3. Vacuum pump

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

[✓ *No*] *Yes (please specify)*

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* Thought about options to implement on the farm, but only if there is a feasible payback period.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

[✓ a.] Yes – Because it fits or aligns with our marketing strategy

[✓ b.] Yes – I think it's the way of the future, we have to do our part for climate change
[✓ c.] Yes – Because I'm in favor of alternative energy sources
[✓ d.] No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
k. Other (Please specify) ____

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of 20 years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

We would do it.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Yes! We want to be an environmentally friendly and green dairy farm.

20. What is your general perception of solar power?

Sun, water and wind are (at the moment) the best alternative energy sources available.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Dairy Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 4

2. Address of farm: Fraser Valley

3. Name of person completing this survey: ____________

4. Contact phone: ____________

5. Contact email: ____________

6. Farm type: Dairy

7. Please circle your type of operation:

i. *Pasture-Based Dairy Farm* [✓ *Housed Dairy Farm*] *Other*

If Other, please specify:____________

j. [✓ *Raw milk production*] *Pasteurized milk production* *Other on-site processing*

If Other on-site processing, please specify:____________

8. Please estimate quantities of the farm's production:

Total Number of Cows	Annual Milk Production (Specify if Raw or Pasteurized Milk)	Annual Quantity of Other Dairy Products (Please Specify)
100 – 110 cows	Approximately 1,200,000 liters (3,290 liters per day)	-

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	**Account Number (s)**	**Area or buildings served by account (s)**
BC Hydro	-	4 buildings

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Four buildings. The barn is most feasible for solar.

11. Of these buildings, how many have electrical breaker panels in them? All buildings are electrified.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

The barn has a south-facing roof with dimensions: 74 x 20 meters.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Robotic Milker
2. Two Hot Water Tanks
3. Milk Tank Cooling Compressor

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No [✓ *Yes*] *(please specify)* Utilizes a plate-cooler to cool the milk about 30°C, and considered using methane produced by the cows.

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* Would considered solar if milk processing is done at the farm.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

[✓ a.] Yes – Because it fits or aligns with our marketing strategy
[✓ b.] Yes – I think it's the way of the future, we have to do our part for climate change
[✓ c.] Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
k. Other (Please specify) ____________________

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of ___10___ years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Farm employees would do this work.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

There would be a benefit if milk processing is done at the farm.

20. What is your general perception of solar power?

The Sun's energy is a bottomless source of energy. We should look into alternative energy only if the life cycle emissions are lower than what is currently producing electricity (i.e Hydro).

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Poultry Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write ‘unsure’ next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 5

2. Address of farm: Fraser Valley

3. Name of person completing this survey: ____________________

4. Contact phone: ____________________

5. Contact email: ____________________

6. Farm type: Poultry

7. Please circle your type of operation:

c. [✓ *Chickens only*] *Chickens + Turkey* *Turkey only*

If other, please specify: ____________________

d. [✓ *Meat Only*] *Meat + Eggs* *Eggs only*

If other, please specify: ____________________

8. Please estimate quantities of the farm’s production:

	Number of Broilers (raised for meat)	**Number of Layers (raised for eggs)**	**Annual Meat Production**	**Annual Egg Production**	**Other (please specify)**
Chicken Farms	~90,000 birds every 8 weeks or 6.5 x per year		~1,200,000 kg per annum		
Turkey Farms					

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)
BC Hydro	-	4 – 40’ x 400’ single story broiler barns

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? 4 barns

11. Of these buildings, how many have electrical breaker panels in them? All of them.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

Pitched 4/12 roof, covering an area ~40’ x 400’, with the length oriented east & west.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Mechanical ventilation (fans)
2. Lighting
3. Feeding equipment

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

[✓ *No*] *Yes (please specify)*

15. Have you considered solar energy options on your farm in the past?

[✓ *No*] *Yes (please specify)*

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
[✓ b.] Yes – I think it's the way of the future, we have to do our part for climate change

c. Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
[✓ k.] Other (Please specify) Large roof area, along with its southerly exposure may lend itself conveniently and naturally to solar energy generation.

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of 3 years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Depends on the extent of maintenance required.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Yes, I think that as a farmer, actively striving to reduce CO2 emissions contributes to being viewed as a responsible citizen who is doing 'their part'.

20. What is your general perception of solar power?

Somewhat skeptically given our climate, having said that I have also seen it work very well in other environments.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Poultry Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write ‘unsure’ next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 6

2. Address of farm: Vancouver Island

3. Name of person completing this survey: ______

4. Contact phone: ______

5. Contact email: ______

6. Farm type: Poultry

7. Please circle your type of operation:

e. [✓ *Chickens only*] *Chickens + Turkey* *Turkey only*

If other, please specify: ______

f. *Meat Only* [✓ *Meat + Eggs*] *Eggs only*

If other, please specify: ______

8. Please estimate quantities of the farm’s production:

	Number of Broilers (raised for meat)	**Number of Layers (raised for eggs)**	**Annual Meat Production**	**Annual Egg Production**	**Other**
Chicken Farms		4800 birds	100-200 birds a year ~500 old layers to restaurants	~88% production There is a ~4 week period of the year when there is no production (flock change and maintenance)	
Turkey Farms					

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	**Account Number (s)**	**Area or buildings served by account (s)**
BC Hydro	-	New barn (12,500 sq.ft)
BC Hydro	-	Houses

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Various

11. Of these buildings, how many have electrical breaker panels in them? All of them.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

There are many suitable buildings for solar PV.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Mechanical ventilation (fans)
2. Electric motors
3. Heating

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

[✓ *No*] *Yes (please specify)*

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* Yes, but it didn't make economic sense.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

[✓ a.] Yes – Because it fits or aligns with our marketing strategy

b. Yes – I think it's the way of the future, we have to do our part for climate change
[✓ c.] Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
[✓ k.] Other (Please specify) Yes, as long as it's environmentally beneficial and financially beneficial.

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of ___5 - 10___ years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Yes, as long as there is access.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Yes, especially as a self-marketer. Customers like buying from farms that are marketed as being green or using solar/wind energy. If it was 100% quotas, then the benefit wouldn't be as evident as being a self-marketer.

20. What is your general perception of solar power?

Very good idea, but only if it makes financial and environmental sense. It's important to consider the impacts relating to where the material is coming from, how it's being extracted and what the process is at the end of the lifecycle. The underlying materials need to be mined ethically and environmentally.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Poultry Farms

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 7

2. Address of farm: Fraser Valley

3. Name of person completing this survey: __________

4. Contact phone: __________

5. Contact email: __________

6. Farm type: Poultry

7. Please circle your type of operation:

g. [✓ *Chickens only*] *Chickens + Turkey* *Turkey only*

If other, please specify: __________

h. [✓ *Meat Only*] *Meat + Eggs* *Eggs only*

If other, please specify: __________

8. Please estimate quantities of the farm's production:

	Number of Broilers (raised for meat)	**Number of Layers (raised for eggs)**	**Annual Meat Production**	**Annual Egg Production**	**Other**
Chicken Farms			600,000 kg		
Turkey Farms					

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)
BC Hydro	-	2 buildings
BC Hydro	-	1 building

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Three.

11. Of these buildings, how many have electrical breaker panels in them? All of them.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

Approximately 12,000 sq. ft. Current solar panel installation is 2,435.7 sq. ft for a 38.64 kW system.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Barn equipment
2. Office server and PCs
3. ____

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No [✓ *Yes*] *(please specify)* Solar panels and rain water.

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* Yes, a 38.64 kW system was installed in December 2017.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
[✓ b.] Yes – I think it's the way of the future, we have to do our part for climate change

c. Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
k. Other (Please specify) ____

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of 15 years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Third party.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

____

____

____

20. What is your general perception of solar power?

____

____

____

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Vineyards and Wineries

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 8

2. Address of farm: Okanagan

3. Name of person completing this survey: __________

4. Contact phone: __________

5. Contact email: __________

6. Farm type: Vineyards and Wineries

7. Please circle your type of operation:

Vineyard only [✓ *Vineyard + Winery*] *Winery only*

8. Please estimate quantities of the farm's production:

	Vineyard (s) owned and operated by your company	**Vineyard (s) owned and operated separately, but grapes purchased from your company**	**Please circle best choice below**
Size of vineyard (s)		55	Acres
Annual fruit production		180	Tonnes
Annual wine production		100,000	Liters

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	**Account Number (s)**	**Area or buildings served by account (s)**
Fortis BC	-	Resident & Vineyard Workshop
Fortis BC	-	Resident
Fortis BC	-	Winery
Fortis BC	-	Irrigation

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Six

11. Of these buildings, how many have electrical breaker panels in them? All of them.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?
Current solar installation could be increased by 40 kWh using only south facing roofs.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Winery Heating & Cooling
2. Irrigation 30hp electric pump
3. Lighting

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No [✓ *Yes*] *(please specify)* 10 kWh installed in May 2016.

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* 10 kWh installed in May 2016.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
b. Yes – I think it's the way of the future, we have to do our part for climate change
c. Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
[✓ k.] Other (Please specify) Government needs to give incentives / tax-breaks etc. as current payback time is not sustainable.

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of 5 years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

So far, it hasn't proven necessary.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Somewhat.

20. What is your general perception of solar power?
Great if the sun is out. Solar panels also help to keep the roof cool, leading to AC cost savings.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Vineyards and Wineries

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 9

2. Address of farm: Okanagan

3. Name of person completing this survey: ____________

4. Contact phone: ____________

5. Contact email: ____________

6. Farm type: Vineyards and Wineries

7. Please circle your type of operation:

Vineyard only [✓ *Vineyard + Winery*] *Winery only*

8. Please estimate quantities of the farm's production:

	Vineyard (s) owned and operated by your company	**Vineyard (s) owned and operated separately, but grapes purchased from your company**	**Please circle best choice below**
Size of vineyard (s)	12.5		Acres
Annual fruit production	30		Tonnes
Annual wine production	2000		Cases

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)
District of Summerland	-	Winery and house

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Two

11. Of these buildings, how many have electrical breaker panels in them? Both are electrically wired.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

Winery is 1,500 sq. ft., and the house is 5,000 sq. ft.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Chilling (cooling system) for tanks
2. Pneumatic press (2.5 tonne press)
3. Crusher / Stemmer

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No [✓ *Yes*] *(please specify)* Geothermal is used for heating purposes

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* Yes, however the winery is relatively new and in recent years capital has been spent on equipment and production costs. Once these costs are paid off, the will consider implementing either wind or solar.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

[✓ a.] Yes – Because it fits or aligns with our marketing strategy

b. Yes – I think it's the way of the future, we have to do our part for climate change
[✓ c.] Yes – Because I'm in favor of alternative energy sources
[✓ d.] No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
k. Other (Please specify) ____

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of ________ years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

____

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Yes. The farm is seen as one of the most sustainable and organic farms. They focus on a minimal land impact and solar is seen as a great environmentally friendly material to use that would help build on this image. Having solar is something customers would come to expect as part of that 'minimal impact' image.

20. What is your general perception of solar power?

Look forward to the day when everyone uses solar. It would be nice to be able to create energy and sell it back to the grid.

____

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Vineyards and Wineries

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 10

2. Address of farm: Vancouver Island

3. Name of person completing this survey: ____________

4. Contact phone: ____________

5. Contact email: ____________

6. Farm type: Vineyards and Wineries

7. Please circle your type of operation:

Vineyard only [✓ *Vineyard + Winery*] *Winery only*

8. Please estimate quantities of the farm's production:

	Vineyard (s) owned and operated by your company	**Vineyard (s) owned and operated separately, but grapes purchased from your company**	**Please circle best choice below**
Size of vineyard (s)	30		Acres
Annual fruit production	70-95		Tonnes
Annual wine production	6000-7000		Cases (each case is 9L)

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)
BC Hydro	-	Buildings

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Four

11. Of these buildings, how many have electrical breaker panels in them? All are electrically wired.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

The winery is most suitable for solar PV. It has a large flat deck roof and good sun exposure.

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Winery (chiller system requires 2 pumps that run 24/7)
2. Ceiling mounted heating units for constant temperatures
3. Press with large pumps and compressors

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

[✓ *No*] *Yes (please specify)*

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* Yes, solar has previously been considered.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
b. Yes – I think it's the way of the future, we have to do our part for climate change
c. Yes – Because I'm in favor of alternative energy sources
d. No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
i. No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
[✓ k.] Other (Please specify) Power will likely be much more expensive in the future, so it makes sense to be self-sufficient, however, it depends on what the budget allows.

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of _________ years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Yes, as long as there is access to the system.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Yes from a business strategy perspective as they are cost-effective. No from a marketing strategy perspective, as you aren't allowed to charge more for an environmentally friendly product. Customers care about how good the wine is, not so much whether or not the farm is sustainable.

20. What is your general perception of solar power?

Solar is improving all the time.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Questionnaire for Vineyards and Wineries

Feasibility of Solar Electricity on Farms in BC

Please fill out all questions to your best knowledge. Where options exist, please circle your choice. If you do not know the answer to a question or are unsure, please contact Midgard or write 'unsure' next to the question.

SECTION 1 – BACKGROUND INFORMATION / PRODUCTION

1. Name of farm (If Applicable): FARM ID 11

2. Address of farm: Vancouver Island

3. Name of person completing this survey: __________

4. Contact phone: __________

5. Contact email: __________

6. Farm type: Vineyards and Wineries

7. Please circle your type of operation:

Vineyard only [✓ *Vineyard + Winery*] *Winery only*

8. Please estimate quantities of the farm's production:

	Vineyard (s) owned and operated by your company	**Vineyard (s) owned and operated separately, but grapes purchased from your company**	**Please circle best choice below**
Size of vineyard (s)	8.5 acre (65 the hole property)		Acres
Annual fruit production	20 Tonnes (+ 30 Tonnes from other vinyards)		Tonnes
Annual wine production	1500 (2012) to 4500 (2017)		Cases

SECTION 2 – ELECTRICITY USAGE

9. Please specify the area or number of buildings served by each account number provided.

Electricity Utility Provider	Account Number (s)	Area or buildings served by account (s)
BC Hydro	-	Various buildings

SECTION 3 – SOLAR SUITABILITY

10. What is the total number of buildings on your farm? Six

11. Of these buildings, how many have electrical breaker panels in them? All are electrically wired.

12. What is the approximate roof size of buildings with electrical breaker panels in them? Alternatively, what is the approximate size of the largest building on your farm (i.e., that would be suitable for rooftop solar PV)?

SECTION 4 – LOADS

13. What are the top three items that consume the most electricity on your farm?

1. Geothermal cooling system for winery and tanks
2.
3.

SECTION 5 – RENEWABLE ENERGY

14. Do you currently use solar or any forms of renewable energy on your farm?

No [✓ *Yes*] *(please specify)* Geothermal cooling and heating system.

15. Have you considered solar energy options on your farm in the past?

No [✓ *Yes*] *(please specify)* Yes, a quote was put together, but the ROI was too low for the project to be economically viable.

16. Going forward, would you consider installing solar energy options as an alternative energy source on your farm? Please circle all answers which best represents your opinion:

a. Yes – Because it fits or aligns with our marketing strategy
b. Yes – I think it's the way of the future, we have to do our part for climate change
c. Yes – Because I'm in favor of alternative energy sources
[✓ d.] No – Because it's too costly or the cost is unknown
e. No – Because there is not enough space available on my farm to install solar panels
f. No – Want to minimize potential health issues due to Electromagnetic Fields (EMF)
g. No – Electrical equipment will create risk of fire
h. No – Because I don't see the value
[✓ i.] No – Solar PV panels are not aesthetically pleasing
j. No – Lack of sunshine (solar resource)
[✓ k.] Other (Please specify) Potential for roof damage.

17. If yes to question 16, please specify what would be considered a reasonable payback period?

It is reasonable if the initial investment is paid off after a maximum of 10 years after installation.

18. If yes to question 16, would you consider doing the non-electrical maintenance (i.e., clearing the panels from dirt and snow on a regular basis) or would you likely hire a third-party to do this work?

Likely to hire a third-party to do it.

19. Would the addition of alternative/green energy be a benefit to your brand, business strategy or reputation (e.g.: being 'green' or 'carbon neutral')? Yes or No and Why?

Yes.

20. What is your general perception of solar power?

Not skeptical towards solar. It would not be a technical problem. Economics are currently the holdback.

Thank you for your time completing this Survey. Midgard welcomes any further comments, ideas, or thoughts you may have - please include these with your survey.

Appendix G: Historical Consumption Data

For confidentiality reasons, all identifying information has been removed from the following consumption data results.

Name: Farm ID 3

Farm Type: Dairy

Region: Okanagan

Account: 3 buildings

Top loads: Milk cooling, hot water tank, and vacuum pump

Farm ID	Date	Usage	Unit
3	14/11/2017	16400	kWh
3	13/09/2017	12400	kWh
3	13/07/2017	12640	kWh
3	12/05/2017	15520	kWh
3	14/03/2017	22240	kWh
3	12/01/2017	26320	kWh
3	10/11/2016	13200	kWh
3	12/09/2016	11840	kWh
3	12/07/2016	11520	kWh
3	11/05/2016	11440	kWh

Average Monthly Electricity Consumption: 7,900 kWh/month

Average Annual Electricity Consumption: 92,000 kWh/year

Name: Farm ID 5

Farm Type: Poultry

Region: Fraser Valley

Account: 4 - 40’ x 400’ single story broiler barns

Top loads: Mechanical ventilation, lighting and feeding equipment

Farm ID	Date	Usage	Unit
5	2017-12-01	6840	kWh
5	2017-10-30	7140	kWh
5	2017-10-01	5340	kWh
5	2017-08-31	12000	kWh
5	2017-07-30	5400	kWh
5	2017-07-01	9780	kWh
5	2017-05-30	4740	kWh
5	2017-05-01	1080	kWh
5	2017-03-28	5580	kWh
5	2017-03-03	8640	kWh
5	2017-01-31	6960	kWh
5	2016-12-30	6240	kWh
5	2016-12-01	6600	kWh
5	2016-10-30	5160	kWh
5	2016-10-01	9540	kWh
5	2016-08-31	5760	kWh
5	2016-07-29	11160	kWh
5	2016-07-01	5040	kWh
5	2016-05-30	7560	kWh
5	2016-05-01	1500	kWh
5	2016-03-29	7260	kWh
5	2016-03-02	5700	kWh
5	2016-01-31	6540	kWh
5	2015-12-30	6180	kWh
5	2015-12-01	6420	kWh
5	2015-10-30	7800	kWh
5	2015-10-01	5100	kWh
5	2015-08-31	10740	kWh
5	2015-07-30	5520	kWh
5	2015-07-01	8460	kWh
5	2015-05-30	5040	kWh
5	2015-05-04	1440	kWh
5	2015-03-26	5940	kWh
5	2015-03-06	7080	kWh
5	2015-02-02	4680	kWh
5	2014-12-24	4020	kWh

Farm ID	Date	Usage	Unit
5	2014-12-02	4560	kWh
5	2014-10-29	3060	kWh
5	2014-10-01	6960	kWh
5	2014-09-03	4920	kWh
5	2014-07-28	6600	kWh
5	2014-07-22	4140	kWh
5	2014-06-01	5760	kWh
5	2014-04-30	4800	kWh
5	2014-03-28	4260	kWh
5	2014-03-02	4620	kWh
5	2014-01-28	4560	kWh
5	2014-01-01	5520	kWh
5	2013-11-30	3960	kWh
5	2013-10-29	6540	kWh
5	2013-10-03		kWh
5	2013-08-30	8220	kWh
5	2013-07-30	5820	kWh
5	2013-07-03	5820	kWh
5	2013-05-27		kWh
5	2013-05-05	10140	kWh
5	2013-03-27	5820	kWh
5	2013-03-01	3540	kWh
5	2013-02-03	1680	kWh
5	2012-12-28	6780	kWh
5	2012-12-03	5760	kWh
5	2012-10-25	4320	kWh
5	2012-10-04	8160	kWh
5	2012-09-01	7380	kWh
5	2012-07-30	6660	kWh
5	2012-06-30	6480	kWh
5	2012-06-01	4200	kWh
5	2012-05-01	10440	kWh
5	2012-03-27	6480	kWh
5	2012-03-03	9600	kWh
5	2012-01-30	7920	kWh

Average Monthly Electricity Consumption: 6,160 kWh/month

Average Annual Electricity Consumption: 74,000 kWh/year

Name: Farm ID 6

Farm Type: Poultry

Region: Vancouver Island

Account: Barn (12,500 sq. ft.)

Top loads: Ventilation for cooling, electric motors and heating

Farm ID	Date	Days	Usage	Unit
6	2016-10-01	31	1714	kWh
6	2016-11-01	30	1692	kWh
6	2016-12-01	31	1801	kWh
6	2017-01-01	31	2395	kWh
6	2017-02-01	28	3140	kWh
6	2017-03-01	31	3847	kWh
6	2017-04-01	30	4619	kWh
6	2017-05-01	31	5608	kWh
6	2017-06-01	30	7749	kWh
6	2017-07-01	31	8221	kWh
6	2017-08-01	31	8670	kWh

Average Monthly Electricity Consumption: 3,600 kWh/month

Average Annual Electricity Consumption: 44,000 kWh/year

Name: Farm ID 7

Farm Type: Poultry

Region: Fraser Valley

Account: 2 buildings

Top loads: Barn equipment, office server and PCs

Farm ID	Date	Days	Usage	Unit
7	29-Sep-17	60	24,180	kWh
7	31-Jul-17	61	24,480	kWh
7	31-May-17	62	26,340	kWh
7	30-Mar-17	59	24,900	kWh
7	30-Jan-17	62	25,500	kWh
7	29-Nov-16	62	22,920	kWh
7	28-Sep-16	62	26,820	kWh
7	28-Jul-16	59	24,840	kWh
7	30-May-16	60	26,760	kWh
7	31-Mar-16	63	21,120	kWh
7	28-Jan-16	59	21,300	kWh
7	30-Nov-15	62	23,640	kWh
7	29-Sep-15	62	23,700	kWh
7	29-Jul-15	61	24,120	kWh
7	29-May-15	60	23,760	kWh
7	30-Mar-15	61	25,320	kWh
7	28-Jan-15	61	24,120	kWh
7	28-Nov-14	60	22,500	kWh
7	29-Sep-14	62	28,320	kWh
7	29-Jul-14	61	26,520	kWh
7	29-May-14	62	23,220	kWh
7	28-Mar-14	58	26,040	kWh
7	29-Jan-14	62	29,160	kWh
7	28-Nov-13	62	27,600	kWh
7	27-Sep-13	60	29,460	kWh
7	29-Jul-13	61	31,740	kWh
7	29-May-13	62	27,720	kWh
7	28-Mar-13	58	29,460	kWh
7	29-Jan-13	63	33,780	kWh
7	27-Nov-12	62	29,160	kWh
7	26-Sep-12	61	28,980	kWh
7	27-Jul-12	60	26,280	kWh
7	28-May-12	61	28,260	kWh
7	28-Mar-12	58	27,360	kWh
7	30-Jan-12	62	29,700	kWh

Average Monthly Electricity Consumption: 13,000 kWh/month

Average Annual Electricity Consumption: 160,000 kWh/year

<u>Name: Farm ID 8</u>

Farm Type: Vineyards & Wineries

Region: Okanagan

Account: All buildings (resident, winery, irrigation)

Top loads: Winery heating & cooling, irrigation 30 hp electric pump, and lighting

Farm ID	Date	Days	Usage	Unit
8	10-30-2017	62	8477	kWh
8	08-29-2017	62	7780	kWh
8	06-28-2017	58	5602	kWh
8	05-01-2017	62	12289	kWh
8	02-28-2017	61	20544	kWh
8	12-29-2016	58	15779	kWh
8	11-01-2016	64	11601	kWh
8	08-29-2016	61	6403	kWh
8	06-29-2016	58	4623	kWh
8	05-02-2016	62	6605	kWh
8	03-01-2016	63	17433	kWh
8	12-29-2015	61	20730	kWh
8	10-29-2015	58	12566	kWh
8	09-01-2015	63	8095	kWh
8	06-30-2015	60	3838	kWh
8	05-01-2015	63	10182	kWh
8	02-27-2015	59	24354	kWh
8	12-30-2014	63	28858	kWh
8	10-28-2014	62	7992	kWh
8	08-27-2014	61	8399	kWh
8	06-27-2014	58	3112	kWh
8	04-30-2014	63	10446	kWh
8	02-26-2014	61	19955	kWh
8	12-27-2013	63	39900	kWh
8	10-25-2013	60	8396	kWh
8	08-26-2013	61	8006	kWh
8	06-26-2013	61	5865	kWh
8	04-26-2013	60	7930	kWh
8	02-25-2013	60	21906	kWh
8	12-27-2012	64	29489	kWh
8	10-24-2012	62	8676	kWh

Average Monthly Electricity Consumption: 6,300 kWh/month

Average Annual Electricity Consumption: 76,000 kWh/year

Name: Farm ID 9

Farm Type: Vineyards & Wineries

Region: Okanagan

Account: Winery (1500 sq.ft) and house (5,000 sq.ft)

Top loads: Cooling system for tanks, pneumatic press, crusher/stemmer

Farm ID	Date	Usage	Unit
9	2017-12-01	10480	kWh
9	2017-10-30	6560	kWh
9	2017-10-01	7920	kWh
9	2017-08-31	8960	kWh
9	2017-07-30	8080	kWh
9	2017-07-01	6880	kWh
9	2017-05-30	4160	kWh
9	2017-05-01	5520	kWh
9	2017-03-28	6560	kWh
9	2017-03-03	8640	kWh
9	2017-01-31	11840	kWh
9	2016-12-30	8640	kWh
9	2016-12-01	6960	kWh
9	2016-10-30	6480	kWh
9	2016-10-01	5680	kWh
9	2016-08-31	6720	kWh
9	2016-07-29	5840	kWh
9	2016-07-01	5120	kWh
9	2016-05-30	4640	kWh
9	2016-05-01	7280	kWh
9	2016-03-29	7840	kWh
9	2016-03-02	12720	kWh
9	2016-01-31	15040	kWh
9	2015-12-30	13920	kWh
9	2015-12-01	11840	kWh
9	2015-10-30	8400	kWh
9	2015-10-01	6000	kWh
9	2015-08-31	6960	kWh
9	2015-07-30	8240	kWh
9	2015-07-01	7250	kWh
9	2015-05-30	4560	kWh
9	2015-05-04	4000	kWh
9	2015-03-26	5040	kWh
9	2015-03-06	8800	kWh
9	2015-02-02	14560	kWh

Farm ID	Date	Usage	Unit
9	2014-12-24	11120	kWh
9	2014-12-02	12560	kWh
9	2014-10-29	6640	kWh
9	2014-10-01	6720	kWh
9	2014-09-03	10960	kWh
9	2014-07-28	7680	kWh
9	2014-07-22	8000	kWh
9	2014-06-01	7120	kWh
9	2014-04-30	7040	kWh
9	2014-03-28	11120	kWh
9	2014-03-02	11120	kWh
9	2014-01-28	13120	kWh
9	2014-01-01	11920	kWh
9	2013-11-30	8400	kWh
9	2013-10-29	5680	kWh
9	2013-10-03	8960	kWh
9	2013-08-30	8080	kWh
9	2013-07-30	7760	kWh
9	2013-07-03	3520	kWh
9	2013-05-27	3040	kWh
9	2013-05-05	5680	kWh
9	2013-03-27	6800	kWh
9	2013-03-01	9840	kWh
9	2013-02-03	10320	kWh
9	2012-12-28	6880	kWh
9	2012-12-03	5200	kWh
9	2012-10-25	3120	kWh
9	2012-10-04	7840	kWh
9	2012-09-01	7680	kWh
9	2012-07-30	7360	kWh
9	2012-06-30	6400	kWh
9	2012-06-01	3680	kWh
9	2012-05-01	6480	kWh
9	2012-03-27	7600	kWh
9	2012-03-03	11440	kWh
9	2012-01-30	10240	kWh

Average Monthly Electricity Consumption: 8,000 kWh/month

Average Annual Electricity Consumption: 95,000 kWh/year

Name: Farm ID 10

Farm Type: Vineyards & Wineries

Region: Vancouver Island

Account: Winery

Top loads: Winery itself (chiller system requires 2 pumps that run 24/7), Ceiling mounted heating units for constant temperatures, and Press with large pumps and compressors

Farm ID	**Date**	**Usage**	**Unit**
10	01/02/2015	10200	kWh
10	01/03/2015	5700	kWh
10	01/04/2015	4800	kWh
10	01/05/2015	2700	kWh
10	01/06/2015	3000	kWh
10	01/07/2015	3600	kWh
10	01/08/2015	5700	kWh
10	01/09/2015	7500	kWh
10	01/10/2015	9300	kWh
10	01/11/2015	24900	kWh
10	01/12/2015	27000	kWh
10	01/01/2016	19800	kWh
10	01/02/2016	12000	kWh
10	01/03/2016	6300	kWh
10	01/04/2016	3900	kWh
10	01/05/2016	3300	kWh
10	01/06/2016	6000	kWh
10	01/07/2016	4200	kWh
10	01/08/2016	6900	kWh
10	01/09/2016	9000	kWh
10	01/10/2016	10800	kWh
10	01/11/2016	10800	kWh
10	01/12/2016	30900	kWh
10	01/01/2017	26100	kWh
10	01/02/2017	21600	kWh
10	01/03/2017	8700	kWh
10	01/04/2017	6000	kWh
10	01/05/2017	3500	kWh
10	01/06/2017	2650	kWh
10	01/07/2017	5250	kWh
10	01/08/2017	6900	kWh
10	01/09/2017	8867	kWh
10	01/10/2017	11233	kWh
10	01/11/2017	24000	kWh

10	01/12/2017	30300	kWh

Average Monthly Electricity Consumption: 11,000 kWh/month

Average Annual Electricity Consumption: 130,000 kWh/year

Name: Farm ID 11

Farm Type: Vineyards & Wineries

Region: Vancouver Island

Account: Winery

Top loads: Geothermal cooling system for the rooms in the winery and tanks (pumping water)

Farm ID	Date	Usage	Unit
11	23/11/2017	20880	kWh
11	24/10/2017	19920	kWh
11	22/09/2017	14760	kWh
11	23/08/2017	15240	kWh
11	24/07/2017	13800	kWh
11	22/06/2017	12720	kWh
11	24/05/2017	12960	kWh
11	25/04/2017	15240	kWh
11	23/03/2017	16080	kWh
11	22/02/2017	16800	kWh
11	23/01/2017	22080	kWh
11	21/12/2016	19920	kWh
11	22/11/2016	20400	kWh
11	21/10/2016	18720	kWh
11	21/09/2016	16680	kWh
11	22/08/2016	18480	kWh
11	21/07/2016	17880	kWh
11	21/06/2016	15240	kWh
11	20/05/2016	16440	kWh
11	22/04/2016	16320	kWh
11	22/03/2016	14640	kWh
11	22/02/2016	15480	kWh
11	21/01/2016	16200	kWh
11	21/12/2015	15960	kWh
11	23/11/2015	15360	kWh
11	22/10/2015	15720	kWh
11	22/09/2015	13320	kWh
11	21/08/2015	12480	kWh
11	22/07/2015	12720	kWh
11	22/06/2015	13920	kWh
11	22/05/2015	9600	kWh
11	23/04/2015	10920	kWh
11	23/03/2015	18360	kWh

Average Monthly Electricity Consumption: 16,000 kWh/month

Average Annual Electricity Consumption: 190,000 kWh/year

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