BUILDING A NETWORK OF CLEAN ENERGY SYSTEMS: A CASE STUDY OF THE T'SOU-KE FIRST NATION SOLAR PROJECT

by

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Abstract

During the last ten years, several Aboriginal communities in British Columbia (BC) have built various forms of clean energy systems with some form of government and private support. There is, however, little comprehensive scholarly analysis of these projects, ones that evaluate their ability to meet the interests of a community and the factors determining their success. This research undertakes a case study analysis of a solar energy project in BC installed in 2009 by the T'Sou-ke First Nation, near the southern tip of Vancouver Island. In this research, I examine the evolution of the solar project, assess the impacts of the project on the community, and evaluate the replicability of the project in other communities. The results of my case study are as follows: First, the solar project evolved as a result of Comprehensive Community Planning by the community. Second, the solar project had four main impacts on the community namely, limited energy autonomy, a small net reduction in greenhouse gas emissions, short to medium term employment benefits, and local community and other economic benefits. Third, the main component of the project, that is, the grid-tied PV systems is still difficult to replicate in other communities without any form of government and private support. I also identify the lessons from this project that will be helpful for other communities interested in solar and other clean energy projects.

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List of Abbreviations

BC	British Columbia
BCUC	British Columbia Utilities Commission
BOS	Balance of system
CANSIA	Canadian Solar Industries Association
CCP	Comprehensive Community Planning
CCPA-BC	Canadian Centre for Policy Alternatives, B.C. Office
CEF	Clean Energy Fund
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CH_4	methane
GHG	greenhouse gas
GWP	global warming potential
INAC	Indigenous and Northern Affairs Canada
JIRC	Joint Indian Reserve Commission
KW	Kilowatts
KWh	kilowatt-hours
LCOE	levelized cost of energy
MW	mega-watts
MWh	megawatt-hours
N_2O	nitrous oxide
NEU	Neighbourhood Energy Utility
NPV	Net Present Value
O&M	Operations and maintenance
PV	Photovoltaic

RAC	Research Advisory Committee
SOP	standard offer program
TOU	time of use
T'SEG	T'Sou-ke Smart Energy Group
UNBC	University of Northern British Columbia
VIP	Vision in Progress

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CHAPTER 1: INTRODUCTION

1.1 Background

> A First Nation cannot survive without a healthy environment. If we take care of the environment, the environment will take care of us. Offsetting fossil fuels or the destruction of [the] planet in any way is something that all First Nations can grasp because we have a deep connection to the land, the animals, and the air.
> - (Chief Gordon Planes, interview by author, August19, 2015)

There has been a recent growing interest among Aboriginal communities in British Columbia (BC) to build clean energy projects. Aboriginal peoples are the first peoples of North America before European explorers arrived at that place. In Canada, there are three different Aboriginal groups namely, Inuit, First Nations and Métis (Indigenous and Northern Affairs Canada 2016a). Clean energy projects generally refer to projects that create electricity, heat, and fuel from non-conventional and non-fossil fuel sources of energy such as the wind, solar insolation, geothermal, hydropower, ocean energy (thermal gradient, wave power, and tidal power), and biomass (Natural Resources Canada 2016a; Gritsevskyi 2008, sec. 2, par. 3). However, it is important to note that not all non-fossil fuel projects are considered clean.

For example, a large water dam that blocks migrating fish from reaching its spawning grounds and impacts water flows, temperatures and silt load of rivers may not be regarded as clean (Daigneau 2013). Similarly, the cutting or clearing of a forest to produce energy from biomass may not be counted as clean because of the loss of a tree's ability to absorb carbon dioxide after it is cut down, and the time it takes for a replacement forest to grow (Cho 2011; Upton 2015). For this research, I am mainly referring to small run- of- the- river hydro, solar and wind projects undertaken by

Aboriginal communities in BC, although clean energy projects are applicable in other communities as well.

There are several reasons why these communities are interested in clean energy: securing the energy future of the community in the face of climate change; mitigating greenhouse gas (GHG) emissions; gaining positive benefits of employment; engaging in Aboriginal business and economic development; and local community development (Sayers 2013; Aboriginal and Northern Affairs Canada and Natural Resources Canada 2011, 12). To meet the interest of clean energy in Aboriginal communities, governments, utility companies, and technology providers have started to lend their support.

During the last ten years, several Aboriginal communities in BC have built various forms of clean energy systems with some form of government and private support. A recent report states that approximately 60 percent of the Aboriginal communities (mainly First Nations) in BC are currently involved in clean energy projects, ranging from ownership to revenue-sharing, and are receiving positive benefits such as jobs, income, and capacity building in all levels of this business development (Sayers 2013). As Aboriginal-owned clean energy projects are still a new phenomenon in BC, comprehensive scholarly analysis of the projects that inform their ability to meet the interests of a community and the factors determining their success is scarce.

I approach this topic through the case study of an innovative clean energy project undertaken by an Aboriginal community in BC. The T'Sou-ke First Nation is a small, grid-connected, community, located on two Reserves around the Sooke basin in the southern tip of Vancouver Island. A reserve is a tract of land set aside for the exclusive use of a First Nation community or a Band in Canada. The members of the Band possess the right to live on reserve lands, and most Bands' administration and political offices are also located on reserves. However, reserve lands are not owned by the Band but are held in trust for the Band by the Crown (First Nations & Indigenous Studies: The University of British Columbia 2009).

The community finished building a 75.6 kilowatt [kW] solar demonstration facility in July 2009 on Reserve 1, reported to be the second largest Aboriginal solar project in BC (T'Sou-ke First Nation 2016). The largest community-owned solar project in BC is of 85.8 kW capacity, and was installed recently by the Lower Nicola Indian Band near Merritt in August 2016 (Eagland 2016). Before T'Sou-ke First Nation, only one other Aboriginal community in BC, Nemiah Valley, had a solar project of (28 kW capacity) installed in 2007 (Karanasios and Parker 2016, 77).

The solar project by the T'Sou-ke First Nation consists of three related components: the solar PV systems, the solar hot water systems, and the energy conservation program. Solar PV systems use solar panels to convert sunlight directly into electricity. There are three grid-tied PV systems installed on two independent structures, and an office building, and an off-grid PV system on a separate office building on Reserve 1. The off-grid PV system is not at an actual off-grid PV system but a model of a PV system in an off-grid and remote community. For this research, I will call the system off-grid as that is how T'Sou-ke First Nation refers to the system in its documents.

Two of the grid-tied PV systems and the off-grid PV system provide electricity to the buildings, and the other grid-tied system mainly exports surplus electricity to the grid. Additionally, there are 40 solar hot water systems, installed in half of the residences in Reserve 1 and Reserve 2, that provide hot water for the members. Solar hot water systems use solar collectors to absorb energy from the sun to heat water. Finally, the Band runs an energy conservation program across the two Reserves to reduce energy demand (i.e. electricity, space heating, and hot water).

1.2 Statement of the objectives and research questions

The main objectives of this research are to understand the evolution of the T'Sou-ke First Nation solar project, to analyze the various impacts of the solar project on the community, and to assess the replicability of the solar project in other communities in BC along with lessons that will guide future community solar and other clean energy projects. In particular, I attempt to answer the following key questions through this research:

1. How did the T'Sou-ke First Nation solar project evolve? Were there any challenges in the planning and implementation of the project? If so, how did the T'Sou-ke First Nation overcome these challenges?

2. What were the energy, environment, employment, and community and other economic impacts of the solar project on the T'Sou-ke First Nation?

3. Is the T'Sou-ke solar project replicable in other Aboriginal communities in BC? If so, are there any lessons or recommendations from the T'Sou-ke solar project that will lead to the success of future solar and other clean energy projects?

1.3 Significance of the research

My research is important for three main reasons. First, I undertake a case study analysis of an innovative Aboriginal community solar project in BC based on the analytical framework designed by Sheeran et al. (2014, 3-20). This is a new framework for case study research of innovative projects and their contributions to the economy. This case study analysis involves both extensive qualitative and quantitative descriptions of the solar project as a whole and is concerned with the impacts of the project on the community and the ability of the project to be replicated in other communities. Previous analysis of the solar project such as by Bekker (2009a, 2009b) has focused mainly on the solar PV systems and is more technical in nature. Another important research study by Ozog (2012, 67-76) is also limited to a brief description of the project and some of its immediate results. Most other analysis of the project as reported in newspapers (online), blogs and articles are also brief and focused solely on the solar PV systems (Troian 2017; McKenna 2014; Dodge and Kinny 2013; Newell and King 2013; Kimmett 2009).

Second, I build upon the financial analysis of the solar project carried out by Bekker in 2009 and extend it to 2014. The new financial analysis takes into consideration the major changes in the solar PV industry that has happened over the last five years, and assesses whether a similar project would be more favourable now compared to 2009. The importance of this analysis is that it brings out the current feasibility of the solar PV systems in BC, in communities that have similar demography and climatic conditions as that of the T'Sou-ke First Nation, and the policies that should follow.

Third, I extend the GHG emission analysis of the solar PV systems calculated by Bekker in 2009 to all the three components of the solar project and re-calculate the emissions. The purpose of the new emission analysis is to understand the benefits of replacing BC Hydro power and diesel with solar energy in BC.

As the T'Sou-ke solar project is one of the largest solar projects by an Aboriginal community in BC, this research will provide a practical understanding of the benefits and challenges of building a solar project, and the lessons from this project will guide other communities interested in building successful solar and other clean energy projects. The implications of this study are also beneficial for other grid-connected Aboriginal communities, and especially for off-grid and remote Aboriginal communities in BC that have similar demography and climatic conditions as that of the T'Sou-ke First Nation. Off-grid and remote communities are communities that are neither connected to the North American electrical grid, nor the piped natural gas network, and are a permanent or long-term (5 years or more) settlement with at least ten dwellings (Aboriginal and Northern Affairs Canada and Natural Resources Canada 2011, 3).

Most off-grid communities rely on diesel generators for their electricity and heating fuel (mostly propane) for their heat (Rezaei and Dowlatabadi 2016, 790). Some of the communities also rely on hydro projects and use diesel generators as a backup during power shortages. The cost of generating electricity from diesel, although subsidized for off-grid communities, could be anywhere from 3 to 10 times higher when compared to that of the grid-connected communities (Rezaei and Dowlatabadi 2016, 790). Moreover, the use of diesel raises significant economic, environmental and social concerns regarding the well-being of the communities (Aboriginal and Northern Affairs Canada and Natural Resources Canada 2011, 11). As such, solar and other clean energy projects provide the potential for reducing, and possibly eliminating the dependence on diesel and other fossil fuels, and their resultant impacts.

1.4 Outline of the project

This project is divided into six chapters in total. In the remainder of Chapter 1, I give a brief overview of the T'Sou-ke First Nation. In Chapter 2, I discuss the key concepts that guide the analysis of the solar project, mainly the solar PV systems as this is the biggest component of the project. Also, I review the analytical case study framework used for the research questions, procedures of data collection and the research protocols. In Chapter 3, I outline the background and the planning process of the solar project. In Chapter 4, I describe the solar project (solar PV systems, solar hot water systems, and the energy conservation program) in detail, and then analyze the energy, environmental, employment and community and other economic impacts of the project on the Band. In Chapter 5, I evaluate the replicability of the T'Sou-ke solar project in BC and provide recommendations for future solar and other clean energy projects. Finally, I summarize the solar project and provide concluding remarks in Chapter 6.

1.5 Brief overview of T'Sou-ke First Nation

The name T'Sou-ke has its origin in the SENĆOŦEN language and refers to the stickleback fish that lives in the estuary of the Sooke River (T'Sou-ke First Nation 2016). SENĆOŦEN language is a Northern Straits Salish language spoken by communities in the Saanich peninsula of Vancouver Island (First Peoples' Language Map of British Columbia n.d.). The location of the T'Sou-ke First Nation is provided in Figure 1. The main office buildings of the T'Sou-ke First Nation are located on the 25 hectares, T'Sou-ke Reserve 1 along the main road between Sooke and Victoria, BC. Reserve 2 is 50-hectares, and located to the south of Reserve 1(T'Sou-ke First Nation 2016).

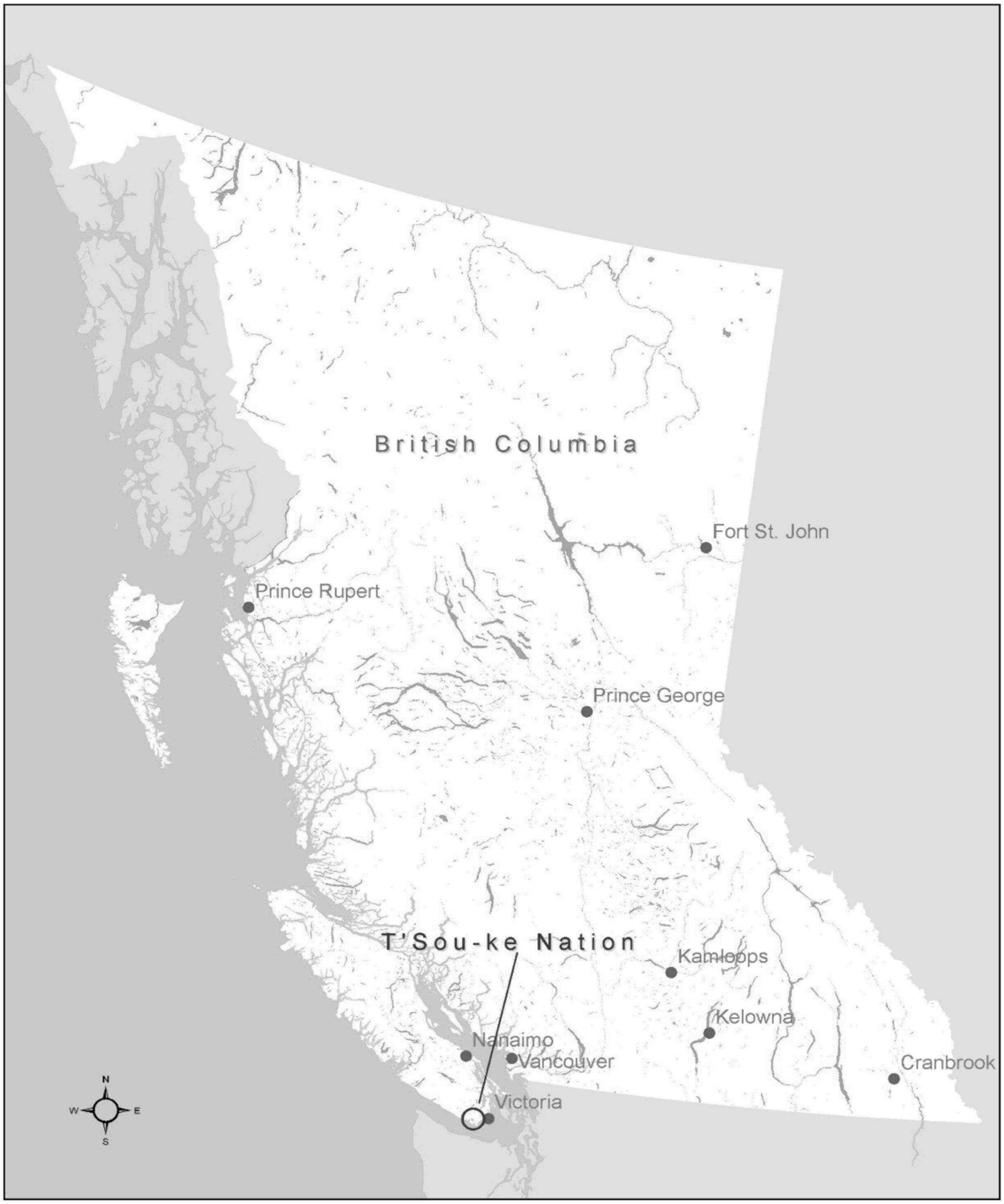

Figure 1: Location of T'Sou-ke First Nation. Map by Statistics Canada (2009, 7).

According to Statistics Canada 2016 census data, the T'Sou-ke First Nation is a small community with a total population of 225 members and an annual population growth rate of 2.7 percent. About 60 percent of the population lives in Reserve 2, while 40 percent of the population lives in Reserve 1 (Statistics Canada 2017). The T'Sou-ke First Nation has an estimated population density of 301.5 people per km which is less than cities like Vancouver and Victoria, but higher than smaller cities or towns in BC (Statistics Canada 2017). In particular, the population density in Reserve 2 is 270.2 people per km^2 while that in Reserve 1 is 365.0 people per km^2 (Statistics Canada 2017). In 2010, about 73.5 percent (125 out of 170) of the T'Sou-ke population (15 years and older) was in the labour force. Among the labour force, about 64.7 percent (110 out of 170) were employed and 12.0 percent (15 out of 125) were unemployed (Statistics Canada 2013).

Like all Aboriginal communities, the people of T'Sou-ke have lived on their traditional territories for thousands of years. Due to their location on the southern tip of Vancouver Island, the T'Sou-ke First Nation had extensive contact with the colonizers in the mid-18th century (Vancouver Island Wilderness and Historical Conservation n.d.). The Hudson's Bay Company was active in the area and often traded with the T'Sou-ke Nation (Vancouver Island Wilderness and Historical Conservation n.d.). However, as the forces of colonialism grew, the T'Sou-ke First Nation along with other First Nation communities were forced into Reserves by the Joint Indian Reserve Commission (JIRC) in 1877 (T'Sou-ke First Nation 2016). The JIRC was established by the Government of Canada and BC to resolve disputes regarding the amount of lands to be reserved for First

Nation communities in Canada. It was in operation from 1876 to 1878 (Union of British Columbia Indian Chiefs n.d.).

Historically, the T'Sou-ke First Nation had its own social and traditional organizational and governance structure. However, as part of colonization, a municipal-style local governance structure was imposed. The T'Sou-ke First Nation is now led by a group of chief and councilors, elected by the members every two years under the election procedures defined by the Indian Act, 1876. The Indian Act is a Canadian federal law that governs matters related to First Nations (First Nations & Indigenous Studies: The University of British Columbia 2009). The T'Sou-ke First Nation conducted its last election in February 2016, and the members elected Gordon Planes as the Chief, and Rose Dumont and Allan G Planes as Councilors (T'Sou-ke First Nation 2016). The Chief and the Council of the T'Sou-ke First Nation enact laws, approve revenue and spending measures, and set the direction for policies and initiatives in the community (T'Sou-ke First Nation 2016). The Band administration, on the other hand, is responsible for coordinating and managing the affairs of the community.

Since 1995, the T'Sou-ke First Nation has been a member of the Te'mexw Treaty Association. The Association is comprised of five First Nations, namely, Malahat, Scia'new (Beecher Bay), Songhees, Snaw-aw-as (Nanoose) and T'Sou-ke, all located on Vancouver Island (Te'mexw Treaty Association n.d.). The objective of the association is to work together to negotiate a modern treaty with the federal and provincial governments in the BC Treaty process (Te'mexw Treaty Association n.d.). Some of the major issues of treaty negotiation include Aboriginal rights, self-government, land and resources, fishing, forestry and finances (BC Treaty Commission n.d.).The treaty negotiation process has six stages, and the Te'mexw Treaty Association is currently in stage five of the process (BC Treaty Commission 2017).

CHAPTER 2: METHODOLOGY

2.1 Discussion of key concepts

2.1.1 Electricity generation capacity and electricity generation

A standard analysis of a solar PV system is carried out in RETScreen which is a project analysis software developed by the Government of Canada. RETScreen empowers decision-makers to identify, assess and optimize the technical and financial viability of potential clean energy projects (Natural Resources Canada 2017a). The main analysis components in RETScreen include financial analysis and emission analysis. In terms of financial analysis, key concepts are electricity generation capacity and electricity generation, pricing of electricity, and system costs and incentives. Similarly, for GHG emission analysis, important concepts include emission factors of different fuel types, and lifecycle GHG emissions from electricity generation. Electricity generation capacity is the maximum electric output an electricity generator can produce under specific conditions and is measured in units of power called watts, such as kilo-watts [kW] or mega-watts [MW] (U.S. Energy Information Administration n.d.).[1] For example, the electricity generation capacity of a common residential rooftop solar PV system consisting of solar panels of a certain wattage is measured in kWs while that of a large solar farm or a power plant would be measured in MWs.

Electricity generation, on the other hand, is the amount of electricity a generator produces over a specific period of time and is measured in units of energy called watt-

1. For reference, 1kW = 1,000 watts and 1MW = 1,000 kW.

hours, such as kilowatt-hours [kWh] or megawatt-hours [MWh] (U.S. Energy Information Administration n.d.).[2] As an example, the electricity generated by a residential solar PV system is given in kWh. Generally, the annual electricity generated [kWh] by a PV system [kW] depends on solar panel wattage, elevation, tilt or roof slope of the panel, average daily sunlight hours for the location, and energy loss (solar panels produce direct current which must be "inverted" into alternating current used by houses and the power grid, resulting in some energy loss. Likewise, panels can become dirty, which reduces their effective capacity). Some of the factors that affect the electricity generated by a system are climate, temperature and solar panel degradation over the years. For instance, increased temperature would increase electrical resistance and reduce PV efficiency. Similarly, local climatic factors would also affect PV output. As a typical utility customer is billed for their electricity use (kWh), the value of solar PV installation is guided by the electricity (kWh) it generates and its net worth after expenses. The more kWh a system generates and the higher its net value, the more valuable is the system (Hay 2016, 4).

2.1.2 Pricing of electricity

Electricity is typically priced using two different approaches, namely cost-based pricing and market-based pricing. In cost-based pricing, the electricity regulator (i.e., the local utility, e.g., BC Hydro) uses "historical average cost pricing" to determine the fixed price of the guaranteed quantity of electricity provided by its facilities (Taylor and

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2. For reference, 1kWh = 1 hour of using electricity at a rate of 1,000 watts and1MWh = 1 hour of using electricity at a rate of 1,000 kW.

Hoberg 2011). Under this pricing scheme, rates equal the average cost of producing one unit of electricity over the lifetime of a given generating facility (Taylor and Hoberg 2011). In market-based pricing, on the other hand, electricity prices fluctuate with the movements in the intersection of supply and demand (Taylor and Hoberg 2011). For residential consumers, the electricity rate is fixed and mainly priced using cost-based pricing in B.C and most provinces. However, Alberta has a deregulated electricity market where consumers who are not on a contract pay a fluctuating electricity rate based on market prices. Furthermore, Ontario has a partially restructured electricity market where market forces determine a portion of the generation costs, although the electricity regulator – the Ontario Energy Board, still sets the price (Natural Resources Canada 2016b; National Energy Board 2017, sec. 2, par. 1-3). For cross-border electricity trading, B.C and other provinces use market-based pricing (Taylor and Hoberg 2011).

With electricity rates being regulated by the provinces, the actual electricity prices vary across Canada, as every electric utility has different charges that apply. The common charges in a residential BC Hydro bill of a customer include a fixed charge, an energy charge, and a rate rider. The fixed charge is typically a basic recurring charge that all customers pay whether or not they use any electricity and is associated with metering, and billing. The energy charge, or the variable charge, is the charge for the actual consumption of electricity (kWh) and is two-tiered. Finally, the rate rider is a charge to recover additional and unpredictable energy costs such as low water inflows and it is applied to the total of all charges, before taxes. As an example, the average BC Hydro bill of a residential customer is $160.73 for using 1500 kWh of electricity for 62 days. The fixed charge is $11.77 ($0.18990 per day for 62 days), and the energy charge is $118.06

($0.08580 for 1376 kWh and $0.12870 for the next 124 kWh). The rate rider is $7.29 (5.0% of the total fixed and variable charges), and taxes are $7.65 (5.0% of the total of fixed charge, variable charge, and the rate rider) (BC Hydro 2017a).

Assuming there is no accompanying change in grid status, solar PV installations do not affect the fixed charge but reduces the energy charge associated with electricity bills resulting in lower utility bills for a customer (Hay 2016, 9). For off-grid PV systems, there is no fixed charge. Moreover, the higher the utility's energy charge, the greater the value of the electricity produced by a PV system and greater the energy savings. Energy savings are the electricity that would otherwise be purchased from the utility but is displaced with the electricity production from the PV system.The financial savings from a PV installation are also higher if the utility decides to escalate energy prices in the future.

2.1.3 System costs and incentives

The core cost of a PV system includes direct capital costs, indirect capital costs and operations and maintenance costs. Direct capital costs are costs of a specific piece of equipment or components of the PV. Examples of direct capital costs include the cost of the solar panels, invertors, and the balance of system (BOS) components such as racking, wiring, fuses, breakers, and monitoring equipment. (Hay 2016, 6). Indirect capital costs, on the other hand, are soft costs associated with the PV and include installation costs (labour), grid-connection, engineering, permitting, and sales tax. Both the direct capital costs and the indirect capital costs are upfront costs and incurred in a year zero of the cash flow analysis. In general, the direct capital costs are about 42 percent of the total cost of a PV while indirect capital costs are about 58 percent of the total installed cost of a PV (Poissant and Bateman 2014, 11).

Operations and maintenance (O&M) costs, on the other hand, are ongoing annual expenses required to maintain, service and or replace critical components of a PV system. Examples of O&M costs include re-torqueing electrical connections, replacing fuses, locating ground faults, and repairing or replacing invertors and panels. O&M costs can be reported in various forms such as a simple fixed annual cost, fixed annual cost as a percentage of the overall capital investment, fixed annual cost proportionate to the system size, and a variable annual cost proportionate to the projected annual electrical production of the PV system. Solar PV has high upfront capital costs (direct and indirect) and low annual O&M costs, although, there might be some increase in O&M costs over the years due to the aging of the PV components. An important metric for assessing the PV costs is to calculate the total installed cost per watt of a system, which is given by the total system cost divided by the systems 'nameplate capacity' in watts (Hay 2016, 7).

Funding, grants, and incentives are essential to solar PV in locations where solar has not yet achieved grid parity. Incentives and funding are typically sector specific and generally come from federal, provincial and local governments and utility companies. While the reasons for providing these incentives and funding differ for each source, the common belief is that clean energy and energy efficiency merit financial support. As an example, the federal government aims to foster energy independence and environmental responsibility, while the provincial and local governments and utility companies aim to reduce individual energy costs and demand (Hay 2016, 13).

2.1.4 Financial analysis

The financial analysis of a solar PV system is based on the concepts discussed in Section 2.1.1 to Section 2.1.3 and includes a thorough analysis of the expected costs and benefits. The common measures of evaluating the economic feasibility of a PV system are simple payback period, net present value (NPV), and levelized cost of energy (LCOE). In calculating all these measures, assumptions about system lifetime, electricity price, energy escalation, and system costs and incentives are made. Simple payback determines the number of years for the energy savings from the PV system to offset the initial cost of the system (the shorter the simple payback, the less risky the investment). In general, assessing how quickly a solar investment might pay off and whether it can pay-off within the project lifetime provides an initial indication of economic viability. The formula for calculating payback years for investment is given below. The calculation involves dividing the initial costs of a PV system by the yearly energy savings, i.e., the kWh of electricity that will not have to be purchased from the utility multiplied by the electricity rate and minus any O&M costs.

$$\text{Payback years} = \frac{\text{Initial cost(\$)}}{\text{Electricity production(kWh/year)} \times \text{Cost of electricity(\$/kWh)} - \text{O\&M costs(\$/year)}}$$

While simple payback is a widely used measure, it has several limitations that lead to under or over-estimation of the true payback years of the solar investment. For instance, simple payback ignores several critical investment characteristics such as the time value of money, energy price escalation, variable rate electricity pricing, and opportunity cost (Hay 2016, 19).[3] Alternative measures such as NPV and LCOE are more complex, but remove some of the drawbacks of simple payback. Both these measures consider the time value of money and energy price escalation. NPV takes into account every cash flow in a period, positive and negative, and discounts back to today to see if the project is profitable or not. NPV is given by the following formula:

$$\text{NPV}=\sum_{t=1}^{T}\frac{\text{Cash flow}_t}{(1+i)^t}-\text{Initial Cash Investment}$$

where, t= Cash flow period; i= Discount rate assumption

Generally, a positive net present value means an economically feasible investment. However, a positive NPV does not always suggest that the investment should be made, as there are important considerations such as the opportunity cost of the capital and the lifespan of the investment (Hay 2016, 20). While NPV is a widely used measure to analyze clean energy technologies, it is extremely dependent on the discount rate and the financial assumptions used in the calculation. It is therefore important to perform sensitivity analysis when performing NPV analysis, as the variables used in the calculation are projections and are subject to change and error (Williams 2012). Sensitivity analysis is an investigation of potential changes and errors in certain variables

3. Time value of money recognizes that a dollar today is generally worth more than the same dollar in the future. Ignoring time value of money means that energy savings in future are valued as the same as present, thereby underestimating the pay-back period (Hay 2016, 19). Accurate analysis of an energy investment should consider discounting the future energy savings and costs on investment. Similarly, not accounting for energy price escalation, i.e., the real inflation-adjusted price of electricity and variable rate electricity pricing (block or tiered pricing) will overestimate the pay-back period. Also, simple pay-back is not well-suited to compare energy investments that have different expected useful lives (Hay 2016, 20).

in a clean energy installation (e.g., initial cost of the system, O&M costs and system lifetime) and their impacts on the conclusions to be drawn from the model (Pannell 1997, 139; Baird 1989).

LCOE, also closely related to NPV, can be thought of as the price at which energy must be sold to break even over the lifetime of the technology. It yields an NPV in terms of cents per kWh, i.e., the per- kWh cost in discounted real dollars of building and operating a system over an assumed financial life (Darling et al. 2011, 3134; U.S. Energy Information Administration 2017). The simplified formula for LCOE is as follows:

$$\text{LCOE} = \frac{\text{Lifecycle cost}(\$)}{\text{Lifetime energy production}(\text{kWh})}$$

The main advantage of this measure is that it allows for comparisons between different electricity sources, such as roof-mounted PV and utility-provided electricity, and across different system life spans (Hay 2016, 21). However, like NPV, the value of LCOE is also impacted by the key inputs in the calculation, such as the system costs, financing, insurance, O&M costs, taxes, and incentives. While these two measures are better than simple payback, and widely used for decision-making purposes, they have limitations as well. Most of these measures can be calculated using the clean energy management software, RETScreen. Depending on the assumptions, the value of payback, NPV, LCOE and other measures will vary for each system. A robust financial analysis of a solar PV system should include calculation and comparison of all these measures in different scenarios (e.g., pre-tax scenario, without O&M costs and insurance scenario, post-tax with equity scenario) as required.

2.1.5 GHG emission factors of different fossil fuels for electricity generation

Different fossil fuels emit different amounts of GHG emissions relative to the energy they produce when burned for electricity or heating. Typically, the amount of GHG emissions displaced by solar PV depends on the fuel being displaced, its GHG emission factor , and the regional location of the PV system. Also, as solar insolation increases, lifecycle GHG emissions decrease. For example, the doubling of solar insolation from Europe-North to US-North leads to a halving of the life-cycle carbon emission factors (Nian 2016, 1485). The GHG emission factor is the average emission rate of a given GHG for a given source, relative to units of activity (United Nations Framework Convention on Climate Change 2014). Generally, GHG emission factors are reported in units of carbon dioxide equivalent (CO_2e) to take into account greenhouse gases other than carbon dioxide (CO_2) , such as methane (CH_4) and nitrious oxide (N_2O). To express it in terms of CO_2e, the emission factors of CH_4, and N_2O are multiplied by their global warming potential (GWP).

GWP is a measure of how much energy the emissions of one ton of a gas will absorb over a given period of time, relative to the emissions of one ton of CO_2 (United States Environmental Protection Agency 2017). The time-period generally used for GWPs is 100 years and the 100-year GWPs of CH_4 and N_2O are reported to be 25 and 298 respectively (Forster et.al. 2007, 212). Figure 2 provides the GHG emission factors of different fossil fuels such as coal, natural gas, and petroleum. Among all the fossil fuels, coal has the highest GHG emission factor, followed by petroleum and natural gas.

Between different types of coal, anthracite coal has the highest GHG emission factor, and among petroleum products, heavy fuel oil has the highest GHG emission factor.

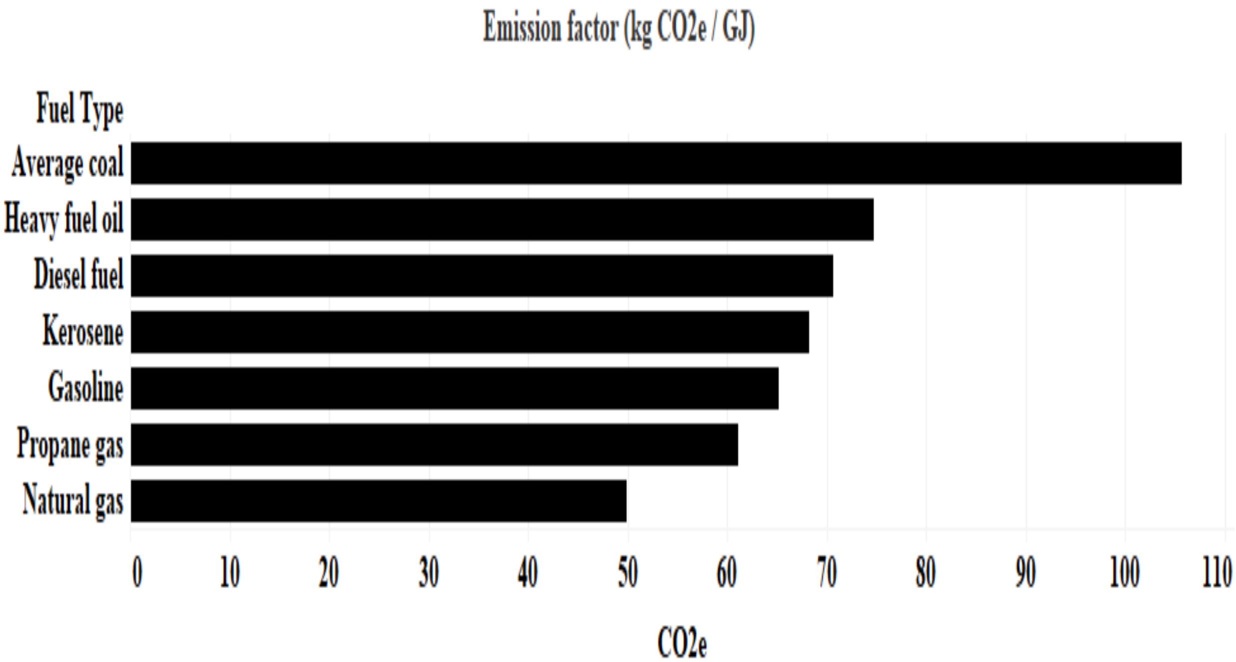

Figure 2: GHG emission factors of different fossil fuels for electricity generation. Data from United States Environmental Protection Agency (2014, 1); BC Ministry of Environment (2016, 12).

2.1.6 Lifecycle GHG emissions of different electricity generation sources

During electricity generation, solar PV and other clean energy technologies generally do not emit any GHGs as compared to fossil fuels. Bio-energy and hydropower, however, do emit GHGs. For example, per MWh, biomass power plants emit more CO_2 than coal plants, and co-firing biomass at coal plants increases CO_2 emissions and decreases facility efficiency (Partnership for Policy Integrity 2014). Similarly, hydro reservoirs created by dams are a dominant source of methane emissions; in fact 25 percent more in terms of per area rate than was historically estimated (Deemer, et al. 2016, 949).

However, GHG emissions occur during production, transportation, construction and decommissioning of the clean energy technologies, and hence it is important to consider lifecycle GHG emissions. Typically, lifecycle GHG emissions account for emissions from all stages of an electricity generation method, such as construction, operations and decommissioning. The average life cycle GHG emissions of various electricity generation technologies are given in Figure 3. Among clean energy technologies, solar PV has the highest average lifecycle GHG emissions of 46 gCO_2e per kWh. The next highest average lifecycle GHGs are emitted by geothermal, at 45 gCO_2e per kWh, and solar thermal, at 22 gCO_2e per kWh. Wind, ocean energy, and hydropower, on the other hand, have the lowest average life-cycle emissions of 12 gCO_2e per kWh, 8 gCO_2e per kWh and 4 gCO_2e per kWh respectively (Moomaw et al. 2011, 186). Among fossil fuels, coal has the highest average life-cycle GHG emissions of 1000 gCO_2e per kWh. It is followed by oil with average lifecycle GHG emissions of 840 gCO_2e per kWh, and natural gas with average lifecycle GHG emissions of 469 gCO_2e per kWh (Moomaw et al. 2011, 186). GHG emission analysis is based on the concepts discussed in Section 2.1.5 to Section 2.1.6, and a basic analysis can be carried out with the RETScreen software.

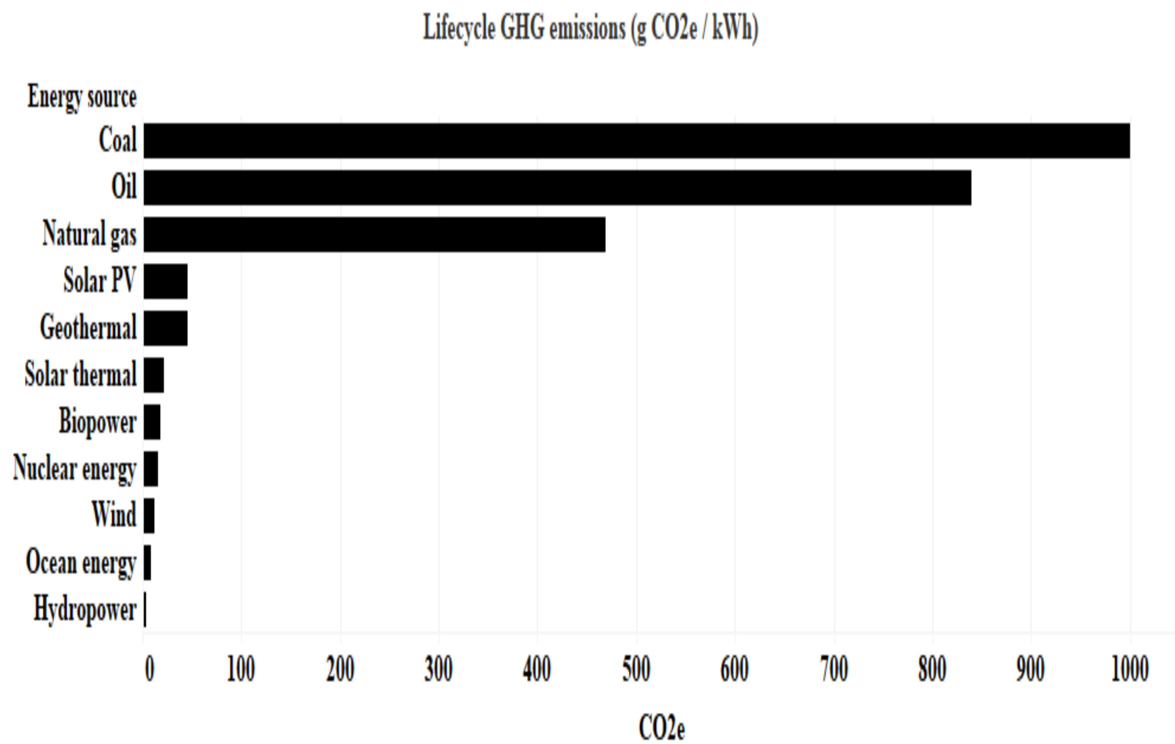

Figure 3: Life cycle GHG emissions from different electricity generation technologies. Data from Moomaw et al. (2011, 186).

2.2 Analytical case study framework

The case study analysis of the solar project is guided by an independent analytical framework designed by a team of researchers at The Future Economy Initiative. "The Future Economy Initiative is a project of Ecotrust and the E3 Network- a national network of economists for equity and environment- that is bringing rigorous economic analysis to new markets of energy, food, housing and labour" (Future Economy n.d.). The main goals of the initiative are to document and study the social, economic, and environmental impacts of emerging innovative projects and identify factors that contribute to their emergence, success, and limitations. As with most innovative projects in general, despite their potential importance, there is a lack of awareness of their existence and their impacts, leading many to assume that there are no desirable alternatives to business-as-usual (Sheeran et al. 2014, 2). I chose this particular framework for the case study as it is designed to evaluate emerging and innovative clean energy projects. This analytical framework was also used by Lee (2015) for the case study of the City of Vancouver's Neighbourhood Energy Utility (NEU), which is the city's first clean district heating system. The NEU provides space heating and hot water to the new Southeast False Creek community by capturing waste thermal energy from sewage (City of Vancouver 2017).

The analytical framework (in the form of questions and annotations) provides a coherent structure for analyzing case studies to build a body of evidence that can enable more rigorous economic research (Sheeran et al. 2014, 2). The framework's focus is on three key areas of a project namely; innovation, evaluation, and contributing factors.[4] The first part, Innovation, requires a researcher to provide the history of the origin of the project, its main features, the challenges that the project responds to, among others (Sheeran et al. 2014, 3-5). The second part, Evaluation, requires that a researcher provides quantitative data, supplemented by descriptions of the impacts of the innovative project along key dimensions such as environment, livelihoods and opportunities, empowerment, and others (Sheeran et al. 2014, 6-14).The final part, Contributing Factors, requires that a researcher describes if the project is scalable and or replicable in

4. For more details, see the analytical framework at: http://futureecon.com/wp-content/uploads/future-economy-framework_new.pdf.

other social, political or economic contexts, and whether the project catalyzes additional economic development or further innovations, among others (Sheeran et al. 2014, 15-19).

For this case study, in terms of innovation, I look at how the T'Sou-ke solar project evolved, followed by a description of the project in detail, and identifying the need or challenge in the community that led to the project. For evaluation, I consider net GHG emissions reduction from the project, job creation for the members, and local community and other economic benefits. Finally, in terms of contributing factors, I examine the ability of the project to be replicated in other communities.

The framework suggests that a researcher follows a mixed-methods approach for the analysis, as it allows for both careful and qualitative descriptions of the project, as well as quantitative analysis of the project's impact on the community and the larger economy (Sheeran et al. 2014, 3). As such, for the case study of the T'Sou-ke solar project, I used a mixed-methods approach that involves both qualitative and quantitative data analysis.

2.3 Data collection methods and research protocols

I collected the quantitative data for this research from unpublished reports of the T'Sou-ke First Nation. One of the main reports that I analyzed was the: "Renewable Energy Toolkit: T'Sou-ke Solar Project," published in March 2010 and prepared by the T'Sou-ke First Nation in partnership with HEMMERA. HEMMERA is an environmental consultancy that provides green services or products related environmental information and services in Vancouver, BC.[5] The other two key reports were the: "Power Production, Emission and Financial Analysis for T'Sou-ke Nation's Photovoltaic Demonstration Project," published in August 2009, and "Data Monitoring for T'Sou-ke Nation's Photovoltaic Demonstration Project," published in October 2009, both prepared by Bekker.[6]

For collecting the qualitative data, I conducted "semi-structured interviews" with the members of the community, external participants who worked on the project, and a clean energy expert based in BC. "Semi-structured interviews" is a method of inquiry that combines a pre-determined set of open-ended questions with the opportunity for the interviewer to explore particular responses further (Community Sustainability Engagement Evaluation Toolbox 2010). The process of data collection involved three basic steps. In the first step, I contacted the T'Sou-ke First Nation Project Manager, Andrew Moore, with my proposed case study in early May 2015. Based on my initial communication with Mr. Moore, I submitted a form of intent to the T'Sou-ke Band Manager, Michelle Thut. Later in the month, I received an expression of interest in my case study from the Band. I then established a participant agreement with the T'Sou-ke First Nation for the research. See Figure D.1 for the participation agreement.

In the second step, I submitted my proposed case study for an ethics review to the University of Northern British Columbia (UNBC) Research Ethics Board in June 2015. The Board conducts reviews according to the guidelines of the *Tri-Council Policy*

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5. See https://www.hemmera.com/services for more details.

6. Jessica Bekker worked on the T'Sou-ke First Nation solar project as an Electrical Engineering Co-op student from the University of Victoria.

Statement: Ethical Conduct for Research Involving Humans 2014. In the review, the Board considered various ethical dimensions of the case study such as recruiting research participants, obtaining informed consent, data handling and my role as an independent researcher. See Figure D.2a and D.2b in the Appendices for UNBC ethics approval and renewal.

In the third step, I submitted my proposed case study for review to the Research Advisory Committee (RAC) at the Canadian Centre for Policy Alternatives, B.C. Office (CCPA-BC) in June 2015. CCPA-BC provided me the funding to conduct this case study through the Rosenbluth internship in Policy Research, 2015.[7] See Figure D.3 in the Appendices for CCPA-BC RAC approval. In the fourth and final step, I visited the T'Sou-ke First Nation in August 2015 and spent two weeks in the community to conduct interviews. An initial meeting with Andrew Moore helped me identify the community members who participated in the planning or execution process of the solar project and hence were directly involved with the project. As an independent researcher, I met these community members and provided them the information letter, which described the purpose and significance of the study and the consent to participate. See Figure D.4 in the Appendices for the Information Letter or Consent Form. Some of these community members, in turn, helped me identify other members of the community who could participate in the study. This method is known as "snowball sampling" wherein the currently enrolled research participants are used to recruit additional research

7. The Rosenbluth internship in Policy Research is an annual recurring award that provides mentorship and financial support for a graduate student employed as a public policy intern at CCPA-BC. See https://www.policyalternatives.ca/offices/bc.

participants[8] (Oregon State University 2010). A total of nine members of the T'Sou-ke First Nation participated in the interviews. Also, during the same time, I interviewed three external participants, two of whom worked on the solar project in research and administrative roles, and another participant who was a clean energy expert based in BC. All my participants chose to be "named" in my analysis and did not want to remain anonymous.

CHAPTER 3: SOLAR PROJECT BACKGROUND AND PLANNING

8. The main benefit of snowball sampling is that it allows for studies to take place that might be impossible to conduct because of a lack of participants. The limitation of snowball sampling is that it is usually impossible to determine the sampling error or make inferences about the population based on the obtained sample (Glen 2014).

3.1 Starting Comprehensive Community Planning (CCP)

> The solar project came from our people coming together in a manner of comprehensive community plan. What helped is the land management code where we manage our own lands, that way we go at the speed of business. Also, the other thing too is that this kind of project was done for our children and our children not born yet. Even though we are working on the now…we are looking at the seven generations and 100 years from now what it is gonna look around here.
>
> - (Chief Gordon Planes, interview by author, August19, 2015)

In the evolution of the solar project at the T'Sou-ke First Nation, Comprehensive Community Planning (CCP) has played a major role. CCP is a broad planning tool that is devised for Aboriginal communities to build a roadmap to sustainability, self-sufficiency and improved governance capacity (Indigenous and Northern Affairs Canada 2016b, 1). This comprehensive process enables a community to establish a vision for its future and implement projects to achieve this vision, helps ensure that the community programs are well-developed, and integrates and links all other plans that the community has produced (Indigenous and Northern Affairs Canada 2016b, 2).

The guiding principle of CCP aligns with the Aboriginal tradition of living "sustainable" lives based on a long-term view of sharing and protecting the land, the animals and the plants for the future generations (Indigenous and Northern Affairs Canada 2016b, 3). As part of the CCP process, each community has to decide what sustainability means to them and how they can achieve the longevity of their people, culture, environment, and economy (Indigenous and Northern Affairs Canada 2016b, 3). As such, CCP is available to all First Nations in BC. Indigenous and Northern Affairs Canada (INAC) has funded CCP projects for over ten years, although the communities can undertake CCP without its support as well (Hemphill 2014). The first five communities who originally piloted CCP projects in 2004-06 were Okanagan, Lytton, Squiala, We Wai Kai (Cape Mudge) and Yekooche. As of August 2011, 117 First Nations communities have started the CCP process although this does not necessarily mean that they have a completed plan (Indigenous and Northern Affairs Canada 2016b; Indian and Northern Affairs Canada 2006).

T'Sou-ke First Nation's introduction to CCP was through Mr. Andrew Moore, Project Manager, who was entrusted with the task of organizing a collective vision for the community. Mr. Moore learned about this comprehensive planning tool while working with the Department of Aboriginal Affairs and Northern Development Canada or as it is currently known, INAC. The federal department at the time was planning on expanding CCP so that more First Nations communities would receive its benefits. Mr. Moore brought the idea of CCP to the Band. The former T'Sou-ke First Nation Chief then went to one of the CCP workshops and decided to start the community planning process (Moore, interview by author, August 18, 2015).

In 2007-08, the T'Sou-ke First Nation secured $25,000 in funding from INAC First Nations Infrastructure Fund and an additional $10,000 in funding from the British Columbia Capacity Initiative to start the CCP process (T'Sou-ke First Nation 2010a, 5). The initial funding lasted for three years and the community later received support from other INAC funded programs to complete the planning process (Moore, interview by author, August 18, 2015). The CCP process at the T'Sou-ke First Nation began with 12 Band members forming the T'Sou-ke Vision in Progress (VIP) group (T'Sou-ke First Nation 2010a, 8). In the first stage, the group met every three weeks for a year in the

Band hall to discuss the community's strengths, weaknesses, opportunities, and threats. As an incentive, the VIP members each received $30 honorarium per meeting (T'Sou-ke First Nation 2010a, 8). The outcomes of the meetings were then put on a special 8'x12' notice board in the Band hall for feedback from the members. At the end of the first stage, the VIP group came up with a visioning statement for the community that read, "Our vision is for an economically independent, safe and healthy community. We see ourselves as self-governing, accountable, stewards of our land, generating a respect and understanding for our people's culture and heritage, united, educated, in sobriety, to provide for all generations to come" (T'Sou-ke First Nation, 2010b).

In the second stage, the VIP team developed ideas based on this vision and shared it with the larger community through special meetings and workshops. Elders, Band staff and council, youth, and parents and children participated in these meetings. The ideas mostly revolved around the theme of community sustainability. After several rounds of discussion with the community members, the VIP group solidified these ideas into four key goals and several smaller goals for the T'Sou-ke First Nation.

3.2 Outcomes of Comprehensive Community Planning

The four key goals considered by the VIP group were energy autonomy, food self-sufficiency, cultural renaissance and economic development. The other goals covered areas including governance, land management, resources and environment, education, health, infrastructure development, social development and fisheries (T'Sou-ke First Nation 2010a, 10). To achieve each of these goals, the group laid down a set of objectives, designed projects and created supporting activities. The four key goals were the group's priority in the short to medium-term, and the Band has made considerable progress in addressing them. The four goals are presented in detail in Table 1. All other goals were considered more long-term and are presented in Table 2. The Band was able to complete CCP in a timely manner with a few minor challenges along the way such as difficulties in organizing the first few meetings with the VIP group and getting certain members, particularly, young mothers to attend the special meetings and workshops (Moore, interview by author, August 18, 2015).

Table 1: T'Sou-ke First Nation key Comprehensive Community Planning goals

1. **Energy autonomy**

- Objective: To produce enough heat and electricity without relying solely on outside power sources such as the province's electrical grid.
- Project(s): Solar project (solar PV systems, solar hot water systems and energy conservation program).
- Activities: Partnerships with municipalities, universities and the industry, knowledge dissemination through workshops, conferences, project tours and mentorship of other Aboriginal communities.

2. **Food self-sufficiency**

- Objective: To develop secure nutrition sources to avoid vulnerability to increasing global prices and climate change.
- Project(s): Community greenhouse.
- Activities: Traditional food gathering, jam making and teaching and training.

3. **Cultural renaissance**

Table 1 (continued)

- Objective: To integrate traditional art and culture into every aspect of life.
- Project(s): T'Sou-ke Arts Centre (Heritage building and museum and community longhouse).
- Activities: Art exhibition, community lunch, tribal journey and culture nights

4. **Economic development**

- Objective: To explore Aboriginal business ventures promoting economic development on the reserve(s).
- Project(s): Retail outlets, wasabi plantation and oyster farming.
- Activities: Commercial and industrial development.

Source: List from T'Sou-ke First Nation (2010a, 10); Moore, interview by author (August 18, 2015).

Table 2: Other sustainability goals

Goals	Objectives	Project(s)	Activities
Governance	Focus on self-governance, community involvement, transparency and accountability.		Improving communication among Band members. Extending the term of the Chief and the Council from two to four years. Negotiating a beneficial treaty agreement for the Band.

Table 2 (continued)

Land management, resources and environment	Responsible stewardship of reserve land and resources.		Environmental and archaeological management. Developing, ratifying and implementing land use planning policies.

Education	Having own jurisdiction.	K-6 school on one of the T'Sou-ke First Nation Reserves	Integrating First Nations culture in the education curriculum.
		Exploring partnerships with Camosun College and the University of Victoria.	Creating additional opportunities for members to pursue further education on reserve.
Health	Improving the quality of health of the community members.	Elders assisted living facility on the reserve.	Better administration of health services in the reserve.
		Drug and alcohol detox center on the reserve.	Joining and implementing inter-tribal health authority.
Infrastructure Development	Improving outdated reserve infrastructure.	Connecting Reserve 1 and Reserve 2 to a sewage system.	Ensuring safe access to the main road; improving sidewalks and getting new stoplights.
		New administration building.	Investigating clean energy projects.

Table 2 (continued)

Social Development	Full suitable employment and alleviation of social barriers.		Hosting workshops for life skills development and generating employment opportunities on reserve.
			Providing capacity building and establishing partnerships.

Fisheries	Having self-sufficiency.	Oyster farming.	Claim of beach tenures, development of commercial fisheries and renewal and extension of halibut and black cod licenses.

Source: Data from T'Sou-ke First Nation (2010a, Appendix A).

3.3 Focusing on energy autonomy

The first key goal of energy autonomy was the driving force behind the solar project (see Chapter 4, Section 4.2.1 for a detailed analysis on energy autonomy). Energy autonomy is generally defined as the ability of an energy system to be able to function fully, without the need of external support in the form of energy imports through its own local generation, storage and distribution system (Rae and Bradley 2012, 6499). Energy autonomy, in its purest sense, is theoretically and practically impossible, as the design, manufacturing, installation, commissioning, operation and maintenance of energy system is highly likely to use outside facilities. However, there are varying degrees of autonomy that are practically achievable depending on how the system boundaries are drawn. The first option is being net energy neutral, i.e., the community or energy system generates more energy locally than it consumes, and exports the remainder and offsets any energy imports. The other option is off-grid, where the energy system is capable of generating and storing enough energy to meet the needs of the entire community with no requirements for energy imports and minimal reliance on outside expertise (Rae and Bradley 2012, 6500).

The choice of having solar project over other clean energy technologies was inspired by the fact that T'Sou-ke Reserve 1 receives great solar insolation. The project also uniquely benefitted from the expertise of one of the T'Sou-ke Band members who had previously worked with solar technology (T'Sou-ke First Nation 2010a, 12). The solar project was carried out in two phases. The first phase of the solar project started with a 75.6 kW solar PV installation in two of the office buildings and two separate structures in Reserve 1. It was later supplemented with solar hot water installations in 40 member residences, on both the Reserves, and an energy conservation program in the Band promoted by a youth-led energy group. Additionally, Phase 1 included installation of two electric car chargers and an electric vehicle charging station powered by solar PV. This phase also consisted of hosting a solar forum in summer 2009 to showcase the solar project and share T'Sou-ke First Nation's experience with other communities (T'Sou-ke First Nation 2010a, 15).

3.4 Planning and implementation of the solar project and the key challenges

Phase 1 of the solar project was completed within a time frame of two years since the beginning of the CCP process began in 2007. In particular, the solar PV and the solar hot water systems took about three months to install (Moore, interview by author, August 18, 2015). As this was the first phase, the Band faced some major challenges during the planning and implementation of the project. The first challenge was for the T'Sou-ke staff to apply for, obtain, and manage all the funding for the solar project. The T'Sou-ke First Nation applied and received funding from about 16 sources (government and private) to cover the costs of the solar project. The Band leveraged the main capital funding from Natural Resources Canada's Innovative Clean Energy Fund (CEF) to raise the remaining funds for the solar project. Some of the other important funding sources for the project are listed in Table A.

With multiple funders and their conflicting requirements, the funds were dispersed in multiple timelines resulting in significant delays during the course of the project. For instance, sometimes one funder would want to see if other funders had contributed to the project before adding their own part. At other times, a funder would only pay actual expenses already incurred, which meant that the T'Sou-ke Nation had to spend the money before they were reimbursed (T'Sou-ke First Nation 2010a, 22). The second challenge faced by the T'Sou-ke First Nation was to get the grid-connected PV systems to work post-installation, which took about nine months. As stated by Mr. Moore:

> The inverters would crash and switch off when electricity was fed into the utility. BC Hydro insisted that we and the installers had made a mistake somewhere. This argument went on for months. It was during one of the events during Winter Olympics that the Chairman of BC Hydro shared a box with our Chief and our solar progress was discussed. Following which, BC Hydro sent a 'fixer' to look at the problem. He could not solve it and sent for a specialist from California. The specialist said there was too much resistance on the line. BC Hydro had put the transmission boxes too far away from the installations that led to the resistance. From our point of view, it was more of a psychological resistance on BC Hydro's part as they sell electricity, don't buy it. (Moore, interview by author, August 18, 2015).

The third challenge was the solar hot water systems in the members' houses. Many of the hot water systems had installation deficiencies. Although the Band managed to obtain some additional funding from Natural Resources Canada to fix the broken hot water systems, it became a financial burden, as some of the existing problems persisted, and the Band decided it was best to leave the responsibility of the solar hot water systems to the individual members (Thut, interview by author, August 17, 2015). As a precautionary step, the Band also discontinued the plan of installing solar hot water systems in all the 86 other member residences in Phase II of the solar project. Mr. Moore mentioned some of the problems with the solar hot water systems:

> The solar hot water systems were a good opportunity and seemed cost-effective during the time when the project was being implemented. However, it proved to be more difficult to do, and there were lots of problems with the project in terms of plumbing, wiring, and maintenance. [The] majority of the solar hot water systems had installation faults which led to the freezing of pipes in winter, proving disastrous for the homeowners. Additionally, the solar hot water contractor went bankrupt halfway through the project owing us a lot of money that was paid up front, despite the fact that it came highly recommended by Natural Resources Canada. (Moore, interview by author, August 18, 2015).

While these challenges led to delays in the completion of the project and added stress for the community members, the Band learned some important lessons in project planning and implementation, so that such challenges can be mitigated in future solar and other clean energy projects in Aboriginal communities (see Chapter 5, section 5.2 for the lessons). With the completion of Phase I, the Band decided to proceed further and start Phase II of the project, focusing on knowledge dissemination and research into energy storage and other renewable energy options. All the components of Phase II of the project are listed in Figure 4. As of 2017, the Band has implemented most of these project components without any difficulties.

1. Increasing the scope of conservation and energy awareness on the reserve, including working with BC Hydro to conduct energy conservation retrofits in all the reserve's buildings until they are equivalent to passive house standards.
2. Expanding the conservation activities of the T'Sou-ke Smart Energy Group over a three year program to work with other First Nations, municipalities and schools.
3. Getting nine of the T'Sou-ke Nation's solar hot water trainee's additional industry certification by the Canadian Solar Industries Association (CANSIA).

4. Evaluating opportunities in wave energy on the reserve. Currently, there is a wave energy project in partnership with the T'Sou-ke First Nation.

5. Evaluating opportunities of wind power installation for T'Sou-ke Reserve #2 located on a windy coastline. The T'Sou-ke First Nation announced a $750 million wind-energy project in 2013, four years after the solar project. However, the project is currently on hold because of its inability to find a customer. As stated by one of the project's spokesperson, BC Hydro wasn't interested in wind power and proposed the $9-billion Site C dam a year later (Michael 2016).

6. Disseminating project related knowledge to other First Nations, municipalities, schools, universities, public and tourists through workshops, conferences and guided tours.

7. Research into energy storage opportunities. Currently, the T'Sou-ke First Nation is in partnership with Schneider Electric to research energy storage opportunities.

Figure 4: Phase II Project components. List from T'Sou-ke First Nation (2010a, 19); Moore, interview by author (August 18, 2015).

CHAPTER 4: SOLAR PROJECT ANALYSIS

4.1 Description of the main components of the solar project

4.1.1 Solar PV systems

At the core of the T'Sou-ke solar project are four solar PV systems with a total electricity generation capacity of 75.6 kW on Reserve 1. An early sketch of the project, along with pictures of all the four PV systems (Canoe Shed, Hilltop, Administration, and Fisheries) is provided in Figures B.1a to B.1.e in Appendix B. The largest PV system is a 39.9 kW grid-tied system on the Band's Canoe Shed. The solar panels have been affixed to a separate roof structure on the actual Canoe Shed to support the weight. In the middle of the roof structure amongst the panels, there is a display of the T'Sou-ke logo of the 'sun.' This system does not have any electrical load, i.e., it is not providing electricity to any of the Band's offices, and the surplus electricity is exported to the grid, making it the highest revenue generating system out of all the four PV systems (Bekker 2009a, 24).

The second largest PV system is a 22.4 kW Hilltop grid-tied system, and the solar panels have been affixed to a customized ground mount structure so that the ancient midden underneath the gravel soil is not disturbed. Some of the surplus solar power generated by this system is used by the Administration building, and the rest is exported to the grid (Bekker 2009a, 19). The third system is a 7 kW grid-tied system installed on the roof of the Band's office, i.e., the Administration building. This system has a battery bank that stores up to two days of power for the emergency load of the building in case of a power outage (Bekker 2009a,14). The emergency load maintains communication, kitchen appliances, heating, and can provide power for medical equipment (Bekker 2009a, 14). While the Administration and Hilltop systems are both connected to the Administration building's meter, the Canoe Shed system is connected to its own meter. For the grid-tied PV systems, there are three net-metering programs with BC Hydro for exporting surplus electricity to the grid (Bekker 2009a, 29).

The fourth PV system is a 6.3 kW system on the roof of the Fisheries building (another T'Sou-ke First Nation office), and simulates an off-grid PV system used in remote communities. This PV system is designed to supply 57.2 percent of the electricity load of the Fisheries building, and the rest of the power (42.8 percent) can be provided by other sources such as diesel. As T'Sou-ke First Nation is grid-connected, the band uses grid electricity instead of diesel (Bekker 2009a, 16; Moore, interview by author, August 18, 2015). This PV system has a battery bank that stores electricity produced in the day for use during nighttime or cloudy weather (Bekker 2009a, 16). For guidance, two diesel powered First Nations communities, Nemiah Valley in BC interior and Hesquiaht in West Coast, Vancouver were studied. The diesel costs in these communities were reported to be $2 per litre, equivalent to 90 cents per kWh, which is ten times higher the residential BC Hydro rate (Bekker 2009a, 9). Due to high diesel costs, other needed and basic social programs were not funded in these communities (Moore, interview by author, August 18, 2015).

Some of the key statistics of the T'Sou-ke solar PV component as reported by Bekker (2009b, 22-26) are presented in Table 3. The 75.6 kW PV system produces 87,902 kWh of annual electricity, of which 20,635 kWh (23 percent) is consumed by the Band's Administration and Fisheries buildings, and 67,267 kWh (77 percent) is surplus electricity exported to the grid. While the annual electricity load for the Administration building is 15,353kWh, the Hilltop and the Administration PV system provide about 14,135kWh. The rest of the electricity (1,218kWh) is purchased from BC Hydro. The surplus electricity from the Hilltop and Administration system is thus 19,995 kWh, and the net surplus electricity exported to the grid is thus 67,267 kWh. Similarly, for the Fisheries building, the annual electricity load is 11,376 kWh (this is the electricity load after energy efficiency measures were undertaken). The historical electricity load of the Fisheries building before the energy efficiency measures was about 16,085 kWh per year. The Fisheries PV system provides about 6,500 kWh of electricity per year, and the remaining 4,876 kWh of electricity is provided BC Hydro Bekker (2009b, 22-26). Among all the PV systems, the Canoe Shed PV system produces the most surplus solar power as it does not have any electrical load (Bekker 2009a, 24). Also, the surplus electricity exported to the grid has a micro-grid potential, i.e. the solar power can be rerouted to provide power to a maximum of six residential buildings with an annual electrical consumption of 11,000 kWh (Bekker 2009a, 31).[9]

Table 3: Key T'Sou-ke solar PV system statistics, 2009

System location and capacity	Electricity production (kWh/year)	Historical BC Hydro electrical load	Electricity consumption (kWh/year)	Surplus electricity exported to BC Hydro grid (kWh/year)

9. In general, a typical residential building generally consumes about 11,000 kWh per year (BC Hydro 2017b).

	(kWh/year)			
Canoe Shed 39.9 kW	47,272	--------	---------	47,272
Hilltop 22.4 kW+ Administration 7 kW	34,130 (27,358+6,772)	15,353	14,135	19,995
Fisheries 6.3 kW	6,500	11,376	6,500	--------
Total	**87,902**	**26,729**	**20,635**	**67,267**

Source: Data organized using Bekker (2009b, 22-26).

4.1.2 Solar hot water systems

The second main component of the solar project is the solar hot water systems that provide domestic water heating in member residences in Reserve 1 and Reserve 2 of the T'Sou-ke First Nation. Solar hot water systems were installed in 40 member residences, i.e., about one- half of the community. The hot water systems in the T'Sou-ke residences consist of solar collectors mounted on the roof of the house; a pump for circulating the heat transfer fluid; a heat exchanger for transferring the heat to storage; and one or two storage tanks for storing the hot water when there is no sun (Natural Resources Canada 2003, 4). As per Mr. Moore, considering that only 20 solar hot water systems are currently functional due to technical difficulties, there is approximately a 10 to 20 percent reduction in the energy or electricity use from water heating in the residences (Moore, interview by author, August 18, 2015).

4.1.3 Energy conservation program

The energy conservation program is the third important component of the solar project. The T'Sou-ke First Nation carried out the energy conservation program across the two Reserves on the Band office buildings and member residences. The focus of the program was on two central areas: a) reducing energy through behavioural changes, and b) reducing energy through small technical changes in the energy systems of the existing buildings, and structural components (Ozog 2012, 68). To promote behavioural changes among members in the reserve, the Band formed the T'Sou-ke Smart Energy Group (T'SEG).

The T'SEG was comprised of four young adults and a mentor. The group actively advocated for changing energy habits. An important step in this direction included designing and implementing energy conservation workshops for members of all age groups. For instance, Eco Kids Camp, a two-day workshop was organized for kids aged between three and five. This workshop included recycled crafts, physical activities, earth day stories, and games. Furthermore, a one-day workshop was organized for elders that included an energy conservation presentation by the T'SEG, crafts, documentary screening, and a fun game of Eco Earth Bingo (T'Sou-ke Smart Energy Group n.d.).

To encourage small technical changes in the energy systems of the existing buildings, home energy audits were performed in 86 member residences across the two Reserves with the help of City Green Solutions. City Green is a non-profit organization in BC that provides home energy evaluations and energy efficiency services.[10] Among the 86 residences, about 93% are single-detached houses, and the rest are apartments in a

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10. See https://www.citygreen.ca/ for more details.

duplex, and are all heated with electricity (Statistics Canada 2017). As part of the energy audits, City Green Solutions tested for air leakage in the houses through windows, doors and electrical outlets, and determined if more insulation could be added to the walls (Ozog 2012, 70). The organization also identified options to seal up the "envelope" of the house and made small technical application changes such as wrapping hot water pipes in foam, hot water tanks in blankets and using low flow shower heads (Ozog 2012, 70).

Additionally, the Band implemented BC Hydro's energy conservation program with the help of T'SEG. This program is available for free on Reserves, and provides a Band with energy saving kits; free installation of energy savings product for lighting, hot water, heating, appliances, insulation and draft proofing; and personalized energy efficiency and education. As stated by Mr. Moore who worked on implementing the program in the Band, behavioural changes have led to approximately 10 percent energy savings in the residences, and small technical efficiency changes in the existing buildings have lead to another 10 to 20 percent savings in energy in the residences (Moore, interview by author, August 18, 2015).

4.2 Project costs and financial analysis

The total cost of the T'Sou-ke solar project was about $1,250,000, as reported by T'Sou-ke First Nation (2010a, 16) and is presented in Table 4. The majority of the cost consisted of solar PV systems $800,000 (64 percent) followed by solar hot water systems $300,000 (24 percent), and the energy conservation program $150,000 (12 percent).

Table 4: T'Sou-ke solar project costs

Solar project components	Cost ($)
Solar PV systems	$800,000 (64%)
Solar hot water systems	$300,000 (24%)
Energy conservation program	$150,000 (12%)
Total	**$1,250,000**

Source: Data from T'Sou-ke First Nation (2010a, 16).

The Band received funding for about 80 percent of the costs of the PV systems and full costs of the other two components of the solar project (Bekker 2009a, 4). Table 5 provides a breakdown of the costs of the solar PV systems that include direct capital costs, indirect capital costs, and operations and maintenance costs and the incentives received for all the four PV systems as reported by Bekker 2009a (26, 22, 18, 12). For solar hot water systems, a breakdown of the costs was not available. The total installed cost of the PV systems was $801,645 (of which 80.8 percent was covered from grants and funding). Direct capital costs comprised about 56.8 percent of the system costs and included solar panels costs, inverter costs, and balance of system costs (e.g., combiner boxes, roof mount, ground mount, battery bank, etc.). Indirect capital costs, on the other hand, comprised about 43.2 percent of the system costs and included installation cost (labour), permitting cost, and sales tax. Other costs such as the annual operations and maintenance costs of the PV systems are nominal, about 3.7 percent of the annual power revenue (i.e., $200 out of $5,389), and are mainly expenses to maintain the battery banks.

Table 5: T'Sou-ke PV systems costs and incentives, 2009

System location and capacity	Direct capital costs			Indirect capital costs ($)	Total costs ($)	Grants and funding ($)	O&M costs/ year ($)
	Solar panel costs ($)	Inverter Costs ($)	Balance of system costs ($)				
Canoe Shed 39.9 kW	167,808	31,098	16,687	167,000	382,593	340,508	------
Hilltop 22.4 kW	94,208	14,376	51,086	105,000	264,670	235,556	------
Administration 7kW	29,440	4260	7,963	39,000	80,663	71,790	100
Fisheries 6.3kW	26,496	4260	7,963	35,000	73,719	----------	100
Total	**317,592 (39.6%)**	**53994 (6.8%)**	**83,699 (10.4%)**	**346,000 (43.2%)**	**801,645 (100.0%)**	**647,854 (80.8%)**	**200**

Source: Data organized using Bekker 2009a (26, 22, 18, 12).

To aid the financial analysis, I calculated the actual cost per watt of the PV systems and the funding per watt from the total project cost and incentives reported by Bekker 2009a (26, 22, 18, 12). The T'Sou-ke PV costs and incentives per watt are graphically represented in Figure 5. The total cost per watt of the PV systems are also disaggregated into direct capital cost per watt and indirect capital cost per watt. Direct capital cost per watt includes the cost per watt of the solar panels, inverters, and balance of system costs and indirect capital cost per watt includes the labour and installation costs and other soft costs. The total cost per watt of a PV system is given by the system cost (direct capital cost plus indirect capital cost) divided by the systems' nameplate capacity in watts. The total cost per watt for each of the four PV systems, namely the Canoe Shed, Hilltop, Administration, and Fisheries PV system was $9.58 per watt, $11.81 per watt, $11.52 per watt, and $11.70 per watt respectively. Similarly, the per watt funding for the three PV systems, i.e., the Canoe Shed, Hilltop, and Administration was $8.53 per watt, $10.51 per watt, and $10.25 per watt, respectively.

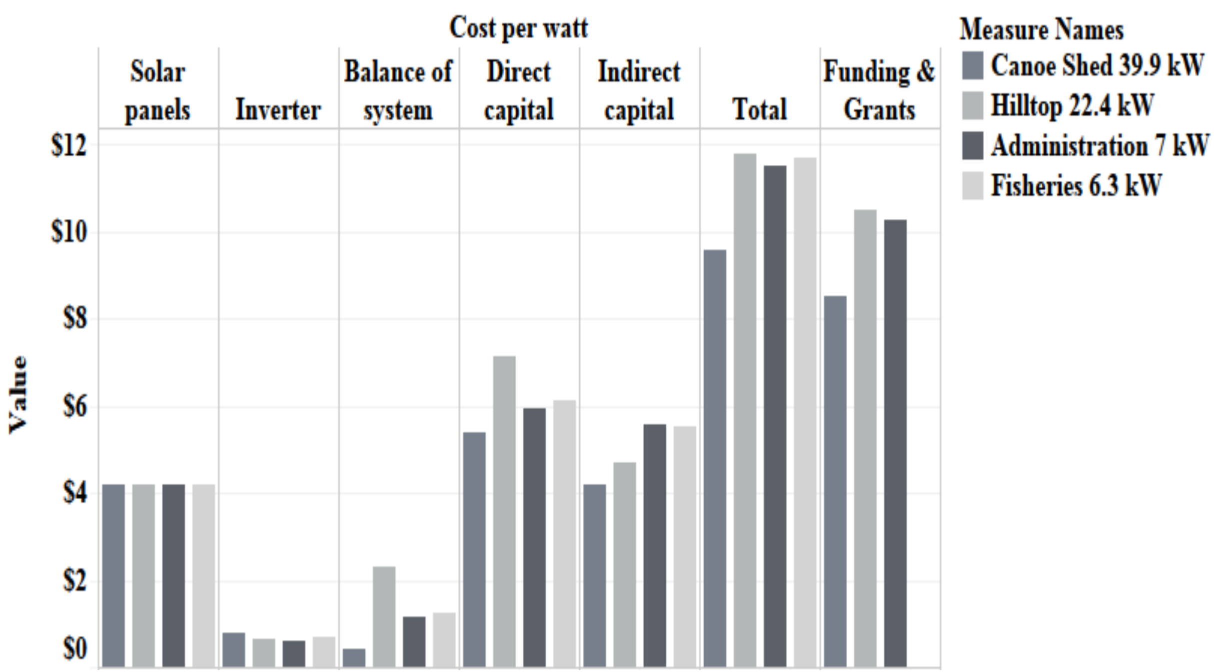

Figure 5: T'Sou-ke PV systems costs and incentives per watt, 2009**.** Author's calculation using data from Bekker (2009a, 26, 22, 18, 12).

For the new financial analysis, I compare the actual cost per watt of all the four PV systems on average in 2009 to the average cost per watt of the systems in 2014 to analyze the changes in the solar PV financials in the last five years. Figure 6 shows the costs per watt of the T'Sou-ke PV systems in 2009 and 2014. The comparable 2014 cost data for solar PV is taken from Table 9 of the National Survey Report of PV Applications in Canada which reports solar PV data till 2014 (Poissant and Bateman 2014, 11). As seen from the Figure, the cost of the solar panels has fallen by 79 percent, followed by a 79 percent fall in the balance of system costs, and a 36 percent fall in the inverter costs. The total direct capital costs of the PV systems which include solar panel costs, inverter costs, and balance of system costs have fallen by 74 percent. The indirect capital costs, on the other hand, which include installation, permitting and sales tax, have fallen by 54 percent. In total, the costs of the PV systems including direct capital costs and indirect capital costs have fallen by 65 percent.

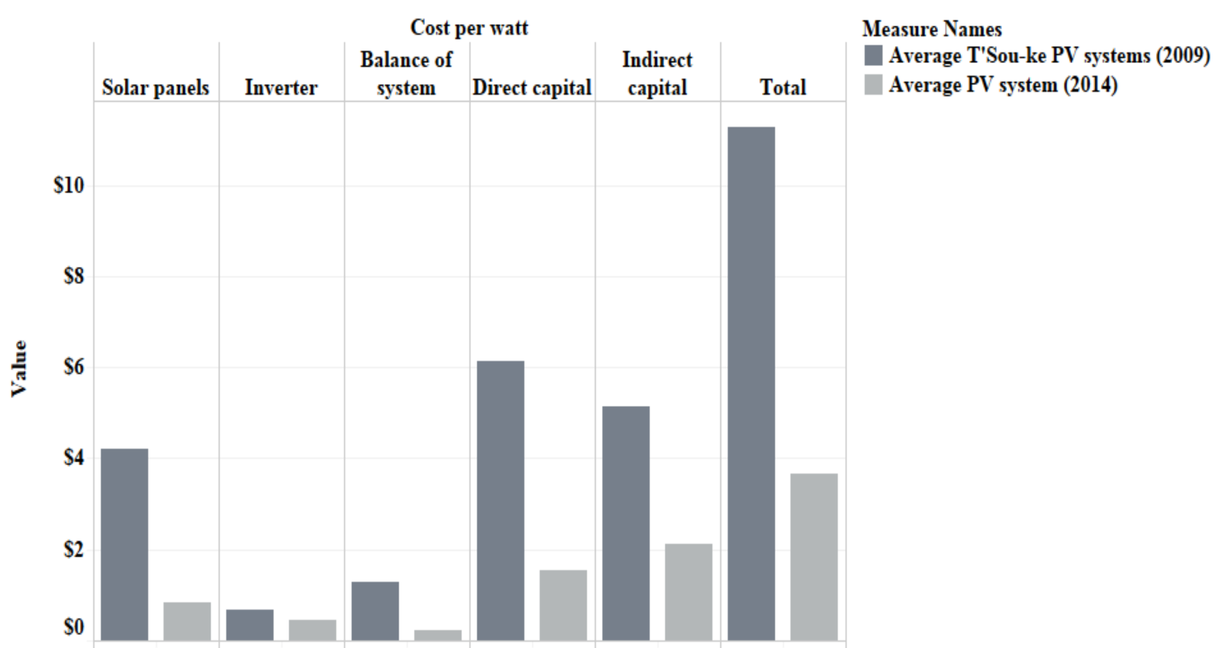

Figure 6: T'Sou-ke PV system costs, per watt, 2009 and 2014. Author's calculation using

data from Bekker (2009a, 26, 22, 18, 12), Poissant and Bateman (2014, 11).

While the costs per watt in Figure 5 and Figure 6 represent the actual costs of the four PV systems on average in 2009 and the average cost of the PV systems in 2014, Figure 7 shows the high and low costs per watt of the PV systems in 2014 in relation to the average cost per watt in 2009 using data from Bekker (2009, 26, 22, 18, 12); Poissant and Bateman (2014, 11). As seen from Figure 7, the cost per watt cost of a PV system in 2014 is 43 to 74 percent lower than the cost per watt of the T'Sou-ke PV system in 2009. This major fall in the cost per watt of a PV system affects the current economic viability of these systems. Moreover, the cost per watt of PV systems is expected to fall further in the future, thus making the economic case for PV stronger.

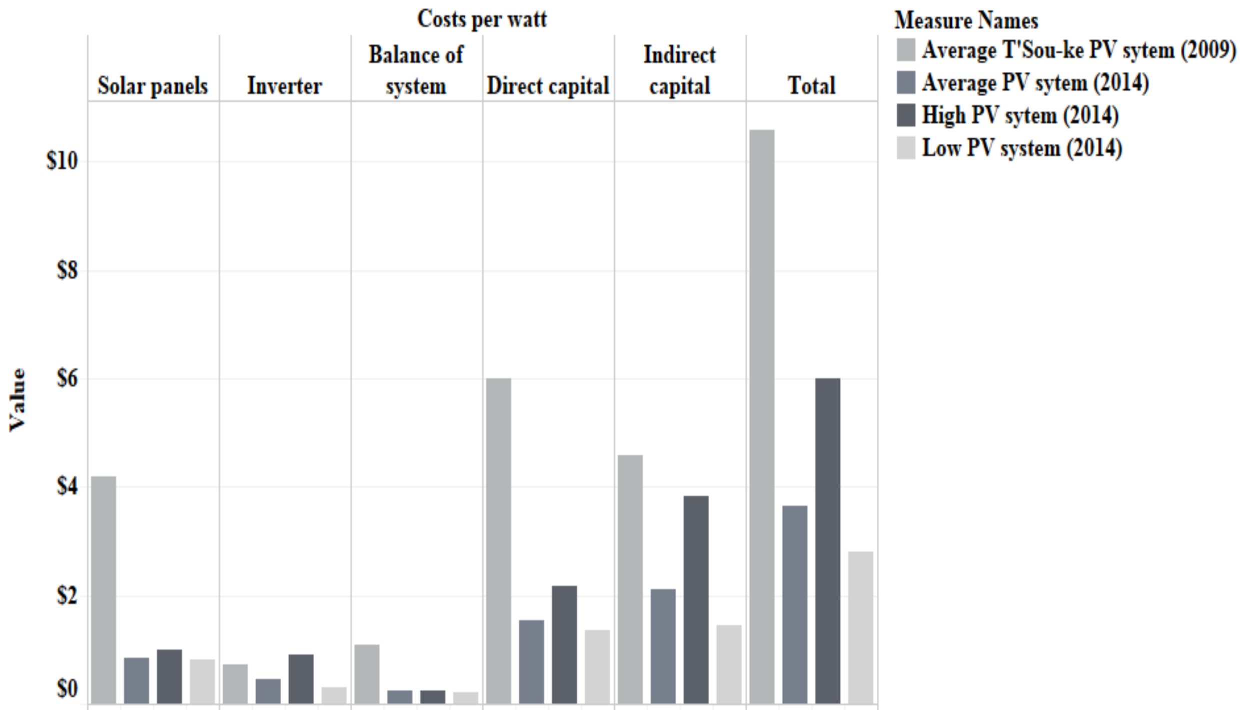

Figure 7: T'Sou-ke PV systems costs, per watt, 2014 (Average, High, and Low prices). Author's calculation using data from Bekker (2009a, 26, 22, 18, 12); Poissant and Bateman (2014, 11).

Bekker also carried out a financial analysis in 2009 to measure the economic viability of the solar PV systems. The solar hot water systems, however, were not separately analyzed. As a financial measure, simple payback for the systems was calculated (see page 14 for the payback formula). The main assumptions for the calculation included 25 years of system life, electricity value of 8.16 cents per kWh (grid-tied systems), diesel fuel cost of $0.90 per kWh (off-grid system), 1.5 percent inflation rate, 0.5 percent annual solar panel degradation and 80 percent funding (for the three grid-tied PV systems). In general, the real lifetime of PV systems is more than is used to calculate energy costs and earnings (Maehlum 2014). According to Bekker's analysis, among all the grid-tied PV systems, the Administration PV system was reported to have the longest payback (19.6 years), followed by the Hilltop PV system (13.0 years) and the Canoe Shed PV system (10.9 years). For the payback calculation of the grid-tied PV systems, the savings from avoided grid electricity purchase is $3,857 for the Canoe Shed PV system, $2,232 for the Hilltop PV system and $553 for the Administration PV system, respectively (Bekker 2009a, 26, 22, 18).

The Fisheries system (simulating off-grid), on the other hand, had the shortest payback (7.8 years) among all the PV systems (Bekker 2009a, 12). For the payback calculation of the Fisheries PV system, the base case and proposed scenarios were considered with diesel. The base case scenario assumes that the building is completely powered by diesel while the proposed case scenario assumes that 42.8 percent of the electrical load of the building is powered by diesel. The diesel cost which includes generator, fuel and operations and maintenance costs in the base case scenario is estimated to be about $14,482 while that in the proposed case scenario is estimated to be about $5,002. The diesel cost savings is the difference between the diesel costs in the base case and proposed case scenarios and is estimated to be $9,480 (Bekker 2009a, 12-14).

However, as the financial analysis included grant funding, the simple payback of the three grid-tied PV systems (Canoe Shed, Hilltop, and Administration), are underestimated, and the true payback for the grid-tied PV systems is as high as 178 years (Bekker 2009a, 29). The internal rate of return was also calculated, but because the analysis includes funding, the real rate of return is overestimated as well.

Based on the financial analysis, the Canoe Shed, Hilltop, and the Administration PV systems (all grid-tied) were not considered economically feasible without funding. The Fisheries PV system (simulating off-grid) was the only PV system that was considered economically viable without funding. For the new financial analysis, I re-calculate the simple payback period of all the four PV systems based on 2014 prices (other assumptions remaining the same) to analyze the changes in the economic viability of these systems at current prices.

Other measures such as NPV and LCOE were not included in the analysis given the unfeasibility of the PV systems as reflected from the simple payback calculations. Table 6 compares the simple payback of all the four PV systems with funding and without funding in 2009 and 2014. As seen from Table 6, with funding, the payback period has lowered by 6.8 years for the Canoe Shed PV system, 8.6 years for the Hilltop PV system, and 12.8 years for the Administration PV system. Without funding, the payback has fallen by 61.5 years for the Canoe Shed PV system, 82 years for the Hilltop PV system, and 121.66 years for the Administration PV system.

Table 6: T'Sou-ke PV systems payback years, 2009 and 2014 comparison

System location and capacity	Simple payback years			
	(with funding) 2009	(with funding) 2014	(without funding) 2009	(without funding) 2014
Canoe Shed 39.9 kW	10.9	4.1	99.19	37.7
Hilltop 22.4 kW	13	4.4	118.57	36.6
Administration 7kW	19.6	6.8	178.06	56.4
Fisheries 6.3kW	------	------	7.8	2.42

Source: Author's calculation using data from Bekker (2009a, 26, 22, 18, 12); Poissant and Bateman (2014, 11).

Note: The payback period of the Fisheries system as calculated by Bekker assumes diesel as base case scenario. However, if the payback period were calculated given that the system actually uses grid electricity, the payback years would be much higher.

As can be seen from the new financial analysis, with funding, all the three PV systems (Canoe Shed, Hilltop, and Administration) are economically feasible, with low payback periods in 2014. However, without funding, only the Fisheries PV system is feasible with the lowest payback. The grid-connected PV systems are yet to be economically viable without funding in 2014 as the payback is still high, although much lower compared to 2009. The off-grid PV systems, on the other hand, have a better financial case and are feasible without funding in 2014. More importantly, they are also beneficial for off-grid and remote communities in BC and across the country that have similar demography and climatic conditions as that of the T'Sou-ke First Nation but are reliant on costly and environmentally harmful diesel for their electricity needs. One of the major barriers for the grid-connected PV systems in the province is still the high installed cost, and less power revenue. In BC, the second significant barrier is the competition from cheaper hydropower and wind energy systems. Lastly, the third important barrier in the province is the decline in BC Hydro's interest in facilitating independent power production with commitment to the contentious Site C which will produce a large amount of power, about 1,100MW (Shaw et.al. 2017). While these are notable barriers in the progress of grid-tied solar in BC at present, it is possible that some of these barriers will be eliminated in the future as the price of solar falls more and the price of electricity rises. In the meantime, BC should consider promoting the uptake of off-grid PV systems that have an advantage over the grid-tied systems at present. The significance of the financial analysis from a policy perspective is that the support towards solar and other clean energy projects should be continued until they become economically feasible. Some of the policies that BC can adopt to advance solar technology are discussed in Chapter 5, Section 5.1.

4.3 Energy, environment, employment and community and other economic impacts of the solar project

4.3.1. Energy autonomy

The impacts of the solar project on the T'Sou-ke First Nation are analyzed based on the analytical case study framework discussed in Chapter 2, Section 2.2. As per the framework, energy, environment, employment, community and other economic aspects of the project are considered. Energy autonomy, i.e., the ability to produce enough electricity and heat to live without relying solely on outside power sources such as the province's electrical grid, was one of the main goals of the T'Sou-ke solar project (T'Sou-ke First Nation 2010a, 10). With the Hilltop plus Administration PV system and the Fisheries PV system, the Band is producing enough electricity to replace 77.23 percent of the baseline BC Hydro power in the Administration and Fisheries buildings annually.[11] The rest of the power in these building is still provided by BC Hydro. As this was a demonstration project for the community, only the Band offices are on solar power; the rest of the Band still gets it electricity from BC Hydro.

Figure 8 shows electricity demand and surplus electricity exported to the grid from the Hilltop and Administration PV system and Canoe Shed PV system in 2009 (the first year of the project) at different times of the year (Bekker 2009b, 22-26). Sooke, like much of the Vancouver Island, has a milder climate than other parts of Canada (warm and dry in the summer and above-freezing in the winter). In the summer months (April to August), the Hilltop plus Administration PV system meets the electricity demand of the Administration building and generates surplus electricity (the most surplus electricity generated during July) that is exported to the grid. In the same manner, the Canoe Shed PV system, having no electric load, exports all the electricity to the grid throughout the year. However, during the months of late fall and winter (November to February), when the electricity generated is not enough, the Band buys some electricity from BC Hydro to supplement the needs of the Administration building (Figure 8).

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11. Out of 26,729kWh annual electricity provided by BC Hydro initially, about 20,635kWh electricity is now displaced by the solar PV systems (see Table 3, Section 4.1.1). The electrical load includes appliances, lighting, heating, cooling and electronics (Bekker 2009a, 33).

When the electricity outflow (net generation) is greater than inflow (net consumption) in summer, the charge on electricity is $0, i.e., only the fixed charge appears on the bill, and the Band gets an electricity credit for future electricity use, thereby becoming net-zero in electricity costs. In a cost Net-zero energy building (NZEB), the amount the utility pays the building owner for the renewable energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year (Crawley, Pless, and Torcellini 2009, 20).[12] Every year on the anniversary date of joining the program, the Band receives a payment of 9.99 cents per kWh for surplus electricity provided to the grid from BC Hydro as per the net-metering program (BC Hydro 2017a). The annual power revenue from surplus electricity generation was estimated to be $5,389 in the first year of the project (Bekker 2009b, 8-9). The power revenue is based on the annual surplus electricity produced by the Canoe Shed PV system (47,272kWh) and the Administration plus Hilltop PV system (18,777kWh) (Bekker 2009b, 8-9).

12. See https://www.nrel.gov/docs/fy09osti/46382.pdf for other definitions of NZEB.

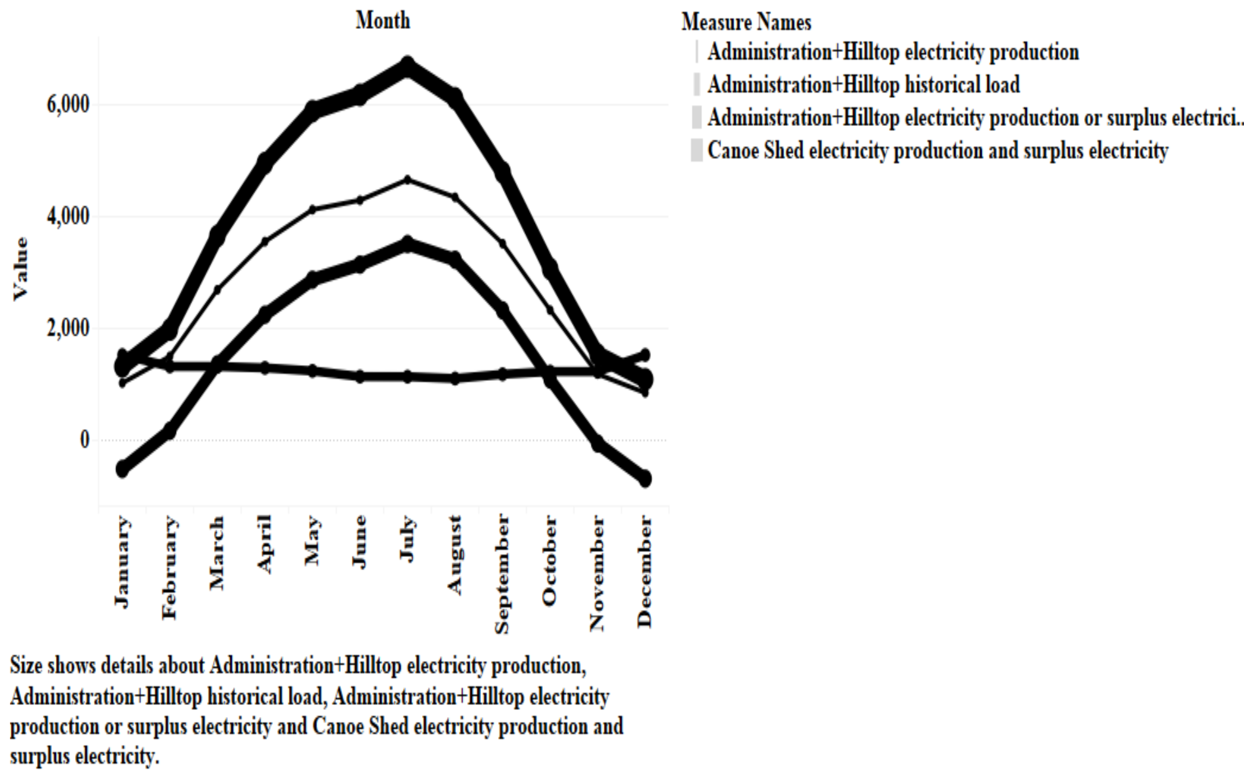

Figure 8: Electricity demand and surplus electricity exported to the grid (kWh), 2009, monthly. Data from Bekker (2009b, 22-26).

Like electricity, hot water and heating in the member residences is another part of the energy picture of the Band. For example, electric water heating can account for about 20 percent of the electricity bills, and electric space heating can account for another 40 to 50 percent of the electricity bills in the winter months (Natural Resources Canada 2017b; BC Hydro 2017c). As per calculations by Mr. Moore who worked on implementing the project, on average, the solar hot water systems have reduced approximately 4 percent of the electricity use for hot water for the residents (20 percent of the 20 percent used for hot water heating), and the energy conservation program has reduced up to 20 percent of the community's energy demand that includes space heating (Moore, interview by author, August 18, 2015).

While the Band is not completely energy autonomous, there is 24 percent reduction in energy use due to the energy conservation program and the solar hot water project. Moreover, there is reduction in energy purchase from BC Hydro for the Administration and Fisheries building by 77 percent because of the energy conservation program and the solar PV project. Furthermore, the two office buildings of the Band are now more resilient in case of a power outage in Vancouver Island (Moore, interview by author, August 18, 2015). In particular, the project provides a direction for off-grid Aboriginal communities that are trying to get off diesel and secure their energy futures.

An important point to consider here is that the degree of energy autonomy that a community can achieve through a clean energy project is dictated by the scale and the degree of separation from surrounding communities and their associated resources (Rae and Bradley 2012, 6500). For instance, a grid-connected community is only likely to be capable of achieving a limited degree of autonomy as the motivations or benefits of doing so are unlikely to outweigh the financial and technical costs associated with it. A remote or off-grid community, on the other hand, is likely to be able to achieve far greater degree of autonomy, as it is the most achievable and cost-effective option (Rae and Bradley 2012, 6500). So, while the goal of energy autonomy was important for the T'Sou-ke solar project, and the Band did achieve some limited degree of autonomy, it is debatable as to whether the goal of energy autonomy was the best goal for the community for the project.

4.3.2 GHG Mitigation

The solar project was an opportunity for the T'Sou-ke First Nation to show a reduction in greenhouse gas emissions. As the community is grid-connected, the solar PV systems are displacing BC Hydro power in both the Administration and Fisheries buildings. In addition, the solar hot water systems and conservation measures are reducing baseline energy load in the member residences. BC Hydro generates 90 percent of its electricity from hydroelectric facilities. The rest of the electricity is supplemented by electricity from three natural gas-fired thermal power plants, electricity purchased from independent power producers who operate run-of-river, wind and biomass and other clean energy projects, and imported (coal and gas fired) electricity from the neighboring jurisdictions, i.e., Alberta and Northwest U.S. (BC Hydro 2017e; Dowlatabadi 2011, sec. 2, par. 3).

As lifecycle emissions of solar PV are considered which is higher than hydro, there is a marginal increase in the GHG emissions from switching from BC Hydro to solar (see Figure 3 for lifecycle GHG emissions from different electricity generation technologies). Table 7 shows the GHG emissions increase from the T'Sou-ke First Nation Band offices before and after the installation of the solar PV systems. I calculate these emissions based on primary data on monthly power production of the PV systems as reported by Bekker (2009b, 22-26).

The net annual GHG emissions increase from the two buildings based on replacing BC Hydro power with new solar power is estimated to be 385.26 $kgCO_2e$ per year. The emission increase from the Administration building is about 263.9 $kgCO_2e$ per year and that from the Fisheries building is about 121.36 $kgCO_2e$ per year.[13] However, given how small the increase in GHG emissions is from the PV systems, it does not have any significant effect on decision-making.

Table 7: Net annual GHG emissions in the Band offices from solar PV

System location and capacity	**Base case electricity consumption using only BC Hydro (kWh/ year)**	**Electricity consumption using solar PV (kWh/ year)**	**Electricity consumption using supplemental BC Hydro (kWh/ year)**	**GHG emissions from using only BC Hydro ($kgCO_2e$ /year)**	**GHG emissions from using solar PV and supplemental BC Hydro ($kgCO_2e$ /year)**
Administration 7KW	15,353	14,135	1,218	419.59	683.49 (650.21+33.28)
Fisheries 6.3 KW	11,376	6,500	4,876	310.90	432.26 (299+133.26)
Total	**26,729**	**20,635**	**6,094**	**730.49**	**1,115.75**

Source: Author's calculation based on data from Bekker (2009b, 22-26).
Note 1: The GHG emission estimates are calculated based on BC Hydro GHG emission factor of 0.02733 $kgCO_2e$ per kWh based on data from BC Hydro (2017d). The GHG emission factor is an average of GHG intensities for three years (2004, 2008 and 2009) of electricity generated by BC Hydro facilities and power purchased from independent power producers. It is not clear whether the BC Hydro emission factor reported by BC Hydro includes lifecycle emissions.

Note 2: The GHG emissions from using solar PV is the electricity consumption using solar PV multiplied by its lifecycle GHG emissions which is 0.046 gCO_2e per kWh (see Figure 3 for lifecycle emissions from solar PV).

13. The GHG emission numbers are arrived at by multiplying the GHG emission factor with the amount of electricity consumption using base case BC Hydro, and using solar power and supplemental BC Hydro. The net GHG emissions increase is the difference between the GHG emissions from using only BC Hydro and that of GHG emissions from solar PV and supplemental BC Hydro.

I also calculate the net GHG emission reductions from the other two T'Sou-ke solar project components. For the solar hot water systems and the energy conservation program, I use the data from my personal interview with Mr. Moore, August 18, 2015. Table 8 shows the GHG emissions increase and reductions from all the T'Sou-ke project components. The net increase in GHG emissions from the solar PV systems is about 385.26 kg CO2 per year or 0.38 tonnes CO_2e per year. The net reduction in GHG emissions from solar hot water systems, on the other hand, is about 211.46 kg CO_2e per year or 0.21 tonnes CO_2e per year, considering that solar hot water systems are functional in 20 households.[14] Furthermore, conservation measures like energy efficiency retrofits in all the 86 households and the two Band's offices have led to a reduction in GHG emissions by another 4785.58 kg CO_2e per year or 4.78 tonnes CO_2e per year (assuming that energy efficiency measures have led to 20 percent reduction in energy use).[15]

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14. For the purpose of calculation, I assume that hot water represents 30 per cent of the BC Hydro use in a house and that solar hot water heater provides about 60 per cent of the water heating needs (BC Hydro 2016). An average household in BC uses about 11,000 kWh of electricity per year, of which 3,300 kWh of electricity is on account of hot water. For the 20 Band houses, the annual hot water usage is thus 66,000 kWh, and that provided by solar hot water heaters is 39,600 kWh, thereby reducing BC Hydro consumption to 26,400 kWh. The GHG emissions numbers are based on the base case BC Hydro consumption multiplied by the BC Hydro emission factor, and solar hot water consumption multiplied by its lifecycle emissions which is 0.022kgCO_2e/kWh (see Figure 3). The net GHG emission reduction is the difference between the emissions from hot water using only BC Hydro and that from using solar hot water systems and supplemental BC Hydro.

15. The GHG emission reduction estimate from the energy conservation program is similarly calculated. I assume that the electricity consumption of all the 86 residences is 946,000 kWh (11,000 kWh being the average electricity consumption per household). The reduced consumption on account of energy conservation program is 756,800 kWh (20 per cent reduction in energy use). The GHG emission numbers are arrived at by multiplying electricity consumption before and after energy conservation measures with BC Hydro emission factor. The net GHG emission reduction from the energy conservation program is the difference between the GHG emissions from using base case

The total net reduction in GHG emissions from the solar project for the T'Sou-ke First Nation is thus about 4.61 tonnes CO_2e per year which is the difference between the emissions reduction from solar hot water systems and the energy conservation program and that of solar PV systems.

Table 8: Net annual GHG emissions reduction from the T'Sou-ke project

Project components	Net GHG emissions reduction (tonnes CO_2e/year)
Solar PV systems	(-0.38)
Solar Hot water systems	0.21
Energy conservation program	4.78
Total	**4.61**

Source: Author's calculation based on data from Bekker (2009b, 22-26); Moore, interview by author, August 18, 2015.

As the solar PV is replacing BC Hydro power which has a low GHG emission factor, there is a small direct increase in GHG emissions for the community. For solar hot water systems, on the other hand, there is a small direct reduction in emissions. However, it is important to note that the GHG intensity of BC Hydro, on which the GHG emission factor is based, only includes a subset of emissions from generation and delivery of electricity and not all emissions associated with electricity consumption. For

BC Hydropower in 86 houses and two Band offices and that of reduced BC Hydro power in the 86 houses plus the two Band offices.

example, the GHG intensity does not include emissions from electricity imports for domestic use or the emissions from the combustion of woody debris to comply with the 'water license' (Dowlatabadi 2011, sec. 2, par. 4).

Although BC Hydro has a low GHG emission factor, one of the main benefits of integrating solar PV into the electricity mix in BC is that it will reduce the demand on the utility. Another benefit of installing solar PV is that the province's electricity exports will reduce another utility's dependence on fossil fuel sources (e.g., Alberta) (Baxter 2014; Umbra 2016). While the benefits of replacing hydropower with solar are limited in terms of direct emission reduction, replacing a fossil fuel such as diesel or coal with solar power, on the other hand, has higher direct benefits. The emission factors of different fossil fuels are provided in Figure 2, Section 2.1.3 for comparison.

As an example, if diesel were being replaced by solar power (57.2 percent) in the Fisheries building, the net carbon emission reduction from the building would be about 7.7 tonnes CO_2 per year (Bekker 2009b, 8). So, for off-grid Aboriginal communities that are diesel-dependent, the reduction in GHG emissions from a solar project will be much higher compared to grid-tied communities. For instance, Lasqueti Island, a remote community of 400 households, in the east of Vancouver Island, that generates 100 percent of its electricity from diesel reported that their 55 kW hybrid solar PV reduced CO_2 emissions by 28 tonnes per year (42 tonnes per year to 14 tonnes per year) (Government of British Columbia n.d.).

4.3.3 Employment Benefits

Creating employment opportunities for the Band members and building capacity was one of the focal points of the solar project. Table 9 provides employment related statistics of the T'Sou-ke First Nation in 2009 (during the project), and in 2011 as per Census and National Household Survey data. In 2005, about 66.6 percent of the working-age population (those aged 15 and older) of the T'Sou-ke First Nation was in the labour force compared to 73.5 percent in 2010. Likewise, the employment rate for the T'Sou-ke Nation in 2005 was 53.3 percent compared to 64.7 percent in 2010, and the unemployment rate in 2005 was 20 percent compared to 12 percent in 2010.

Among the employed T'Sou-ke members, about 38 percent of the members worked full-year, full-time and the rest of the members worked part-year or part-time in 2005 compared to 64 percent in 2010 (Statistics Canada 2009). As per Statistics Canada (2012), 49 to 52 weeks is considered full year, and 30 or more hours most weeks is considered full- time. Most of the employed T'Sou-ke community members either work in the goods producing industries (e.g. agriculture, forestry, fishing and hunting; mining and oil and gas extraction; and construction) or the service producing industries (e.g. transportation and warehousing; administrative support; health care and social assistance, among others) and the rest worked in public administration (Statistics Canada 2009).

Table 9: Key Labour Force Statistics, T'Sou-ke Reserves I and II, 2009 and 2011

Labour force participation counts and rate	**T'Sou-ke Reserves I and II (2009)**	**T'Sou-ke Reserves I and II (2011)**
Population aged 15 and over	150	170
Labour force	100	125
Employed	80	110
Unemployed	20	15
Not in labour force	50	45
Participation rate (percent)[a]	66.6	73.5
Employment rate (percent)[b]	53.3	64.7
Unemployment rate (percent)[c]	20.0	12.0

Source: Statistics Canada (2009); Statistics Canada (2013).

[a]Participation rate is the total labour force expressed as a percentage of the population aged 15 years and over (Statistics Canada 2012).
[b]Employment rate is the number of employed persons expressed as a percentage of the population 15 years of age and over (Statistics Canada 2012).
[c]Unemployment rate is the number of unemployed persons expressed as a percentage of the labour force (Statistics Canada 2012).

The solar project provided full-time employment to about 11 members of the T'Sou-ke First Nation for three months at $15 hourly wage during the installation of the solar PV and solar hot water systems on the Reserves (Moore, interview by author, August 18, 2015). In addition, the energy conservation program also employed four other Band members. For a small community like the T'Sou-ke First Nation, this was about 10 percent of its working age population and 75 percent of the unemployed labour force at the time. Moreover, the project also trained one woman as a solar installer, thereby promoting "non-traditional" employment for women. For solar installations, the members received five days (eight hours per day), i.e., 40 hours of total training. Post installation, nine of the Band members became CANSIA certified solar installers (Moore, interview by author, August 18, 2015). Most of the Band members who worked on the solar project were either unemployed or underemployed during the time of the project and mainly came from the struggling forestry and fishery industry (T'Sou-ke First Nation 2010a, 3). For instance, Larry Underwood who worked on the project had already lost his job in the forestry industry, and was looking for opportunities to relocate back. He expressed during the interview:

> My life was in the sawmill, and that was back in 2008. I worked at the Campbell River. Then my mill went down. Also, I got tired of chasing the mills. Every mill I went to has gone down over the years. I went through three mills, and they all went down at some point. So, I tried to come back home to decide what I want to do in life and this project of installing solar hot water systems in the houses came up which was great. (Underwood, interview by author, August 20, 2015)

Three years after the T'Sou-ke solar project, between 2011 and 2015, four members of the T'Sou-ke Band were employed in the Solar Colwood program as a result of a partnership between the T'Sou-ke First Nation and the City of Colwood. The Solar Colwood program offered incentives to more than 500 Colwood residents to undertake over 1000 renewable energy and energy saving upgrades which included solar hot water systems, ductless split heat pumps, electric vehicle charging stations, solar photovoltaics, and smart home monitoring systems using a grant from the federal governments' CEF (City of Colwood n.d.). As of now, most of the trained T'Sou-ke members have secured full-time employment on reserve in other areas such as Band administration, forestry, and fisheries. Currently, there is one Band member working on the energy conservation program (Moore, interview by author, August 18, 2015). While the trained members are not working on other solar projects post Solar Colwood, they are willing to work in the solar industry if there is a local opportunity. Moreover, all the members enjoyed the clean nature of the solar job and learned electrical skills of wiring and building codes, inspection and testing which they believe are transferrable to other jobs on the reserve.

The T'Sou-ke First Nation has benefited positively from the solar project in terms of short to medium term employment creation and skills training. Similar employment benefits can be expected for other Aboriginal communities investing in solar and other clean projects. As per a major paper on climate justice, clean energy projects can generate 3 to 30 times more direct jobs than equivalent investment in fossil fuel infrastructure, and help build a cleaner and greener energy future (Lee 2012). Currently, in BC, there are about 1,300 jobs in solar and wind energy projects and about 14,100 jobs in different clean energy projects combined (Comette, et al. 2015). Other provinces such as Ontario has created about 2000 direct manufacturing jobs and other construction jobs from solar PV under the feed-in-tariff (FIT) Program (Ontario Ministry of Energy 2015).

4.3.4 Local community benefits and other economic benefits

The solar project was also an opportunity for the T'Sou-ke First Nation to make impacts on the local community and engage in business and economic development. The Band started by providing solar PV tours and energy conservation workshops to other First Nation communities, schools, municipalities, and other institutions. For instance, in

2014-15, the Band hosted about 32 schools, 54 municipalities and numerous other tourists at T'Sou-ke First Nation (Moore, interview by author, August 18, 2015). While the tours and workshops have brought in extra funds for the Band, they have also increased the visibility of the T'Sou-ke First Nation in BC and across Canada as a leader and entrepreneur in clean energy.

Next, the Band actively participated in setting up the District of Sooke-Climate Change Action Committee (Moore, interview by author, August 18, 2015). The purpose of the committee is to make recommendations to the District regarding ways to improve environmental sustainability in workplace operations and reduction of the environmental footprint and CO_2 emissions of the District (Sooke Region Volunteer Centre 2013). Furthermore, the Band is aiming to build a solar partnership with the District of Sooke similar to that of Colwood (Moore, interview by author, August 18, 2015).

The T'Sou-ke First Nation also became a mentor to other First Nation communities on CCP. As per Andrew Moore, over the last five years, the Band has mentored over 20 First Nations with one to three sessions on CCP under the CCP pilot mentorship program (Moore, interview by author, August 18, 2015). This program was started in 2012 to help all BC First Nation communities receive mentorship support from CCP champions. As part of the program, each community is paired with a mentor. The mentor and mentee(s) are then left to define the nature of the mentorship support (Hemphill 2014). Figure B.2 includes some of the activities in CCP mentorship. The mentorship sessions by the T'Sou-ke Nation have been well received, and some of the Bands have started taking steps towards implementing CCP (Moore, interview by author, August 18, 2015; Bristol, interview by author, August 19, 2015).

Finally, the Band has engaged in several business and economic development ventures since the completion of the solar project. These business ventures are aimed towards addressing the goals of energy autonomy, food security, and cultural renaissance of the Band. For instance, the T'Sou-ke First Nation has partnered with Schneider Electric to research into energy storage and micro-grid potential in the community (Planes, interview by author, August 19, 2015). The Band has also started a commercial wasabi project in partnership with Pacific Coast Wasabi, with $175,000 in funding from the Nuu-chah-nulth Economic Development Corporation. The project aims to grow about 15,000 wasabi plants per harvest in three large greenhouses. As of now, the Band has already finished its first harvest (Moore, interview by author, August 18, 2016). The Band is also operating an 82-hectare oyster farm in the T'Sou-ke basin which aims to produce about three million to 24 million oysters per harvest as a result of a partnership with the Chinese Canadian Aboriginal Development Enterprise. Currently, the Band has finished its first test production cycle. In addition, the Band is setting up the T'Sou-ke Arts Centre to promote traditional art by the community with $60,000 in funding from the BC Arts Council (Moore, interview by author, August 18, 2015). Overall, the solar project has brought benefits to the local community and served as a catalyst for business and economic development, although most of the new projects have received outside funding. In the future, the Band can set up cooperatives to meet the common economic, social and cultural needs of the community.

CHAPTER 5: SOLAR PROJECT REPLICABILITY

5.1 Replicability of the T'Sou-ke solar project in other Aboriginal communities

An important aspect of this research lies in exploring the extent to which the T'Sou-ke solar project may be replicated in other Aboriginal communities in BC. The key factor in the replicability of the project depends on it being financially justifiable. Being a pioneer in community solar energy in the province, the T'Sou-ke First Nation did not have a roadmap, but it will be easier for subsequent communities following the lead. The two components of the solar project, i.e., the solar hot water systems and the energy conservation program, are relatively easy to replicate. For instance, as per a study conducted by Ozog, the solar hot water systems and the energy conservation program were found to be successfully replicable by the Skidegate Band in BC (Ozog 2012, 92). However, it is important to note that both these project components received funding from the government.

The main solar PV component of the project, i.e., the grid-tied systems, is more difficult to replicate. While BC has a substantial solar potential, considering the regional, local and site-specific variations, the economic case of grid-tied solar PV depends on several market factors. For instance, in the short-run, factors such as PV prices, incentives, and electricity rates are important. In the long-run, however, grid-access and energy storage become crucial. The T'Sou-ke solar project was completed eight years ago, as a demonstration when solar PV was much more expensive. The market for solar since then has changed drastically with major changes being the fall in PV prices and rise in the price of electricity as discussed in the next paragraphs.

Between 2010 and 2014, there has been a reduction in the global market prices of PV systems (i.e., solar panels, inverters, and BOS) by a factor of three, and that of solar panels by a factor of five (International Energy Agency 2014, 5). During the same time, the levelized cost of electricity (LCOE) of solar PV has fallen by as much as 54 percent (World Energy Council 2016). The LCOE is an important metric to assess the economic competitiveness of clean energy technologies and other traditional electricity generation sources.[16] The major fall in PV costs can be attributed to wide-scale technological improvements in the solar panels, manufacturing advances, economies of scale and reduction in the balance of system costs, and indirect capital costs such as labour and permitting (International Energy Agency 2014, 13). Furthermore, by 2025, the global weighted average LCOE of solar PV is forecasted to fall by another 59 percent (International Renewable Energy Agency 2016, 10).

Due to falling PV prices, and favorable incentives, the residential and commercial solar PV installations have already attained cost-parity in some of the North American jurisdictions; that is, LCOE from solar PV is comparable to the retail electricity prices paid by the commercial users. This conclusion is based on assumptions of current federal tax subsidies for solar power and ideal geographical location for the solar installation. Moreover, if the preferential treatment of solar PV were to be discontinued, the commercial solar PV systems could reach "grid-parity" in about ten years in the same jurisdictions (Reichelstein and Yorston 2013, 126).

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16. See section 2.1.4 for more details on LCOE.

In BC, however, solar has yet to achieve cost-parity; first, it is competing with cheaper "green" energy sources (i.e., hydro and wind); and second, there are fewer incentives from the provincial and federal governments. While the current estimated cost to install solar PV in BC ranges from $3 per watt to $6 per watt (see Figure 7, Section 4.2), to be cost-competitive with grid power, residential or commercial solar needs to cost about $2 per watt or less (Mui 2016). Some of the incentives for residential or commercial solar PV in BC include provincial sales tax exemptions on purchases of solar PV system components (e.g. solar panels, wiring, controllers and inverters), a net-metering program for systems up to 100 kW for residents, a standard offer program (SOP) for systems ranging from 100 kW to 15MW for communities and municipalities, and recently announced micro-SOP for First Nations and communities for systems ranging from100 kW to 1MW (BC Ministry of Finance 2013, 10; BC Hydro 2017f).

While these are important incentives, they are not enough to close the gap between the cost of solar and grid power in the province at present. For instance, under the net-metering program, electricity prices of at least 31 cents per kWh would be required for PV systems to break even, compared to the current electricity prices of 9.99 cents per kWh (Bekker 2009, 32; Tynan 2010, 36). In the short-run, along with net-metering, applying some other incentives such as the time of use (TOU) rate structure could be effective. In the TOU rate structure, the electric utility customers are charged based on the time the electricity is used, i.e., the customers are charged higher prices during periods of peak demand compared to periods of off-peak demand. For a grid-tied PV system owner, this would mean selling electricity during peak hours, thereby increasing the value of electricity (Tynan 2010, 40). An additional benefit of the TOU rate structure is that it also promotes energy conservation and efficiency. In the long-run, other incentives such as the feed-in tariffs (FIT), or direct subsidies could be considered in BC. FIT allows utility customers to sell clean electricity to the grid at a guaranteed price which is above the market rate for a fixed contract term of 20-30 years. One of the benefits of the FIT policy is that additional provisions can be included for promoting clean energy projects in Aboriginal communities.

For instance, the Ontario FIT policy has two main provisions to encourage the development of Aboriginal clean energy projects, such as reduced security payments and a "price adder." Normally a security deposit of $10 to $20 per kW of project capacity is required to secure a FIT contract, but if there is 50 percent or more Aboriginal ownership of a project, the security deposit is reduced to $5 per kW. Similarly, projects with a minimum percentage of Aboriginal ownership get an increased contract price. As an example, a wind project with a FIT would earn 13.5 cents for every kWh generated. However, if there was 50 percent or more Aboriginal ownership, the price would go up to 15 cents. As such, the higher the Aboriginal participation, the higher is the price adder (Chiefs of Ontario n.d.; Aboriginal Affairs Working Group n.d.). While FIT has many benefits, it only works for grid-connected communities.

The other major change is the rising electricity prices in the province in the past few years. In 2013, BC Hydro filed an application with the British Columbia Utilities Commission (BCUC) for a ten-year rate increase. According to the rate plan, the electricity rates have been set to increase by nine percent and six percent for the initial two years, i.e., 2015-2016. For the next three years, rate increases are capped at 4 percent (2017), 3.5 percent (2018) and three percent (2019) respectively. Finally, rate increases for the last five years of the plan are to be determined by the BCUC and are expected to be around two to three percent (BC Ministry of Energy and Mines 2013). On a cumulative basis, this would mean BC Hydro rate increases of more than 30 percent over the decade, which is a substantial increase in the electricity prices. So, even though grid-tied solar PV may not be cost-competitive in BC now, it is possible that with the rising electricity prices, more incentives and reduction in the price of PV systems, the economic case for grid-tied solar PV could become favourable in the future for Aboriginal communities. In addition, simplifying access to the grid and better energy storage would also have a favourable impact.

The other solar PV component, i.e., the off-grid PV system, on the other hand, is relatively easier to replicate given the economic and environmental advantages of replacing diesel with solar power. As such, off-grid and remote communities in BC are progressively installing off-grid PV systems to displace diesel use in the community. For example, recently, Lasqueti Island community installed two high-penetration PV solar and diesel battery hybrid off-grid electrical systems on the community's school and health centre, with funding from various government and private organizations (Government of British Columbia n.d.). While off-grid PV systems are beneficial, high initial costs remain the main barrier. As most off-grid PV systems need to have battery storage, and back-up (mostly diesel, as seen in the example above), ensuring that the hybrid system optimizes solar input and minimizes fuel consumption remains another barrier (Government of British Columbia n.d.).

5.2 Lessons learned and recommendations for future solar and other clean energy projects

The T'Sou-ke solar project, being one of the largest Aboriginal community projects in BC, provided some important lessons in clean energy project planning and implementation to the community. Based on these lessons, there are six recommendations that can guide other Aboriginal communities planning to invest in solar and other clean energy projects in the future. The recommendations are based on the T'Sou-ke First Nations' experience with the process of the solar project and highlights the important steps required for a successful clean energy project in a community. As T'Sou-ke First Nation Chief, Gordon Planes suggests,

> Don't create the wheels. Look at the successes and tribulations that we went through to get our project off the ground. We will be more than happy to share that with anyone. Also, it's important to make sure that the project is a good fit for the community. For us, it wasn't about the monetary value. It wasn't about creating wealth through making a whole bunch of money in a neck-deep perspective. What we did was something that will be a foundation for us going forward. I think for other First Nations it's about finding that foundation and for us we found ours. (Planes, interview by author, August 19, 2015)

Recommendation 1: Complete the CCP and set a strong community vision: Communities should complete the CCP and set a strong community vision before developing solar or any other clean energy project. The factors that are essential for the success of the CCP include procuring and managing funding, receiving more community participation, and training staff(s) for facilitating planning and visioning sessions, among others. Communities can take various steps to ensure that the CCP is successful. For instance, leveraging funds from one government source can help a Band in receiving more funding from other government and private sources. Similarly, community participation can be increased by providing community members with incentives like meals, honoraria and field trips, and hiring a CCP mentor can ease the training process for the members. In addition to the CCP, communities should also complete other useful plans such as a land use plan, an economic development strategy, and financial planning.

Recommendation 2: Draft a community energy plan and evaluate the full suite of energy options: An energy plan should be drafted by communities with the help of specialized energy consultant(s) before implementing any clean energy project. The main benefit of having an energy plan is that it helps communities use the existing energy more wisely and create new energy in a responsible way. A community's energy plan should firstly state the energy objective of the community, and estimate the community's annual energy demand and supply and the associated costs. Secondly, it should provide an outline to decrease the use of existing energy in the community by considering means of energy conservation and education (see Figure C for energy conservation model by the T'Sou-ke First Nation). Lastly, it should present an evaluation of various clean energy options and specify the one that fits the community the best. Some of the resources required for the energy plan include the community's power and fuel use bills, and the Band's budget.

Recommendation 3: Conduct project pre-feasibility studies and evaluate the financial viability of selling surplus electricity: Communities should undertake a project pre-feasibility study for their territory or reserve before implementing a clean energy project. A pre-feasibility study should consist of an assessment of the energy resource of the Band, grid-interconnection details, and project cost-benefit analysis, among others. For solar installation specifically, it is important to select the right solar installer, preferably with recommendations from the industry and to work out financial bonds or insurance in case of future problems with the systems. Additionally, for grid-tied systems, communities should consider selling excess power to the utility or energy providers through programs such as the standing offer program or net-metering program, with the request sent as early as possible as the application process can be lengthy.

Recommendation 4: Identify potential business partnerships: Partnerships with different levels of government and technology companies should be considered by communities for clean energy projects. As an example, the T'Sou-ke First Nation has a business partnership with Schneider Electric for research into energy storage. One of the major benefits of these business partnerships is that they reduce the costs of the project for the community and provides Bands with various kinds of expertise. Some of the tools that will help to build good partnerships include negotiating and using different agreements. Negotiations are useful in reaching consensus over crucial issues of environmental standards, and business and monetary terms. Similarly, agreements lay out the terms of business, and rights and responsibilities of different partners. Some of the agreements that can be used by communities for partners include relationship agreements, land use agreements, and revenue sharing agreements.

Recommendation 5: Train members and build internal capacity: Communities should seek opportunities for Band member(s) to receive training in various capacities during the planning and implementation of a clean energy project. For providing training in project management and facilitation, a project manager could be hired from the community with the required skill set. Furthermore, communities should partner with solar and other technology companies to provide training to the Band members in the installation and operations and maintenance of the clean energy project. Band members should also get specific industry certification to advance their career, e.g., solar installers could get certified by CANSIA.

Recommendation 6: Share knowledge with other communities: The knowledge gained from implementing the project should be shared with other communities, municipalities, and different actors. This can be facilitated through organizing clean energy forums, participating in community meetings and conferences, and hosting project tours. A major benefit of knowledge sharing is that it helps strengthen existing relationships between communities, fosters new relationships between communities and municipalities generates new ideas, and builds mentorship and support network. The other benefit is that it helps in the creation of a database of community energy projects useful for research and development in the field of clean energy.

CHAPTER 6: CONCLUSION

6.1 Summary of the research

In summary, clean energy projects are of general interest to Aboriginal communities in BC for reasons such as securing the energy future of the community in the face of climate change; mitigating greenhouse gas (GHG) emissions; gaining positive benefits of employment; engaging in Aboriginal business and economic development; and local community development (Sayers 2013; Aboriginal and Northern Affairs Canada and Natural Resources Canada 2011, 12). In particular, clean energy projects are of special interest to off-grid and remote Aboriginal communities, as they rely on diesel generators for their electricity and heating fuel (mostly propane) for their heat, which is three to five times more expensive and is environmentally harmful for them (Rezaei and Dowlatabadi 2016, 790). The purpose of this research was to undertake a case study analysis of a clean energy project by an Aboriginal community in BC, namely the T'Sou-ke First Nation, and understand the benefits and challenges associated with the development of this project in the community. In particular, I attempted to understand the evolution of the T'Sou-ke First Nation solar project, analyze the various impacts of the solar project on the community, and assess the replicability of the solar project in other communities in BC along with lessons that will guide future community solar and other clean energy projects. The findings of my research are summarized as below:

First, I found that Comprehensive Community Planning (CCP) played a major role in the evolution of the T'Sou-ke First Nation solar project. However, the Band faced three important challenges in the planning and implementation of the project. The first challenge was to obtain and manage various funding for the project. The second challenge was to make the grid-connected solar PV systems work post-installation. The third and the final challenge was to fix the solar hot water systems that broke due to installation deficiencies. While the T'Sou-ke First Nation overcame all the three challenges with help from the Band administration, BC Hydro and other funding agencies, such as Natural Resources Canada, all these challenges resulted in delays in the completion of the project and added stress for the community members.

Second, I found that the project had four main impacts in terms of energy use, emission reduction, employment benefits, and local community and other economic benefits. The energy impacts of the project on the T'Sou-ke First Nation include a reduction in the energy use of the community due to the energy conservation program and the solar hot water systems, limited energy autonomy in the form of two net-zero cost buildings and backup power for the Band offices during emergency as a result of the solar PV systems. The environmental impact of the project includes a small reduction in GHG emissions of the Band from switching from BC Hydro to solar energy. The employment benefits include short to medium term employment for the community members and skills training. Lastly, the local community and other economic benefits of the project include solar PV tours and energy conservation workshops for other communities, schools and municipalities, CCP mentorship sessions for other Aboriginal communities, and business and economic development ventures.

Third, I found that the replicability of the T'Sou-ke solar project in other Aboriginal communities in BC largely depends on the funding. For instance, the two main components of the T'Sou-ke solar project, that is, the grid-tied solar PV component and the energy conservation program succeeded because of the funding support. Without funding, the grid-tied solar PV component is still difficult to replicate in other Aboriginal communities in BC because of the upfront costs. The off-grid solar PV component, on the other hand, can succeed without funding and is better for remote communities compared to using diesel both from a financial and environmental point of view. The energy conservation program, on the other hand, is relatively inexpensive and can be carried out easily. While the T'Sou-ke First Nation implemented the energy conservation program after the solar PV installations, other communities should start with conservation first and then move to clean energy. The other main component of the project, that is, the solar hot water systems, was not so successful due to technical and installation difficulties. However, it is possible for other communities to replicate it as there have been new technological developments that remove some of the inefficiencies of the solar hot water systems faced by the T'Sou-ke First Nation. Bands would require funding support for solar hot water systems as well.

The importance of these findings is that it gives an understanding of the benefits and challenges of a solar energy project in an Aboriginal community BC. More so, it gives a future direction in clean energy planning and implementation for other Aboriginal communities in the province through the lessons learned. The six important lessons learned by the Band through the solar project include completing CCP and setting a strong community vision, drafting a community energy plan and evaluating energy options, conducting project pre-feasibility studies and selling power, identifying potential business partnerships, training of the members and capacity building, and sharing knowledge with other communities.

To conclude, the T'Sou-ke solar project can be called an example of a community designed, community owned and a community managed project. Unlike some of the clean energy projects that are third-party controlled, the decision making here lies entirely with the community. As such, for community based clean energy projects, it is important that they arise from within the communities and that there are community 'leaders' or 'champions' to take on the project responsibilities. As a demonstration project, there were parts of the T'Sou-ke solar project that were successful and parts that did not succeed completely. But for a small community like the T'Sou-ke First Nation, the main value was in being entrepreneurial and finding an opportunity to develop a clean energy project through the CCP without having a model to build upon during the time. The T'Sou-ke First Nation stands out as a leader in First Nations led clean energy development in BC. The other important value of the project was in the lessons learned by the Band during the clean energy planning and implementation process that will guide other communities interested in clean energy projects.

6.2 Limitations of the research

The limitations of this research include limited data, restricted scope, and a small number of interviews. Firstly, there is limited data on the solar hot water systems and the energy conservation program with the information used in this project coming from Mr. Moore's own rough estimates. As a result, it was not possible to carry out an independent detailed analysis of these two project components, and the numbers stated are just a rough approximate. Secondly, the scope of this research is restricted as I am studying a solar project that was completed eight years ago. For instance, the analysis of the solar PV component is based on the data from the T'Sou-ke First Nation reports, 2009, and it does not account for any variations in the monthly power production, and energy savings over the years. Thirdly, the number of interviews is small as all the interviews were carried out within two weeks in August 2015 which was restricted time. Consequently, the analysis may be missing critical data and perspectives which might have been available had there been more time to interview more individuals; that said, I do feel that I identified the key informants.

6.3 Suggestions for further research

This research is mainly about the T'Sou-ke solar project. The Band also has other 'green' projects such as a community garden, a greenhouse project, and a wave energy project. I suggest that all these projects be researched for a more comprehensive analysis. Furthermore, another Band in BC, namely, the Lower Nicola Indian Band near Merritt, recently completed the largest solar energy project in the province. I suggest that this project be studied as a case study to understand the key 'success' factors for the community. Another area of research would be quantifying the benefits of the various regulatory programs such as the net-metering program, the standing offer program, and the micro-standing offer program for First Nation communities in BC.

REFERENCES

Aboriginal and Northern Affairs Canada and Natural Resources Canada. 2011. *Status of Remote/Off-grid Communities in Canada.* Ottawa. http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/2013-118_en.pdf.

Aboriginal Affairs Working Group. n.d. "Ontario Aboriginal Energy Partnerships Program: Incentives for Aboriginal Community Participation in the Ontario Feed-in tariff." Accessed October 2, 2017. http://www.aawgecdev.ca/ontario-Aboriginal-energy-partnerships-program.html.

Baird, B.F. 1989. *Managerial Decisions Under Uncertainity, An Introduction to the Analysis of Decision Making.* New York: Wiley.

Baxter, B. 2014. "Is Photovoltaic Energy Better than BC's Grid?" *Vancouver Renewable Energy* (blog), November 5. http://www.vrec.ca/blog/2014/11/05/photovoltaic-energy-better-bcs-grid/.

Bekker, Jessica. 2009a. "Power Production, Emission and Financial Analysis for T'Sou-ke Nation's Photovoltaic Demonstration Project." Paper prepared for T'Sou-ke Nation, Sooke, BC, August 21.

—. 2009b. "Data Monitoring for T'Sou-ke Nation's Photovoltaic Demonstration Project." Paper prepared for T'Sou-ke Nation, Sooke, BC, October 22.

BC Hydro. 2017a. "Residential Bill Details." Accessed August 21. https://www.bchydro.com/energy-in-bc/acquiring_power/current_offerings/net_metering.html?WT.mc_id=rd_netmetering.

BC Hydro. 2017b. "Generating Your Own Electricity." Accessed February 24. https://www.bchydro.com/energy-in-bc/acquiring_power/current_offerings/net_metering.html?WT.mc_id=rd_netmetering.

BC Hydro. 2017c. "Winter Home Heating Tips." Accessed March 3. https://www.bchydro.com/powersmart/residential/savings-and-rebates/efficient-heating-.html.

BC Hydro. 2017d. "EN 16 Greenhouse Gas Intensities." Accessed April 7. https://www.bchydro.com/about/accountability_reports/2011_gri/f2011_environmental/f2011_environmental_EN16_2.html.

BC Hydro. 2017e. "About Independent Power Projects." Accessed March 12. https://www.bchydro.com/energy-in-bc/acquiring_power/meeting_energy_needs/how_power_is_acquired.html.

BC Hydro. 2017f. "Current Offers" Accessed April 5. https://www.bchydro.com/energy-in-bc/acquiring_power/current_offerings.html.

BC Ministry of Energy and Mines. 2013. *10 Year Plan for BC Hydro.* Presentation. Victoria, B.C. https://news.gov.bc.ca/files/Newsroom/downloads/Presentation.pdf.

BC Ministry of Environment. 2016. *2016/17 B.C. Best Practices Methodology For Quantifying Greenhouse Gas Emissions Including Guidance for Public Sector Organizations, Local Governments and Community Emissions.* Victoria, B.C. http://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2016-17-pso-methodology.pdf.

BC Ministry of Finance. 2013. "Energy, Energy Conservation and the ICE Fund Tax." Provincial Sales Tax (PST) Bulletin. http://www2.gov.bc.ca/assets/gov/taxes/sales-taxes/publications/pst-203-energy-conservation-ice-fund-tax.pdf.

BC Treaty Commission. 2017. "BC Treaty Commission." Accessed October 31. http://www.bctreaty.ca/about-us.

Chiefs of Ontario. n.d. "Planned Changes to Ontario's Feed-in-tariff Program Support Increased First Nations Participation in Renewable Energy Sector." Announcement. Accessed September 5. http://www.chiefs-of-ontario.org/node/240.

Cho, Renee. 2011. "Is Biomass Really Renewable?" *Energy* (blog), August 18. http://blogs.ei.columbia.edu/2011/08/18/is-biomass-really-renewable/.

City of Colwood. n.d. "Solar Colwood." Accessed May 16. http://www.colwood.ca/city-services/solar-colwood.

City of Vancouver. 2017. "Southeast False Creek Neighbourhood Energy Utility." Accessed July 9. http://vancouver.ca/home-property-development/southeast-false-creek-neighbourhood-energy-utility.aspx.

Comette, Penelope, Steven Cretney, Maximilian Kniewasser, and Kevin Sauve. 2015. "The British Columbia Clean Energy Jobs Map." Pembina Institute. Accessed

August 5. http://www.pembina.org/pub/the-british-columbia-clean-energy-jobs-map.

Community Sustainability Engagement Evaluation Toolbox. 2010. "Semi-structured Interview." Accessed December 7. http://evaluationtoolbox.net.au/index.php?option=com_content&view=article&id=31&Itemid=137.

Crawley, Drury, Shanti Pless, and Paul Torcellini. 2009. "Getting to Net Zero." *ASHRAE Journal* 51(9):18-25.

Daigneau, Elizabeth. 2013. "Is Hydropower a Renewable Energy or Not?" *Governing: The States and Localities,* September n.d. http://www.governing.com/topics/transportation-infrastructure/gov-hydropower-renewable-energy.html.

Darling, Seth B., Fengqi You, Thomas Veselka, and Alfonso Velosa. 2011. "Assumptions and the Levelized Cost of Energy for Photovoltaics." *Energy and Environmental Science* 4(9): 3133-3139. doi:10.1039/C0EE00698J.

Deemer, Bridget R., et al. 2016. "Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis." *BioScience* 66 (11): 949-964. doi:10.1093/biosci/biw117.

Dodge, David, and Kinney, Duncan. 2013. "T'Sou-ke First Nation Goes All in on Energy Conservation and Solar. *Green Energy Futures*, April 11. Accessed November 11, 2017. http://www.greenenergyfutures.ca/episode/38-tsou-ke-first-nation-goes-all-energy-conservation-and-solar.

Dowlatabadi, Hadi. 2011. "Lifecycle Analysis of GHG intensity in BC's Energy Sources." Briefing Note. Pacific Institute of Climate Solutions. http://www.pics.uvic.ca/sites/default/files/uploads/publications/Lifecycle%20analysis%20of%20GHG%20intensity%20in%20BC%27s%20energy%20sources%20.pdf.

Eagland, Nick. 2016. "Lower Nicola Indian Band Installs Largest Community-owned Solar Panel System in B.C."*Vancouver Sun*, September 7. http://vancouversun.com/business/energy/lower-nicola-indian-Band-switches-on-largest-community-owner-solar-power-system-in-b-c.

First Peoples' Language Map of British Columbia. n.d. "State of the Language."Accessed April 7. http://maps.fphlcc.ca/sencoten.

First Nations & Indigenous Studies: The University of British Columbia. 2009. "The Indian Act". Accessed April 8. http://indigenousfoundations.arts.ubc.ca/the_indian_act/.

Forster, P., V. Ramaswamy, P. Artaxo, T. Berntsen, R. Betts, D.W. Fahey, J. Haywood, J. Lean, D.C. Lowe, G. Myhre, J. Nganga, R. Prinn, G. Raga, M. Schulz and R. Van Dorland. 2007. "Changes in Atmospheric Constituents and in Radiative Forcing." In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller, 131-217. Cambridge, United Kingdom and New York, United States of America: Cambridge University Press.

Future Economy. n.d. "The Future Economy Initiative." Accessed April 13. http://futureecon.com/about-future-economy/.

Glen, Stephanie. 2014. "Snowball Sampling: Definition, Advantages and Disadvantages." Accessed December 11. http://www.statisticshowto.com/snowball-sampling/.

Government of British Columbia. n.d. "Community Energy Case Studies." Accessed October 14. http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/community-energy-systems/community-energy-case-studies.

Gritsevskyi, A. 2008. "Renewable vs. Non-renewable Energy Sources, Forms and Technologies." Paper presented at the 13th meeting of the London Group on Environmental Accounting, Brussels, Belgium, Sept 29- Oct 3. https://unstats.un.org/unsd/envaccounting/londongroup/meeting13/LG13_13a.pdf.

Hay, John F. 2016. *Solar Electric Investment Analysis*. Extension. Lincoln, NE: University of Nebraska-Lincoln. Accessed October 27, 2016. http://extensionpublications.unl.edu/assets/pdf/ec3008.pdf.

Hemphill, Jessie. 2014. "What is CCP Mentorship." *Jessie Hemphill* (blog), March 26. http://www.jessiehemphill.com/blog/what-is-ccp-mentorship.

Indian and Northern Affairs Canada. 2006. *Comprehensive Community Planning for First Nations in British Columbia Handbook: Developed in Partnership with Okanagan, Lytton, Squiala, We Wai Kai (Cape Mudge) and Yekooche First Nations, and the First Nations/INAC Comprehensive Community Planning Working Group.* 1st ed. https://www.aadnc-aandc.gc.ca/DAM/DAM-INTER-BC/STAGING/texte-text/ccphb_1100100021973_eng.pdf.

Indigenous and Northern Affairs Canada. 2016a. "Indigenous Peoples and Communities." Last modified December 22. https://www.aadnc-aandc.gc.ca/eng/1100100013785/1304467449155.

Indigenous and Northern Affairs Canada. 2016b. *Comprehensive Community Planning for First Nations in British Columbia Handbook: Developed in Partnership with First Nation CCP Champions Across British Columbia.* 3rd ed. https://www.aadnc-aandc.gc.ca/DAM/DAM-INTER-BC/STAGING/texte-text/ccphb2013_1378922610124_eng.pdf.

International Energy Agency. 2014. "Technology Roadmap: Solar Photovoltaic Energy." Accessed November 5, 2016. https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapSolarPhotovoltaicEnergy_2014edition.pdf.

International Renewable Energy Agency. 2016. "The Power to Change: Solar and Wind Cost Reduction Potential to 2025." Accessed December 3, 2016. http://www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf.

Karanasios, Konstantinos, and Paul, Parker. 2016. "Recent Developments in Renewable Energy in Remote Aboriginal Communities, British Columbia, Canada." *Papers in Canadian Economic Development* 16: 65-81. http://pced.uwaterloo.ca/index.php/pced/article/view/70.

Kimmett, Colleen. 2009. "First Nation Takes Lead on Solar Power." *The Tye*e, July 24. Accessed November 11, 2017. https://thetyee.ca/News/2009/07/24/FirstNationSolarPower/.

Lee, Marc. 2012. "Enbridge Pipe Dreams and Nightmares: The Economic Costs and Benefits of the Proposed Northern Gateway Pipeline." https://www.policyalternatives.ca/sites/default/files/uploads/publications/BC%20 Office/2012/03/CCPA-BC_Enbridge_Pipe_Dreams_2012.pdf (accessed Jan 4, 2017).

—. 2015. "Innovative Approaches to Low-Carbon Urban Systems: A Case Study of Vancouver's Neighbourhood Energy Utility." Canadian Centre for Policy Alternatives - BC Office. Accessed Feb 7, 2017. https://www.policyalternatives.ca/sites/default/files/uploads/publications/BC%20 Office/2015/02/CCPA-BC-NEU-Case-Study.pdf.

Maehlum, Mathias Aarre. 2014. "The Real Lifespan of Solar Panels." Last updated May 7. http://energyinformative.org/lifespan-solar-panels/.

McKenna, Cara. 2014. "T'Sou-ke First Nation Turns to Wasabi in Renewable Energy Push. *The Globe and Mail*, August 24. Accessed November 10, 2017. https://www.theglobeandmail.com/news/british-columbia/tsou-ke-first-nation-turns-to-wasabi-in-renewable-energy-push/article20187542/.

Moomaw, William, Peter Burgherr, Garvin Heath, Manfred Lenzen, John Nyboer, and Aviel Verbruggen. 2011: "Annex II: Methodology." In *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, edited by Ottmar Edenhofer, Ramón Pichs -Madruga, Youba Sokona, Kristin Seyboth, Patrick Matschoss, Susanne Kadner, Timm Zwickel, Patrick Eickemeier, Gerrit Hansen, Steffen Schlömer, Christoph von Stechow, 975-98. Cambridge, United Kingdom and New York, USA: Cambridge University Press.

Mui, Michael. 2016. "Solar Energy Prices Still Too High: Richmond." *24hours Vancouver*. February 14. http://vancouver.24hrs.ca/2016/02/14/solar-energy-prices-still-too-high-richmond.

National Energy Board. 2017. *Canadian Energy Pricing Trends 2000-2010 - Energy Facts*. Last modified March 15. https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/archive/2011cndnnrgprcngtrndfct/cndnnrgprcngtrndfct-eng.html.

Natural Resources Canada. 2016a. "About Renewable Energy." Last modified June 29. http://www.nrcan.gc.ca/energy/renewable-electricity/7295.

Natural Resources Canada. 2016b. "About Electricity." Last modified June 29. http://www.nrcan.gc.ca/energy/electricity-infrastructure/about-electricity/7359.

Natural Resources Canada. 2017a. " RETScreen." Last modified Jan 13. http://www.nrcan.gc.ca/energy/software-tools/7465.

Natural Resources Canada. 2017b. "Water Heaters." Last modified June 22. https://www.nrcan.gc.ca/energy/products/categories/water-heaters/13735.

Natural Resources Canada. 2003. *Solar Water Heating Systems: A Buyer's Guide*. Ottawa, Ontario. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/SOLAR-BuyersGuide-SolarWaterHeatingSystems_ENG.pdf.

Newell, Rob, and Leslie, King. 2013. *T'Sou-ke Case Summary*. N.p.: MC3. Accessed November 11, 2017. http://www.mc-3.ca/tsou-ke.

Nian, Victor. 2016. "Impacts of Changing Design Considerations on the Life Cycle Carbon Emissions of Solar Photovoltaic Systems." *Applied Energy* 183: 1471-1487. doi.org/10.1016/j.apenergy.2016.08.176.

Ontario Ministry of Energy. 2015. "Feed-In Tariff Program Two-Year Review: Background." Accessed December 18. http://www.energy.gov.on.ca/en/fit-and-microfit-program/2-year-fit-review/background/.

Oregon State University. 2010. "Snowball Sampling." Accessed December 6. http://research.oregonstate.edu/irb/policies-and-guidance-investigators/guidance/snowball-sampling.

Ozog, Sarah. 2012. "Towards First Nations Energy Self-Sufficiency: Analyzing the Renewable Energy Partnership between T'Sou-ke Nation and Skidegate Band." MA Thesis, University of Northern British Columbia. Library and Archives Canada (MR87550).

Pannell, D.J. 1997. "Sensitivy Analysis of Normative Economic Models: Theoretical Framework and Practical Strategies." *Agricultural Economics* 16 (2): 139-52. doi:10.1016/S0169-5150(96)01217-0.

Partnership for Policy Integrity. 2014. "The Role of Biomass Energy in EPA's Greenhouse Gas Rule." August 7. http://pfpi.net/wp-content/uploads/2014/08/PFPI-GHG-rule-writeup-August-7.pdf.

Poissant, Y, and P Bateman. 2014. *National Survey Report of PV Power Applications in Canada.* International Energy Agency. http://www.cansia.ca/uploads/7/2/5/1/72513707/national_survey_report_of_pv_power_applications_in_canada_2014.pdf.

Rae, Callum, and Fiona Bradley. 2012. "Energy Autonomy in Sustainable Communities- A Review of Key Issues." *Renewable and Sustainable Energy Reviews* 16: 6497-6506. doi: 10.1016/j.rser.2012.08.002.

Reichelstein, Stefan, and Michael Yorston. 2013. "The Prospects of Cost-competitive Solar PV Power." *Energy Policy* 55: 117-127. doi:10.1016/j.enpol.2012.11.003.

Rezaei, Maryam, and Hadi Dowlatabadi. 2016. "Off grid: Community Energy and the Pursuit of Self-sufficiency in British Columbia's Remote and First Nation's Communities." *Local Environment* 21(7): 789-807. doi:10.1080/13549839.2015.1031730.

Sayers, Judith. 2013. "Include First Nations in Renewable Energy Sector." *Vancouver Sun*, October 25. Accessed February 2, 2016. http://www.vancouversun.com/business/Include+First+Nations+renewable+energy+sector/9085017/story.html.

Shaw, Karena, Dana Cook, Eryn Fitzgerald and Judith Sayers. 2017. "BC First Nations are Poised to Lead the Renewable Energy Transition." *Policynote* (blog), October 12. http://www.policynote.ca/bc-first-nations-are-poised-to-lead-the-renewable-energy-transition/.

Sheeran, Kristen, Frank Ackerman, Noah Enelow, Eban Goodstein, Robin Hahnel, Thomas Michael Power, and Juliet Schor. 2014. *The Future Economy: An Annotated Analytical Framework for Case Studies*. N.p.: Economics for Equity and Environment. Accessed August 15, 2016. http://futureecon.com/wp-content/uploads/future-economy-framework_new.pdf.

Smyth, Michael. 2016. "The Site C Dam Blows Away Major Wind Power Project from B.C." *The Province*, June 10. http://theprovince.com/technology/smyth-the-site-c-dam-blows-away-major-wind-power-project-from-b-c.

Sooke Region Volunteer Centre. 2013. "District of Sooke- Climate Change Action Committee."Accessed April 24. http://www.sookeregionvolunteers.org/event/meeting-special/district-sooke-climate-change-action-committee.

Statistics Canada. 2017. *T'Sou-ke, IRI [Census Subdivision], British Columbia and Capital, RD [Census Division], British Columbia* (Table). *Census Profile*, 2016 Census. Catalogue no. 98-316-X2016001 in Statistics Canada [database online]. Ottawa, Ontario. Last modified November 3, 2017. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E.

Statistics Canada. 2013. *T'Sou-ke, IRI, British Columbia (Code 5917819)* (Table). *National Household Survey (NHS) Profile*. *2011 National Household Survey*. Catalogue no. 99-004-XWE in Statistics Canada [database online]. Ottawa, Ontario. Last modified November 27, 2015. http://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/index.cfm?Lang=E.

Statistics Canada. 2012. "Section 3: Dictionary of Concepts and Definitions." Last modified December 20, 2012. http://www.statcan.gc.ca/pub/71-543-g/2011001/part-partie3-eng.htm.

Statistics Canada. 2009. *2009 Aboriginal Community Data Initiative T'Sou-ke Nation. 2009 Census*. http://www.bcstats.gov.bc.ca/apps/ACDI.aspx.

Taylor, Stephanie, and George, Hoberg. 2011."How Electricity Pricing Works in British Columbia." *GreenPolicyProf* (blog), February 17. http://greenpolicyprof.org/wordpress/?p=508.

Te'mexw Treaty Association. n.d. "Te'mexw Treaty Association." Accessed October 31. http://www.temexw.org/about-us/.

Troian, Martha. 2017. "B.C. First Nation Leads with Green Technology, Sustainability." *CBC News*, April 14. Accessed November 10, 2017. http://www.cbc.ca/news/indigenous/tsou-ke-nation-green-energy-leaders-1.4067833.

T'Sou-ke First Nation. 2016. "Welcome to T'Sou-ke Nation." Accessed October 24. http://www.tsoukenation.com/welcome-to-tsouke-nation/.

—. 2010a. "Renewable Energy Toolkit: T'Sou-ke Solar Project." Unpublished report, T'Sou-ke First Nation, B.C.

—. 2010b. "T'Sou-ke Centre for Sustainable Living." Presentation, T'Sou-ke Nation.

T'Sou-ke Smart Energy Group. n.d. "Environmental Education for Climate Change and Energy Conservation" Presentation, T'Sou-ke Nation, B.C.

Tynan, Sean. 2010. "Solar Photovoltaics in British Columbia." O. SCARP Graduating Projects.
April 30. (doi:10.14288/1.0107195).

Umbra, 2016. "What's Better: New Solar Panels or Old Hydropower?" *Grist*, November 17. http://grist.org/living/whats-better-new-solar-panels-or-old-hydropower/.

Union of British Columbia Indian Chiefs. n.d. " Federal and Provincial Collections of Minutes of Decision, Correspondence, and Sketches: Materials Produced by the Joint Indian Reserve Commission and Indian Reserve Commission, 1876-1910." Accessed October 24. http://jirc.ubcic.bc.ca/.

United States Energy Information Administration. n.d. "What is the Difference between Electricity Generation Capacity and Electricity Generation?" Accessed October 31. https://www.eia.gov/tools/faqs/faq.php?id=101&t=3.

—. 2017. "Levelized Cost and Levelized Avoided Cost of New Generation." Independent Statistics and Analysis. Accessed October 31. https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf.

United States Environmental Protection Agency. 2014. "Emission Factors for Greenhouse Gas Inventories." Last modified April 4. https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf.

—. 2017. "Understanding Global Warming Potentials." Last updated February 14. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

United Nations Framework Convention on Climate Change. 2014. "Definitions." Accessed November 5. http://unfccc.int/ghg_data/online_help/definitions/items/3817.php.

Upton, John. 2015. "Pulp fiction: Why Wood is a Dirty Secret of Clean Energy." *Green Biz*, October 26. https://www.greenbiz.com/article/pulp-fiction-why-wood-dirty-secret-clean-energy.

Vancouver Island Wilderness and Historical Conservation. n.d. "T'Sou-ke First Nations."Accessed October 25. http://www.geog.uvic.ca/viwilds/fn-tsouke.html.

Williams, Chris. 2012. "Finance 101 for Renewable Energy Professionals." *HeatSpring* (blog), March 27. https://blog.heatspring.com/finance-101-for-renewable-energy-professionals/.

World Energy Council. 2016. "World Energy Resources Solar." https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Solar_2016.pdf.

APPENDICES

APPENDIX A

Table A: T'Sou-ke solar project funding sources

Project components	Funding Agency	Type of assistance	Timeline
Solar PV	Natural Resources Canada.	Innovative Clean Energy Fund of $400,000.	Feb-July 2009
	Western Economic Diversification Canada.	Community Economic Development Program funding (amount unknown).	May-July 2009
	Indigenous and Northern Affairs Canada.	Eco Energy for Aboriginal and Northern Communities Program funding of $100,000.	March-April 2009
	Day 4 Energy.	Solar panels and installation support	March-June 2009
	Home Energy Solutions.	Solar panels and installation support	April-June 2009
Solar hot water	Natural Resources Canada	Financial assistance of $300,000 to install solar hot water systems in 37 homes.	March-April 2009
	BC Sustainable Energy Association	Solar BC Program rebates for the installation of solar hot water systems (amount unknown).	April-May 2009

Table A (continued)

	Coast Salish Employment and Training Society	Employment assistance services	Jan-July 2009
Energy conservation program	BC Ministry of Energy Mines and Petroleum Resources	Financial assistance of $150,000 with energy savings retrofits.	April-July 2009
	BC Hydro	Residential Power Smart Program with energy savings kits and Energy Conservation Assistance Program	May-July 2009

Source: Data from Ozog (2012, Appendix D); Moore, interview by author (August 18, 2015).

APPENDIX B

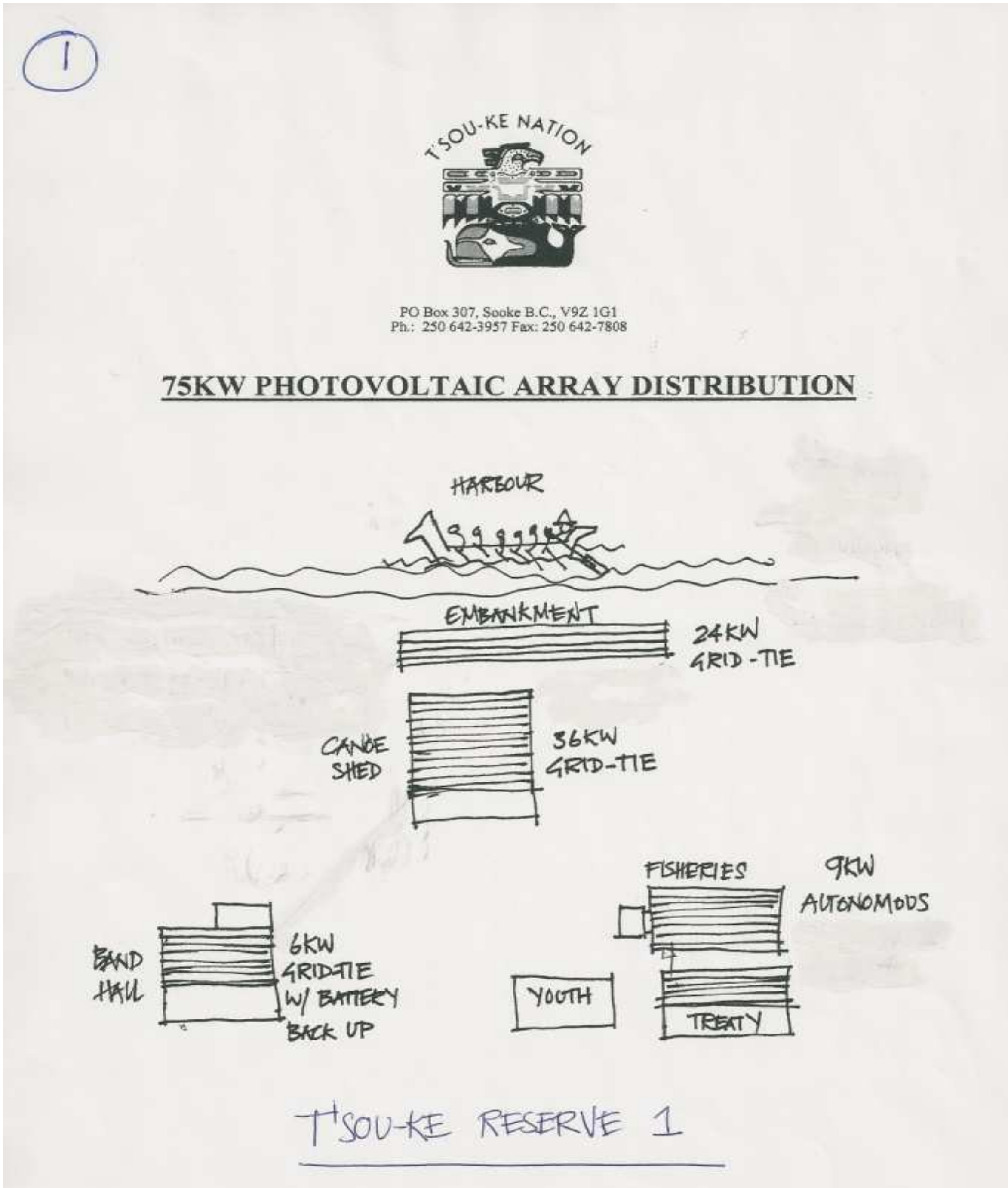

Figure B.1.a: Early sketch of the Solar PV project. Image from T'Sou-ke First Nation (2010a, 13).

Figure B.1.b: 39.9 kW Canoe shed PV system. Image from Bekker (2009a, 24).

Figure B.1.c: 22.4 kW Hilltop PV system. Image from Bekker (2009a, 15).

Figure B.1.d: 7 kW Administration PV system. Image from Bekker (2009a, 20).

Figure B.1.e: 6.3 kW Fisheries PV system. Image from Bekker (2009a, 7).

1. Tours of the community to help the mentor better understand the local context.

2. Informal conversation and storytelling about the community, their CCP process, and the mentor's community and CCP experience.

3. Training in specific tasks, like proposal writing or facilitation.

4. Presentations to groups such as the CCP Advisory Committee, Chief and the Council, and community meetings.

5. Brainstorming and work planning for any phase of the CCP.

6. Offering a sympathetic ear to the CCP staff, since the mentors have "been there" through the tough parts of the CCP process, and survived.

7. In some cases, interviewing and helping to hire the CCP Coordinator and assistant, where none are in place already.

Figure B.2: CCP mentorship activities**.** List from Hemphill (2014).

APPENDIX C

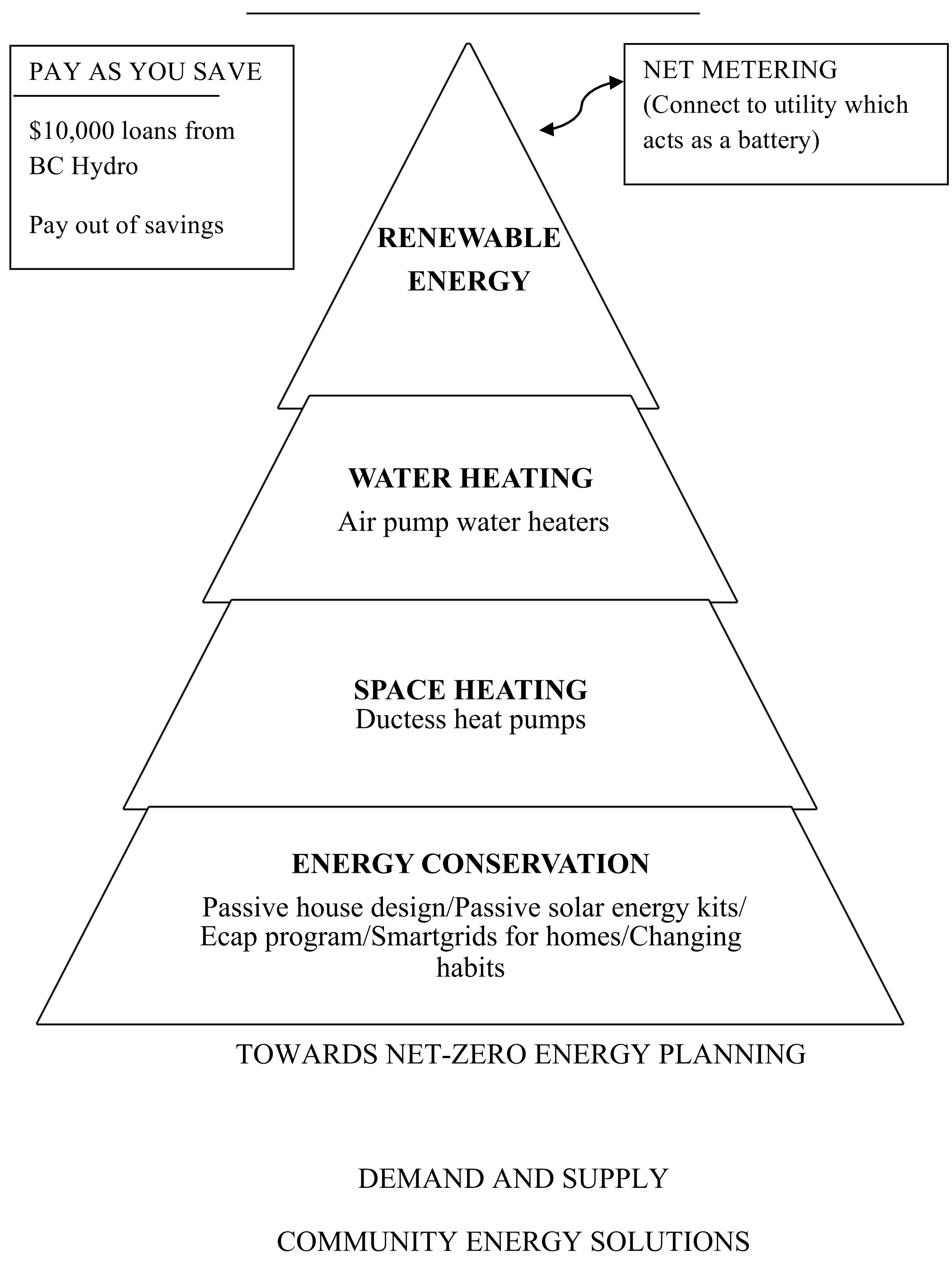

Figure C: Energy conservation model. Created from personal communication with Moore (2015).

Participation Agreement

Title of the study: Building a network of Clean Energy Systems: A Case Study of T'Sou-ke First Nation

Researcher: Ananya Bhattacharya, Graduate Student, MA Development Economics, University of Northern British Columbia

Supervisor(s):
Marc Lee, Senior Economist and Co-Director, Climate Justice Project, Canadian Centre for Policy Alternatives (CCPA)

Dr. Karima Fredj, Associate Professor, Department of Economics, University of Northern British Columbia (UNBC)

This is a written acknowledgement that the T'Sou-ke First Nation has agreed to participate and provide full support in the study conducted by the researcher. [1]

Signature of the Chief/Council Member(s) of T'Sou-ke First Nation

29th May '15

Date

[1] Attached to this Participation Agreement is my previous correspondence with Mitchelle Thut, Administrator at T'Sou-ke First Nation, introducing myself and the purpose of this study as well as the Form of Intent that includes my Research Proposal.
If you still have any questions about this study or myself, please do not hesitate to contact me at 250-981-5650; ananyab4@gmail.com

Figure D.1: Research participation agreement.

The guidelines of the study are as follows:

i. All research activities and publications arising from this research at the T'Sou-ke First Nation will conform to the research principles outlined in the *Tri–Council Policy Statement: Ethical Conduct for Research Involving Humans,* TCPS 2 (2014), Chapter 9, Research Involving the First Nations, Inuit and Mètis Peoples of Canada as well any specificguidelines for Aboriginal research designed by the T'Sou-ke First Nation.

ii. Data obtained from this research will be confidential and treated with anonymity if desired by the research participants.

iii. Data from the study will be stored in a secure location. Audiotapes and interview notes will be labelled with pseudonyms. Transcripts, surveys and other raw data will only be seen by those involved in the research project.

iv. The data collected and stored will not be made accessible to other researchers and/or used for research purposes without the T'Sou-ke First Nation's knowledge and written consent other than those agreed upon.

v. Upon completion of the study the data and records that are collected in the context of the research will either be destroyed or remain in possession of the principal researcher. This could include completed surveys or questionnaires, transcripts and tapes from interviews, etcetera. The analysis and interpretation that arises from the raw data will remain the property of the researcher.

vi. All publications (CCPA Report, M.A Thesis, presentations etcetera) will acknowledge all members instrumental to the completion of the project. Members may include the T'Sou-ke First Nation council Members, staff persons and volunteers who have made contributions in carrying out the study successfully.

vii. Any reports or publications arising from the research shall be submitted to the T'Sou-ke First Nation at the peer-review stage and prior to publication. Reports or publications, which are identified in an approved publication strategy, will not require further review. This research can also be presented orally at conferences without further review or consent.

viii. The T'Sou-ke First Nation community shall be provided with copies of all publications derived from the research project.

Figure D.1: Research participation agreement (continued).

UNIVERSITY OF NORTHERN BRITISH COLUMBIA

RESEARCH ETHICS BOARD

MEMORANDUM

To: Ananya Bhattacharya
CC: Karima Fredj

From: Michael Murphy, Chair
Research Ethics Board

Date: July 23, 2015

Re: **E2015.0617.055.00**
Building a network of Clean Energy Systems: A Case Study of T'Sou-ke First Nation Solar Project

Thank you for submitting revisions to the Research Ethics Board (REB) regarding the above-noted proposal. Your revisions have been approved.

We are pleased to issue approval for the above named study for a period of 12 months from the date of this letter. Continuation beyond that date will require further review and renewal of REB approval. Any changes or amendments to the protocol or consent form must be approved by the REB.

Good luck with your research.

Sincerely,

[signature]

Dr. Michael Murphy
Chair, Research Ethics Board

Figure D.2.a: UNBC research ethics board approval.

UNIVERSITY OF NORTHERN BRITISH COLUMBIA

RESEARCH ETHICS BOARD

MEMORANDUM

To: Ananya Bhattacharya
CC: Paul Bowles

From: Henry Harder, Chair
Research Ethics Board

Date: July 20, 2016

Re: **E2015.0617.055.01(a)**
Building a network of Clean Energy Systems: A Case Study of T'Sou-ke First Nation Solar Project

---

Thank you for submitting a request for renewal and amendments to the Research Ethics Board (REB) regarding the above-noted proposal. Your request has been approved.

We are pleased to issue renewal approval for the above named study for a period of 12 months from the date of this letter. Continuation beyond that date will require further review and renewal of REB approval. Any further changes or amendments to the protocol or consent form must be approved by the REB.

Good luck with continuation of your research.

Sincerely,

Dr. Henry Harder
Chair, Research Ethics Board

Figure D.2.b: UNBC research ethics board renewal.

CCPA
CANADIAN CENTRE
for POLICY ALTERNATIVES
BC Office

July 6, 2015

research • analysis • solutions

Ananya Bhattacharya
2920 Allan Road,
North Vancouver, B. C
V7J 3C2

Approval of 2015 Rosenbluth Internship proposal by CCPA-BC's Research Advisory Committee

Dear Ananya,

This letter is in response to your Rosenbluth Internship proposal submission to the Research Advisory Committee (RAC) at CCPA- BC on June 24, 2015.

The Research Advisory Committee has reviewed your proposal, "Building a network of Clean Energy Systems: A Case Study of T'Sou-ke First Nation" and approved it without any revisions.

Sincerely,

Marc Lee
Senior Economist and Co-Director,
Climate Justice Project
CCPA-BC

1400 – 207 West Hastings Street • Vancouver, BC V6B 1H7
tel: 604-801-5121 • fax: 604-801-5122 • ccpabc@policyalternatives.ca • www.policyalternatives.ca

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Figure D.3: CCPA-BC RAC approval.

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

Information Letter / Consent Form

July 4, 2016

Project Title: Building a network of Clean Energy Systems: A Case Study of T'Sou-ke First Nation Solar Project

Principal Researcher: Ananya Bhattacharya
M.A. Development Economics Candidate
University of Northern British Columbia
Prince George, BC V2N 4Z9
bhattac@unbc.ca

Supervisor(s): Marc Lee
Senior Economist and Co-Director,
Climate Justice Project
Canadian Centre for Policy Alternatives (CCPA), BC Office
marc@policyalternatives.ca

Dr. Paul Bowles
Professor & Acting Chair
Department of Economics
University of Northern British Columbia (UNBC),
paul.bowles@unbc.ca

This project is conducted for Rosenbluth Internship, 2015 by the CCPA- BC Office. In addition, some of the results of this research will be used in my MA project in the Department of Economics at UNBC.

Project Sponsor

The project is funded by the CCPA-BC's Rosenbluth Internship fund.

Purpose of Project

The purpose of this project is to study a clean energy system based on economic, environmental, social and other parameters and provide policy recommendations. My main research question focuses on how does a clean energy system operating on' solar energy' perform compared to a

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Figure D.4: Information letter or consent form.

conventional system of 'diesel energy' in BC. Through this study, I aim to identify the prospects, challenges and the way ahead in moving from a conventional energy system to a more clean energy system for BC using the T'Sou-ke Solar Project as a case.

You are invited to participate in this research to share your expertise in the area of [*insert participant's field*]. Your knowledge and experience with [*insert participant's field*] will be invaluable as I try to understand both the contributions and the challenges faced by yourself and other participants in [*insert participant's field*]. You are in no way obligated to participate in this study and you would be free to withdraw from the study at any time or refuse to answer any question should you so desire. If you choose to withdraw, any data recorded up until your withdrawal will be destroyed.

What will happen during the project?

If you agree to participate in this study, I would like to arrange for a brief interview with you, either in person or by phone at your convenience. The interview will take about 30-120 minutes approximately. You can refuse to answer particular answers during the interview.
I will ask you for a brief description of your involvement in [*insert participant's field*]. I will also ask you about the challenges that you face [*insert participant's field*] and your perception of the future of clean energy initiatives in BC. To help me do an effective analysis, I will ask your permission to audio record your interview. You will have the option to provide your consent or decline a recording before the start of the interview.

Risks or benefits to participating in the project

This project is minimal risk. The potential for harming your [*insert participant's field*] is highly unlikely as I am not seeking any privileged or classified information, and I encourage you as a participant to use your professional discretion in revealing information. My aim is to document the experiences of people involved in a clean energy initiative to do an effective case study analysis. Your participation in this study will inform policy-makers, environment experts, first- nation communities, non-profit organizations and independent researchers about the benefits of clean energy initiatives so that they can make informed decisions.

Confidentiality, Anonymity and Data Storage

Due to the small sample size and detailed interview structure, anonymity cannot be guaranteed to the participants. Notes and recordings from the interviews will be labelled with pseudonyms and kept securely in locked filing cabinets in my office at CCPA and UNBC. The information from this interview will only be seen by the principal researcher and the supervisor(s). Upon completion of the study, the raw data and records will be destroyed.

Study Results

The results of this study will be reported in a CCPA publication and in my graduate project. The study results will also be shared with the T'Sou-ke First Nation in accordance with the research agreement. The CCPA report will be made publicly available for download on the CCPA-BC website and the participants will be informed of the publication via e-mail.

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Figure D.4: Information letter or consent form (continued).

Questions or Concerns about the project

If you have any questions about this research, you can contact the principal researcher at the following e-mail address or telephone number:

Ananya Bhattacharya ananyab4@gmail.com
(250) 981-5650
(604) 801-5121, Extn: 244

You may also contact the faculty supervisor(s) with any questions at the following e-mail address or telephone number:

Marc Lee (CCPA) marc@policyalternatives.ca
(604) 801-5121, Extn: 228

Paul Bowles (UNBC) paul.bowles@unbc.ca
(250) 960-6648

If you have any concerns or complaints about this research, you may contact the Office of Research at UNBC at the following e-mail address or telephone number

Office of Research reb@unbc.ca
(250) 960-5852

Thank you for your time and consideration to participate in this study.

Participant Consent and Withdrawal

The choice to participate in this study is entirely up to you. If you wish to participate you may complete this consent form and return it to the researcher, or I will discuss each item at the beginning of the interview. Even so, you may freely choose to withdraw from the study at any time and have your responses destroyed.

CONSENT

I have read or been described the information presented in the information letter about the project:

YES NO

I have had the opportunity to ask questions about my involvement in this project and to receive additional details I requested.

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Figure D.4: Information letter or consent form (continued).