2011

Major Project Final Report:

Lifecycle Assessment of a Solar Thermal System

Hatley Park Environmental Consulting:

Brooke Davidson, Jari Eikenaar,

Kate Fonteyne, Matthew Girard,

Brandon Leong

Royal Roads University

7/19/2011

1.0 Executive Summary

The Lifecycle Assessment of a Solar Thermal System major project was assigned to Hatley Park Consulting in the fall of 2010. The main objectives of this project were to complete a lifecycle assessment (LCA) and a benefit/cost analysis (BCA) of a solar hot water system that might be installed in the Solar Colwood project.

The project began by reviewing the methodologies of conducting LCA and BCA analyses, in order to determine the most suitable for this project. The GaBi4 software package was identified as a tool for conducting the LCA, and was subsequently acquired by the team. The LCA was planned to be a comprehensive examination of the environmental impacts associated with all stages of the production and use of a solar hot water system. Solar hot water systems were researched to gain a complete understanding of the technology and how it is used to preheat domestic water. Following interviews with community members, contractors, manufacturers, and a representative of SolarBC, a system manufactured by EnerWorks Inc. was identified as the subject of the LCA. The company supplied us with a comprehensive list of the materials used in the system, including embodied energy coefficients and masses for each. At this point it was decided that the LCA would be conducted using this information to determine the emissions of CO_2 created by the production and transport of the system to Vancouver Island; using the GaBi4 software would include a great number of assumptions, and it was felt that this would weaken the results. Following the completion of the LCA, the BCA was conducted by creating four different scenarios that would reflect different possibilities for future changes in the prices of electricity and natural gas, as well as two different discount rates.

The results of the LCA show that the amount of carbon dioxide (CO_2) released during the production and transportation of the solar hot water system is 811.5 kg when transported by freight train, and 829 kg when transported by a semi truck trailer. The amount of CO_2 saved by the solar hot water system is 1810.35 kg when using the BC average for emissions related to energy consumption, and 12419.67 kg if natural gas was used, over the projected 30 year lifespan of the system. As these figures represent net reductions in CO_2 emissions, it was recommended that Colwood residents participate in the Solar Colwood program, if they would like to use solar hot water as a means of reducing their carbon footprint. Further LCA studies might yield more information on the environmental impacts associated with the system; CO_2 emissions are only one consideration, and there may be significant contributions in other categories of pollutants.

The four scenarios analyzed in the BCA show that for natural gas users, there are net negative financial benefits to participating in the program. For electricity users, some scenarios showed net positive benefits, while others did not. Due to the number of variables in the calculations, including the discount rate, fuel inflation rates, currently used fuel, and the various incentive levels in the Solar Colwood program, it is recommended that individuals consider their specific situation to determine if there is a financial incentive to participating in the program. It is also recommended that individuals consider the various social and environmental benefits, which were excluded from the financial calculations but were presented in this report, as possible reasons to install a solar hot water system.

Table of Contents

List of Figures

2.0 Glossary of Terms

Solar Hot Water Heating: This method of heating domestic water involves four components: a solar panel that will be attached to the roof of the home; a hot water tank that can either be added as a secondary tank or be used as a primary tank; a control panel that is used to control the flow of heat-collecting fluid through the system; and a heat exchanger that transfers heat energy from the heat-collecting fluid to the domestic water. This system differs from conventional hot water systems in that the water that enters the tank has already been preheated by solar energy, and therefore requires less energy (from electricity or natural gas, for example) to reach the desired temperature (City of Colwood, 2011).

Lifecycle Assessment (LCA): This method of analysis is used to determine the environmental impacts associated with a product's lifecycle, in this case the components of a solar hot water system. The framework takes into account environmental impacts such as greenhouse gases, the release of environmental contaminants, negative effects on human and animal health, and numerous other effects. The methodology considers all lifecycle stages of a product in a “cradle to grave” process, which takes into account all of the inputs and outputs used to complete a project. A typical LCA is composed of four steps: definition of the goal and scope, completion of an inventory analysis of the product, completion of an impact analysis, and interpretation of the results (Rebitzer *et al.*, 2004, p.702).

Benefit/Cost Analysis (BCA): A tool used to assess the viability of a proposed project. After determining the associated benefits and costs of a project, a calculation can be made to determine whether or not a project is financially viable. A BCA commonly incorporates economic benefits and costs with assigned monetary values, but sometimes can include social and environmental benefits and costs, for which monetary values may be determined and applied (Field *et al.*, 2005, p.9-10).

Benefit: A benefit is something that makes an individual better off, and improves their position or wellbeing. A benefit is measured by an individual’s willingness to pay for something (Field *et al.*, 2005, p.54).

Discount Rate: A discount rate, expressed as a percentage, is chosen to determine the value of costs and benefits of a project in the present, with respect to the future values of the costs and benefits (Field *et al.*, 2005, p.112).

EnerWorks Spectrum Pre-heat Appliance: This is the solar hot water system that will be used in the LCA portion of the research. The system was chosen based on background research on solar thermal installations throughout southern Vancouver Island that showed that the EnerWorks system has been the most commonly installed.

Gabi4 Software: This is the software tool that was used throughout the LCA portion of the research project. It can be used to build a workflow model of all of the components of a solar thermal system; it can show all of the energy inputs and outputs and their associated environmental impacts (GaBi Software, *n.d.*).

Kilowatt Hour (kWh): A kilowatt hour is a measure of electrical energy, either consumed or produced, that is the same as 1000 watts of energy in 1 hour.

3.0 Introduction

This section discusses the framework of the project and report, including an overview of the background concepts.

3.1 Scope of the Project

The sponsors have retained Hatley Park Environmental Consulting to aid the residents of Colwood, BC, in making informed decisions on whether or not to change their conventional water heating systems to solar hot water systems. The timeframe for this project is from January to August 2011. We have been asked to do the following:

a) A review of LCA methodologies, as identified from the literature, and selection of an appropriate methodological framework for the assessment;

b) An LCA performed by the team that examines the energy and materials used during the manufacturing, operation and disposal of a specific solar thermal system that would likely be used in Colwood, BC;

c) Identification of a typical water heating system in Colwood, BC, and a comparison between it and a solar thermal heating system, based on the difference in costs of installation and operation and the difference in environmental impacts; and

d) A BCA to determine the economic, environmental and social benefits and costs of solar thermal systems, for recommendations to residents of Colwood, BC.

3.2 Background Information on Sponsors

This project is sponsored by two Royal Roads University instructors, Drs. Charles Krusekopf and Chris Ling.

Dr. Ling is an Assistant Professor in the School of Environment and Sustainability at Royal Roads University, where he teaches sustainable development. He is currently leading a Royal Roads University research team in a study of the public uptake and acceptance of a sustainable energy incentive program. Dr. Krusekopf is part of the research team led by Dr. Ling, and he has been part of the core faculty at Royal Roads University for six years, in the School of Environment and Sustainability. He is the head of the Master's in Environment and Management program, and he teaches undergraduate courses in environmental economics (Royal Roads University, 2011).

This research is funded by grants amounting to $47,000 from the Pacific Institute for Climate Solutions. The City of Colwood and Royal Roads University will be working closely together to help ensure that the Solar Colwood project is successful. The main purpose of the research is to evaluate the uptake of the Solar Colwood project in the community. In addition, the acceptance of the ideas of energy conservation, reducing carbon emissions and embracing sustainable energy will also be examined. In the partnership between the University and the City, the former is responsible for completing the research and evaluation of the project to make sure that the set goals are met. Drs. Ling and Krusekopf will also attempt to show that knowledge gained during the project will benefit community development and move Colwood towards sustainable energy development. This major project could be a key component in the success and implementation of Solar Colwood, as well as related projects in other municipalities (Royal Roads University, 2011).

3.3 Background Information on Solar Hot Water Systems

A solar hot water system uses energy from the sun to heat water. There are at least three major components to a system: a solar panel, a control panel, a heat exchanger, and a water storage tank (Figure 1).

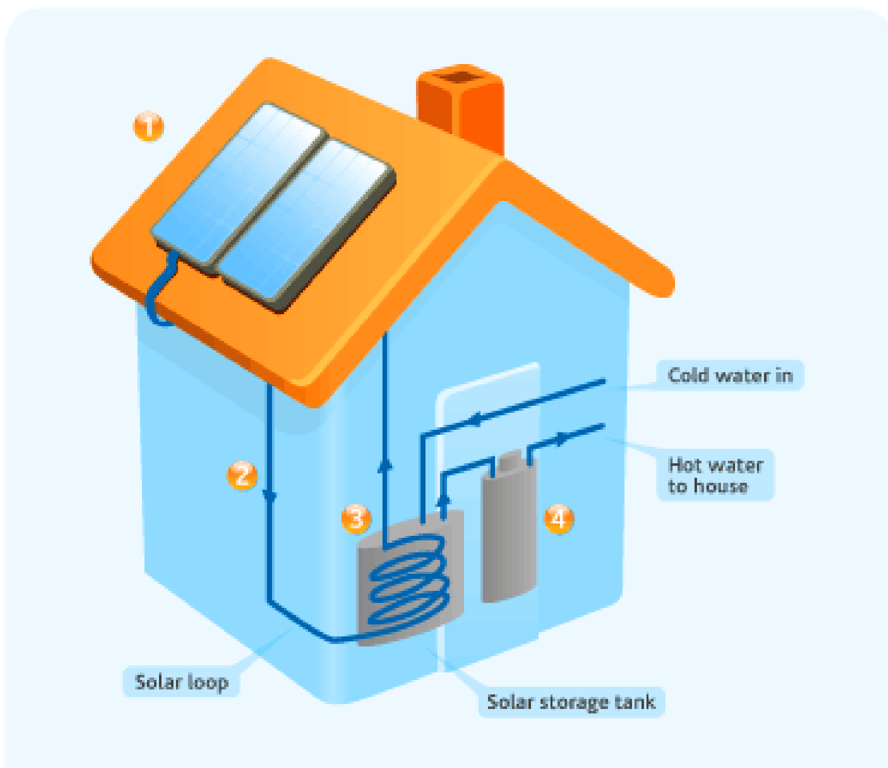

Figure 1: The Basic Configuration of a Solar Thermal System on a House. Courtesy of SolarBC: http://www.solarbc.ca/learn/solar-hot-water-simplified

Typically, panels that contain a matrix of fluid-filled pipes are placed on the roof of a building and oriented towards the sun. As sunlight strikes the panels, heat energy is absorbed by a black plate beneath a transparent glass surface, and is then transferred to the liquid contained in the pipes. Glazing on the surface of the panel prevents the release of heat, allowing the pipes to be exposed to the heat energy for longer to allow for a more efficient transfer of energy. Even on a cool day, if the sun is shining strongly, the temperature within a solar panel can reach in excess of 150°C. A cross section of a panel shows that it has a highly transmissive glass surface overlying a sheet of black chrome-coated copper absorber, which allows for high absorption of solar energy and low emission of thermal radiation (Figure 2). Under this material is a meandering coil of copper pipe, which contains the heat collecting fluid, which is usually either water or propylene glycol (SolarBC, 2008).

The fluid is contained in a closed loop; it is pumped in one direction through the panel, gaining heat energy as it does so. The heated fluid is then circulated back down into the building where,

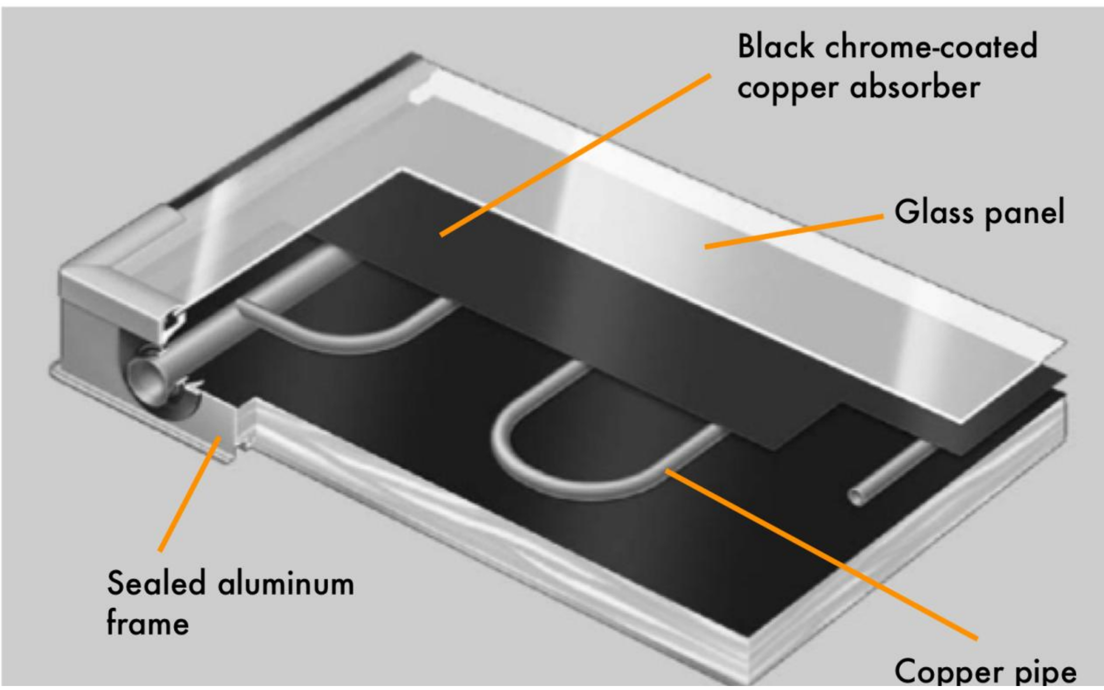

Figure 2: Cross Section of a Typical Collector Panel, courtesy of Veissmann Werke GmbH& Co.

through a heat exchanger, it preheats water in a hot water storage tank. The heat exchanger simply allows the warmed liquid inside the pipes to warm cooler water that comes from the regular municipal supply, and it does this without the glycol or the water contained in the pipe loop ever coming into direct contact with the water to be used in the building (SolarBC, 2008).

Solar hot water systems use either one or two hot water tanks. In a two-tank system, the first tank is used to store the heat collected from the panel. It is then pushed into a second, separate tank by household water pressure when hot water taps are opened (Patterson & Olsen, 2008). In the second tank, energy is used to increase the temperature of the water, typically to 50 to 60°C. In a one-tank system, which is often installed when there is not enough space to add a second water tank, the water in the bottom half of the tank is heated by the solar collector (Robert Barry, Personal Communication, March 29 2011). The warmest water rises to the top of the tank, where a heating element increases the temperature, just as in the second tank in a two-tank system (SolarBC, 2008).

Solar hot water systems are an energy-efficient way of producing hot water while reducing greenhouse gas emissions; hot water is the second largest source of energy consumption in a home, after space heating. The addition of preheated water reduces the amount of energy required to heat the water to a comfortable temperature for domestic use (SolarBC, 2008).

When installing a solar hot water system there is not one specific system that would be applicable to every home. With each installation the variables of available space, water usage habits and requirements, current fuel types, and current hot water systems must be taken into account to develop a system that is specifically tailored to meet the requirements of the home. For example, in a household with one or two residents, it is likely that their hot water requirements will be relatively low, and so a one-tank system might be sufficient for their needs. In a larger household that requires more hot water, a two-tank system might be preferable as it would be able to supply a greater quantity of hot water. Regarding habits, because water will not be pre-warmed by the panel until the sun has been shining, using a lot of hot water early in the morning would mean that there will be greater reliance on the secondary heating system. Although the hot water tanks usually have very good insulating qualities, some heat will inevitably be lost during the dark hours, and the secondary system will be needed to bring the water temperature up (Robert Barry, Personal Communication, March 29, 2011).

3.4 Background Information on the Solar Colwood Project

On January 24, 2011, there was a community gathering at the Colwood Fire Department to announce a grant for clean energy from Natural Resources Canada. Gary Lunn, Minister of State for Sport at the time, was there to publicize the federal government's provision of a $3.9 million dollar grant to support the City of Colwood in their efforts to implement a community-wide solar project. The federal government has funded the project as part of their Economic Action Plan (Natural Resources Canada, 2011).

The main goal of the Solar Colwood project is to retrofit 1000 homes in Colwood with solar thermal hot water systems within the next three years. If this is accomplished, one sixth of the homes in Colwood will have solar hot water systems (Judith Cullington, Personal Communication, 2011). It is hoped that once the installations begin, more and more individuals will express interest in retrofitting their homes. The solar panels will be quite visible, and it is likely that people will ask questions about them; this is expected to increase public interest in solar hot water systems in Colwood.

Solar Colwood is a large project that consists of the implementation of four different components: home retrofits, Colwood Fire Hall retrofits, clean energy for the Colwood Corners redevelopment, and the evaluation of electric vehicle charging infrastructure. The first of these is that home retrofits will be completed to increase energy efficiency. As part of these retrofits, solar hot water systems, which can save the homeowners up to 30% per year on their energy bills, will be installed. Energy-savings can be increased when the solar hot water systems are combined with other energy-saving practices and measures, such as improved insulation and heating systems. When a householder signs up to be part of the Solar Colwood project, their home will first undergo a home energy efficiency evaluation. This assessment will identify whether installing a solar hot water system is worthwhile, and it will also point out other things that can be improved to increase energy savings. Some of these technologies include ductless split heat pumps, smart meters, LED lights, and weather-stripping (City of Colwood, 2011).

The second component of the Solar Colwood project is the installation of solar hot water panels and photovoltaic cells on the Colwood Fire Hall. This will be one of the first buildings to be retrofitted, and this will make it a showpiece for the rest of the community.

The third component of the project is the new clean energy re-development that has been approved for Colwood Corners. Colwood Corners is a shopping complex at the intersection of Sooke Road and Goldstream Avenue. It is an older-style strip mall that has the potential to be transformed into a new development. A plan for redevelopment has been put forth which will take 10 -15 years for completion. In this construction project, mixed-use areas will be built to accommodate residential living and commercial spaces. Government funding will be used in the implementation of solar hot water systems, photovoltaic electricity, and smart home technologies. Construction on Colwood Corners is set to begin in 2011 with the first phase projected to end in 2013 (City of Colwood, 2011).

The final component of the project is the implementation of electric vehicle charging stations. Electric vehicles will become available in BC around 2012, and charging infrastructure will be required to cater to them. This will be addressed with the use of smart meters, the implementation of which will be further explored by the City of Colwood. Colwood hopes to install Level 2 service, which would provide 40 Amp charging for vehicles, a rate that is much faster than that of standard outlets. The BC government is also hoping to implement a number of rapid charging stations in the future, which could charge a vehicle to 80% of its capacity in only five minutes (City of Colwood, 2011).

Hatley Park Environmental Consulting worked with Drs. Chris Ling and Charles Krusekopf to produce an LCA of a solar thermal system that would likely be installed in Colwood. The completion of this LCA has enabled the creation of a report that notes all of the costs to the environment with respect to production, transportation, installation, and disposal. This report can be distributed to members of the Colwood community who are considering the implementation of solar hot water systems in their homes. The other portion of the project was the completion of a BCA to determine the economic, social, and environmental costs and benefits of the solar thermal systems. A conventional system was also compared to a solar hot water system in order to show residents what kinds of savings, if any, they will receive by installing the latter.

3.5 Summary of a Lifecycle Assessment

LCA is the process by which a product or process is assessed for its “cradle to grave” impacts on the environment. Cradle to grave impacts refer to the raw materials and natural resources (energy) from the Earth used in the production, use and destruction of any product or process, and consequently all raw materials and energy that return back to the Earth. Organizations, businesses, and government agencies are currently utilizing this strategy to understand the environmental impacts of their products or processes. The acquisition of this information is used in attempts to create better business practices to decrease negative impacts on the environment, as well as to reduce energy and materials costs for economic benefit. Analysis begins with research to compile all raw materials and energy input and output information required for the product or process. The identified inputs and outputs are assessed to quantify the impacts by the removal from, and later return to, the natural environment (Environmental Protection Agency, 2011).

The goal of an LCA is to determine the environmental impacts associated with a product or process. The LCA considers all the inputs and outputs required for and generated by the entire lifespan of the product or process, and the associated environment impacts. Understanding the lifecycle environmental impacts can be a helpful tool in the decision making process. An understanding of the lifecycle of a product or process can assist those in industry and government in making more informed decisions regarding their environmental and economic practices. (Environmental Protection Agency, 2011)

LCAs may also be conducted by outside parties interested in adopting a new product or process. When researching the utilization of a new product or process, a company must first research different options and criteria; an LCA can be a valuable tool in this process. For example, a company can utilize an LCA to compare and contrast two options; the option most likely to be chosen is the one which is the most economically and environmentally viable (Environmental Protection Agency, 2011).

By understanding which components of a product or process are the most environmentally viable, a business can identify how to address their issues. Companies that address their environmental impacts could also work with other companies to create different methods, to reduce environmental impact throughout the entire product or process lifecycle together. This could potentially create a better product or process at a lower environmental and financial cost, which would benefit both parties (Environmental Protection Agency, 2011).

An LCA is divided into four major phases: goal definition and scope, inventory analysis, impact assessment, and interpretation (Environmental Protection Agency, 2011). These steps are explained below.

Goal Definition and Scope

This includes a definition of the product or process to which the LCA will be applied. The scope refers to the boundaries outlined surrounding the components to be included and the degree to which the environmental impacts will be assessed. Defining the scope early in the LCA will assist individuals in focusing on the required and meaningful results (Environmental Protection Agency, 2011).

Inventory Analysis

Based on the determined scope, research will be conducted on the product or process to list all of the defined energy and material inputs. A list of these attributes will allow a more complete and accurate assessment of environmental impacts from the product or process. Materials will be isolated and individually assessed for the energy inputs and outputs during their creation (Environmental Protection Agency, 2011).

Lifecycle Impact Assessment

The lifecycle impact assessment is an evaluation of the environmental impacts associated with the components of the product or process as defined in the scope and inventory analysis. This process can be achieved by individually researching the material components and their raw material sources, the mode of transport, and all the energy requirements related to raw material extraction. This phase of the LCA can be completed by the use of a variety of software tools (Environmental Protection Agency, 2011).

Interpretation

Interpretation is the synthesis of all of the information generated in the previous three phases of the LCA. Using the scope outlined in the first phase, as well as the inventory and impact assessment results from the second and third phases, the research question may be answered. At this point comparisons can also be made between two products or processes.

3.6 Benefit /Cost Analysis

A BCA is a tool that is used to measure the costs of a policy or program in comparable values. This is a primary tool used by economists to evaluate environmental decisions by looking at the benefits gained by society, and the associated costs. Many consumers use money for their measurement term when performing a BCA, in order to decide on long-run and short-run purchases (Field & Olewiler, 2005, pp 9-10).

The reason a BCA is completed is to present consumers with the information needed to make financial choices. In this project it provides information on the upfront costs and the monetary savings of owning a solar hot water system. With this information, the consumer will be able to make the choice of owning such a system, based on their spending and saving habits. The BCA can also be used to communicate information regarding the environmental impacts of producing a solar hot water system.

The BCA was completed by gathering information from people who already own solar hot water systems and comparing their monthly costs to those who do not. This was accomplished by asking people to provide details on their water heating bills. A simple formula was used to compare the initial costs to the amount gained through savings.

With this method several important pieces of information can be gained, such as:

1. How much water is the household consuming?
2. How much electricity/heating a household is paying for, and how much can be saved?
3. How long will it take for this household to pay off the upfront cost?

The following are some aspects that need to be taken into consideration for a BCA:

How large is the household?

Larger households generally use more hot water; with these, it should be expected that a solar hot water system should pay for itself faster. Smaller households may experience longer payback periods, and will have to take that into consideration before investing in a system.

How much water is used?

Households that use more hot water will likely be able to pay off the solar hot water system more quickly. Households that use less water might have to take that into consideration before investing in a unit.

What are the electricity/heating costs?

Currently in British Columbia, electricity is fairly inexpensive, but it is expected to increase in the future. A rate increase of 8% has been approved this year, and was effective starting May 1, 2011 (BC Hydro, 2011).

Another important consideration in a BCA is the discount rate, which relates to the time value of money; households and individuals who have a high discount rate will most likely make short-term financial decisions, whereas those with a low discount rate will most likely make long-term financial decisions (Krusekopf, Personal Communication, 2011). A variety of different scenarios can be created to show how changes in the discount rate will vary the results of the BCA. With the information provided, we can create typical scenarios that households may experience to give the consumers the most accurate information.

3.7 Research Question

The research question is:

Based on a lifecycle assessment and a benefit/cost analysis, is it recommended that residents of Colwood participate in the Solar Colwood program and install solar thermal systems in their homes?

4.0 Materials and Methods

This section provides an overview of the materials and methods that were used.

4.1 Survey Methods

At the beginning of the project, it was determined that to interview various people to gather information we would have to apply for an ethical review. Using Royal Roads University's template for the ethical review process (Appendix 1), we filled in the questionnaire and devised our own set of questions for three groups of interview subjects: householders, contractors, and manufacturers (Appendix 2). These groups were identified according to the different information that we determined would be required for this project.

4.1.1 Householders

We decided that we would ask householders why they chose to install a solar hot water system, their observations and experiences with it, whether they would recommend their system to others, and if using solar hot water had led to other changes in their lifestyle (such as changes in water or energy usage) or home (such as installing other energy efficient appliances).

Through various contacts in the community, such as City Councilors, it was possible to find a willing interview subject. Our aim was to find a household that had installed a solar hot water system in their home in the recent past. The preferred method for this was an in person interview.

4.1.2 Contractors

We determined that we would attempt to find a local contractor who works with solar hot water systems. It was surmised that they would be found following the interview with the householder. The main questions for the contractor were what kind of solar hot water systems are typically installed in the area, and the typical costs of installation and maintenance. The preferred method for this was via telephone or in person.

4.1.3 Manufacturers

Following the interviews with the householder and contractor, provided that the specific system that had been installed is a viable option under the Solar Colwood program, we decided to approach the manufacturer of the system to acquire detailed descriptions of the components of their solar hot water systems, to be used in our LCA. The preferred method for this was via email or telephone.

4.2 GaBi4 Software

In order to perform our LCA, we conducted an internet search on different software packages that are specifically designed for such work. Following this research, an LCA software package made by PE International called GaBi4 was chosen. The reason GaBi4 was chosen is because it is the most widely-used software package for performing LCAs (GaBi Software, 2011). While researching LCA software the team also came upon the SimaPro program, but it was not chosen for the analysis due to its high purchase cost (Product Ecology Consultants, 2011).

Most LCA software packages, GaBi4 included, typically cost thousands of dollars, but a free temporary license for students is offered for a fully-functioning copy of GaBi4. The process for obtaining the license was simple; copies of student IDs and registration information were sent, along with one of the sponsor's signatures and the school stamp, to PE International, who responded via email with a license key and a link to download the software (GaBi Software, 2011).

The team learned to use GaBi4 through the tutorials provided and through experimentation with the software. It soon became obvious that it is a powerful tool that is capable of performing very in-depth analyses of materials and processes. Due to the time constraints of this project, we decided not to attempt to learn all of GaBi4's functions. After some discussion, it was concluded that learning the basic functions would provide a reasonable estimate of the environmental impacts of a solar hot water system, and that this would be sufficient to complete this project (GaBi Software, 2011).

Part of what makes GaBi4 so powerful is that provides access to large databases of information about the environmental impacts associated with the different inputs and outputs of resource extraction, transportation, manufacturing, and disposal, for a large number of materials. However, not every material or process is accounted for; if one is not in the database, it can be easily added. For example, the hot water tank information had to be entered by us because it was not in the GaBi4 database. The necessary inputs (materials and energy) and outputs (a hot water tank) required to assemble the hot water tank were entered and incorporated into the model. The software allows the user to build a model that shows all of the steps involved in making a product, and how they connect to one another. This makes it easy to keep track of the simplest and smallest things in a workflow. GaBi4 has the ability to create graphs and display the weaknesses of certain inputs and outputs. It also can maintain the information in tables in a spreadsheet. The weaknesses (the production steps that result in the greatest impacts) can be displayed by the different categories. It can display the different types of pollution (such as heavy metals and CO_2) that are created from the different processes involved in making something. GaBi4 also has the ability to export the data into different formats for manipulation or presentation (GaBi Software, 2011).

LCA software such as GaBi4 relies on extensive databases of materials in its models. Although PE International claims that the information in their databases is accurate and current, it is likely that some assumptions have gone into calculating the specific environmental impacts of a particular process. These assumptions introduce certain inaccuracies in the model; when dealing with a product that has undergone a variety of different manufacturing processes, for example, the inaccuracies may compound, resulting in significant errors. In addition to the inherent problems of the model, using GaBi4 requires very specific information on the materials and processes. For example, for something that might seem to be straightforward, such as a piece of steel plate, the calculated environmental impacts may vary greatly, depending on exactly how the steel was produced, shaped, transported, and so on. If these specific details are unknown, then the steel can only be included in the model by making certain assumptions about them, which could introduce significant errors.

4.3 Benefit Cost Analysis

This section includes a review of BCA methodologies, including how one was chosen for this project.

4.3.1 Defining the Project and the Scale

A BCA is potentially an important tool to deliver tangible information to the Colwood homeowners who are contemplating installing a solar thermal heating system. The aim of the BCA is to determine whether or not implementing a residential solar thermal heating system has a monetary net gain or loss.

It was determined that the BCA was to be performed from a homeowner's perspective. The associated social and environmental benefits and costs were commented on, but they were not included as these parameters are difficult to assign monetary value to. However, the results of the BCA will be supplemented with a description of the associated social and environmental benefits and costs, and it is hoped that this information will be considered in the decision-making process. The time frame for the BCA will be 30 years, with a solar hot water system's lifespan estimated to be between 20 to 40 years (SolarBC, 2008). A variety of scenarios will be developed to create a better representation of potential future energy inflation.

4.3.2 Description of the Inputs and Outputs

To generate a qualitative list of benefits and cost for the project of installing a solar hot water system, all of the inputs and outputs of the project are established. Inputs and outputs are listed regardless of the ability to assign monetary values to them. For example, an input would include the cost of purchasing and installing the solar hot water system, while an output would include the energy savings achieved after implementation of the project. Similarly, social diffusion, such as increased neighborhood awareness of energy savings options, is an output of the project, but one to which it is difficult to assign a monetary value.

4.3.3 Estimation of the Social Benefits and Costs

After creating a qualitative list of the benefits and costs for the project of installing a solar hot water system, monetary values are assigned to them. For the purposes of this project, only homeowner benefits and costs were assigned monetary values, since social and environmental benefits and costs are too difficult to assign monetary values to.

4.3.4 Discount Rates

Choosing a Discount Rate for an Environmental Project

To comprehend the costs and benefits associated with an environmental project, it is important to run a BCA using different discount rates. A discount rate expresses the future value of costs and benefits with respect to their present day value. This is important as one dollar spent today is typically valued less than one dollar spent in the future (Whitehead, 2005).

The real rate of interest, which should be utilized when performing a BCA, is determined by subtracting market inflationary expectations from the market interest rate. Market interest rates consider how people value present consumption versus future consumption, which reflects societal values (Whitehead, 2005). The real rate of interest appropriately reflects society's average rate of time preference, and it can be found by examining Canadian bonds, which are purchased primarily by Canadian citizens. Therefore, the real rate of interest is a proxy for society's positive rate of time preference (Olewiler *et al.*, 2002). The BCA was performed using the real rate of interest.

4.3.5 Comparison of the Total Benefits and Costs

After assigning monetary values to the established economic benefits and costs, and adjusting future benefits and costs to present monetary values by application of the determined discount rate, a comparison of benefits and costs is made using the following formula:

Net benefits = Total present value benefits – Total present value costs

The decision to move forward with the project is not dependent upon a positive net benefit. The uncaptured environmental and social benefits must be considered in addition to the net economic benefit when making a definitive decision on installing a solar thermal heating system.

5.0 Results

This section presents the results determined throughout the entire research and writing period.

5.1 Information Gathering, Surveys and Interviews

This section is a summary of the results that were collected during the meetings and emails between the group and the homeowners, manufacturers, and contractors. Results were collected in a variety of situations, including site visits such as the ones to the Solar Colwood Unveiling and the T`Sou-ke Nations.

5.1.1 Solar Colwood

As discussed in section 3.4, Natural Resources Canada has granted the Solar Colwood project $3.9 million to aid in the implementation of clean energy technology. This grant will be used in a number of ways, one of which is to provide an incentive to Colwood residents to install solar hot water systems in their homes. To incentivize Colwood residents, a tiered subsidy plan has been created; the earlier that residents jump on board, the greater the incentives. The first ten homes that are retrofitted with solar hot water systems will receive $3800 towards the cost of installation. The next 200 homes will get $3000 towards their installation. These incentives are substantial, relative to the cost of a solar thermal installation: a typical installation would be expected to cost between $9000 and $9500 (Robert Barry, Personal Communication, May 17, 2011). Colwood hopes to reduce the cost of materials needed by making bulk purchases of solar thermal system components (City of Colwood, 2011).

Householders and businesses that sign up for the installation of solar hot water systems will also receive the benefit of a home energy assessment. Solar Colwood will also make it possible for the householders to meet with Solar Colwood representatives to learn about the benefits of energy conservation projects. Additionally, each Solar Colwood home will be retrofitted with Smart Meters and Smart Home energy management systems. These systems provide the opportunity for the residents to control the operation of their home via control panels (City of Colwood, 2011).

In order to install a solar hot water system, Colwood residents must acquire a building permit from the City. Under the Solar Colwood program, the City will be reducing the cost of permits by 50% (City of Colwood, 2011).

There are several other benefits that Colwood residents will receive by participating in the Solar Colwood initiative. One of the largest is the creation of a number of jobs in the community; local contractors will benefit greatly from the Solar Colwood project, both from monetary gain from installing the systems, and gaining experience with what will likely become a more common technology in the future. Lastly, the residents of Colwood will benefit from a large amount of knowledge being shared throughout the community, with respect to sustainable energy practices. As the installations occur, community members will most likely speak to each other about the pros and cons of them, and this will increase Colwood's social capital considerably (City of Colwood, 2011).

5.1.2 T'Sou-ke Nation Site Visit

On February 1st, Hatley Park Consulting visited the T'Sou-ke Nation community to meet with Andrew Moore, the project manager for the community's various solar projects. He provided us with a comprehensive background to the project's inception and a tour of some of the installations.

During the tour the team gained an understanding of how the community thinks and acts in terms of their power and energy needs. Andrew Moore mentioned how First Nations communities such as this one originally depended on the sun, sea, and wind for energy. They have recently expressed a strong interest in going back to their old ways. Gordon Planes, Chief of T'Sou-ke Nation has said,

"It's good to be a part of using the gifts that the creator gave us in helping us to take care of Mother Earth. It is now appropriate that First Nations take the lead in demonstrating how to live without fossil fuels once again"

This statement signifies how much the people of the T'Sou-ke Nation care about the environment and how they are striving to protect it, and also how they wish others to follow their lead in adopting alternative technologies.

Andrew Moore told us about a number of different projects that the community was working on to make themselves more sustainable. Some of the projects being implemented or practiced are: reducing the use of oil and instead turning to green methods of energy production, planned waste reduction by implementing a composting green-bin program, and plans to build a greenhouse to aid in their food production needs. The community is working to become fully self-sufficient and their plans for a greenhouse are aimed at meeting a large amount of their food needs. They are also working with the children of the community to get them involved in sustainable practices. They are encouraging community involvement with the use of a sustainability goals tree. This involves the children writing down their sustainability goals on leaves, and sticking the leaves on the tree. An example of a child's goal was a promise to shut off the tap when brushing her teeth (Andrew Moore, Personal Communication, Feb. 1, 2011).

In addition to the above sustainability goals and practices that the community is working to implement, there are already a number of conservation programs in practice. Of the homes in the T'Sou-ke Nation community, each is utilizing a different strategy to become more sustainable. The first conservation program that was mentioned is the use of Energy Saving Kits (ESK Program). These kits are given out to the community and they contain such things as energy-saving light bulbs and low flow shower heads. The Energy Conservation Assistance Program was implemented to replace old refrigerators with newer, more energy-efficient ones. The use of social marketing is also being used to encourage the community to continue with sustainable practices. The T'Sou-ke Nation is also working to encourage the implementation of alternative energy projects in other First Nations communities, and they have become a leader in sustainability due to their installation of solar hot water systems in 37 of the 84 homes in the community (Andrew Moore, Personal Communication, Feb. 1, 2011).

The T'Sou-ke Nation solar project was a demonstration project to an extent, since one of their goals was to encourage other First Nations communities to develop ways of using clean energy. The solar project was not only beneficial in terms of clean energy, but also in the creation of several contracting jobs for the community members. When the solar project was put forward one of the main goals for it was to look ahead for the next seven generations. This means that the community wanted to create a program that would benefit not only the current community, but also the generations to come. During the tour of the community it was quite noticeable how proud that community members were of their clean energy adaptations, and they were thrilled to explain and show us the different parts of the systems. The success of this project has been so remarkable, that T'Sou-ke Nation is now one of the most sustainable communities in North America. (Moore, A. Personal Communication, Feb. 1, 2011)

Figure 3: Solar Thermal Panel. Source: J. Eikenaar

The solar community is complete with both photovoltaic cells as well as solar thermal heating panels. Photovoltaic cells are used to provide electricity to the administration building as well as the community. With photovoltaic cells, the solar energy gets converted to direct current then to alternate current to provide electricity to the buildings.

This energy gets stored in 16 large batteries in the administration building, and is used when the sun goes down. During the tour it was mentioned that one time when a power outage occurred, the administration building was able to stay powered due to all of the stored electricity. The other type of solar power used in the T'Sou-ke community is solar thermal heating. These solar thermal panels are on 37 of the 84 homes in the community and they are thicker than the photovoltaic cells. It was mentioned that during the winter the community has to pay for power since they do not get as much exposure to sun as they would in the summer months. This is not an issue though, since the community makes up for these costs, as they produce more energy than they actually need in the summer and can sell the energy back to the grid (Moore, A. Personal Communication, Feb. 1, 2011).

At one point of the tour, one of the residents who learned how to install the solar panels gave a tour of his solar thermal heating system. The system that he had chosen to install was the two tank system. In this system, the solar panel gathers the heat from the sun and heats the water that is passing through the soft copper coils. The heated water then moves towards the first tank and cycles through it to heat the water in the tank. After the water has been heated it gets fed into the 200L secondary tank and since it has already been preheated it takes the water heater less energy to heat it. Ultimately, this saves the household money since their water heater will not have to work so hard to heat the water. It is estimated that the payback period for installing the solar hot water system is about 8 to 10 years (Moore, A. Personal Communication, Feb. 1, 2011).

Figure 4: Two-tank system. Source: J. Eikenaar

During the tour it was quite clear that the most common method of solar thermal heating for a family home involved the two tank method. This method is a much better investment for family homes because they can still use the same amount of water that they normally use but at a cheaper cost. Another way to decrease the cost of electricity to heat the water is to implement low flow shower heads in the home. This way the family will use less water than normal, and they will also save energy with the use of the solar thermal heating system (Moore, A. Personal Communication, Feb. 1, 2011).

The completion of the T'Sou-ke Nation solar project gave a good indication of the pros and cons of solar thermal heaters. After the installation of the solar thermal systems in the community there were a few significant problems that had to be repaired; the original contractor went bankrupt after completing the installation, so other parties had to be involved, which complicated the entire project. The total cost of these repairs was near $100,000 (Moore, A. Personal Communication, Feb. 1, 2011). Since these mistakes were made with the T'Sou-ke project they will hopefully be preventable with other solar thermal system implementations in the future, such as the Solar Colwood project. The T'Sou-ke Nation project was a successful project that will act as an inspiration to other communities that are considering the implementation of solar power.

5.1.3 Householder Interview Results

One of the project sponsors, Dr. Charles Krusekopf, was acquainted with a Colwood family who installed a solar hot water system in early 2010. The family, who wished to remain anonymous, agreed to an interview to discuss the system. In March 2011, one of our team visited the house to meet with the one of the family members. She also arranged to have the contractor who installed the system to be present as well, as it was time for the system's annual inspection, and it was thought he would be willing to speak to our team member about solar hot systems in general.

The householder's family moved to Colwood two and a half years ago, prior to which they had thought that it might be a good idea to install a solar hot water system, as they were interested in improving their home energy efficiency. With this in mind, one of their criteria used to shop for a house was a south-facing roof that would get a lot of sun exposure. When they bought the house, they were told that they could not insure it without replacing the heating system's oil tank, which dated to 1973, the year the house was built. This news gave them the impetus to consider solar hot water as an option, which they knew would be more expensive to install, but would hopefully offer long term benefits, such as reduced energy bills and the knowledge that they would not be using as much fossil fuels as they would if they kept on using oil.

After speaking with about ten different local contractors who work with solar hot water systems, they chose to deal with Victoria's Island Energy, who, in addition to installing the system, helped them apply for various grants and incentives, such as one offered under the SolarBC program, which ended on December 31, 2010. With the assistance of Island Energy, a home energy audit to determine the building's energy efficiency was conducted. This enabled the householders to see where their home could use some improvements, with regards to energy efficiency. According to the householders, they used this information to make upgrades to their home, such as installing a new dishwasher and low flow shower heads, and they will continue to make more upgrades in upcoming years.

As of the interview date, they had not yet received the $1000 grant from the SolarBC program, but they were expecting it quite soon. However, Island Energy offered them a substantial discount at the time of installation, in exchange for using the installation as a teaching workshop for trainees as part of the CanSIA certification process. The final installation cost was approximately $7200. The householders have noticed a reduction in their monthly energy bills, and they estimate that the payback period for installing the system will be ten years.

On the roof of the house are two rectangular solar thermal panels and one small photovoltaic (PV) solar panel. The two larger panels are used to transfer heat energy from the sun to propylene glycol that runs through them in a small bore copper pipe. The small PV panel provides enough current to run the pump that pushes the glycol from the basement of the house up to the panels; as both types of panel only work when the sun is shining, the glycol is only flowing when there is heat energy to be moved from the roof to the basement. The pipes travel down into the house to the basement, where a small heat exchanger transfers the heat energy to water in a double walled hot water tank. As there was limited space in this part of the house, a second water tank, which would increase the hot water capacity of the system, could not be installed. This was likely to be an issue for the household, as there are four people living there. To circumvent this problem an on-demand system was installed; this is essentially a small box that burns natural gas to heat up the warm water from the storage tank as it flows through it whenever a hot water tap in the house is opened. The on-demand heater only heats water that has been pre-heated in the solar panels and stored in the water tank. In the winter months, when the solar panels will not warm the domestic water all the way to the required 120 or 140F, the on-demand system will do so. In the summer months, the solar panels alone are often enough to bring the domestic water up to that temperature, so the on-demand system does not use any fuel.

The householders commented that their hot water system has been largely problem-free since they installed it. Although they have made a few changes to their habits, such as not using a dishwasher or laundry washing machine early in the morning before the sun has been up for long, these have not been major inconveniences. In the first few months of using the system, they did notice that at certain times the water would suddenly go cold, but this was found to be a minor problem with a wire on the on-demand component that was simple to fix.

The family has noticed that the installation has generated some interest in their neighborhood. In particular, some of the neighbors who can see the panels on the south side of the house have asked questions about how the system works, and the cost of installing and running it.

In addition to installing a solar hot water system, the family also upgraded their furnace (from the old oil-burning one to a high efficiency gas model) and replaced their exterior doors to reduce heat loss. They considered replacing some single pane windows, but found that the incentives for doing so are not great, so they relented.

5.1.4 Contractor Interview Results

Following the interview with the Colwood resident, Island Energy's Rob Barry agreed to discuss the specific system installed there, as well as solar hot water systems in general. He provided our team with enough information to begin approaching the manufacturers of the various components of the system, as well as information on how the systems are installed and maintained. Following the interview, it was thought that we had enough information to continue the project by beginning the LCA on the system that was installed in the house, but a follow-up conversation with Mr. Barry informed us that a recent change to the requirements meant that this particular system could not be installed under the Solar Colwood program. Specifically, the new requirement called for the heat exchanger, which is the part that exchanges heat from the propylene glycol to the domestic water, to be double-walled. This is an added safeguard to ensure that the glycol, which is toxic, cannot accidentally leak into the domestic water. Following this conversation, the team pursued other avenues to determine which system should be analyzed in the LCA, and after finding a candidate, Mr. Barry confirmed the suitability of it for installation in Colwood.

5.1.5 Identification of the EnerWorks Solar Thermal Systems

After meeting with Liz Kelly, a representative of SolarBC, the team decided to research the solar hot water systems that have been used on southern Vancouver Island. This research included using the SolarBC website and viewing the map of solar installations across Vancouver Island. The team chose to focus on systems that have been installed on the southern half of the island, as these are the systems that would likely be the most commonly considered for installations in Colwood.

The balloons on the map represent residential installations; each was recorded with respect to its location, system type, and contractors who were responsible for the installation (Figure 5). There were a number of different systems that were used, but the most common system seemed to be the EnerWorks System. This observation was confirmed by Liz Kelly. A table listing each system can be found in the appendix as Table 1.

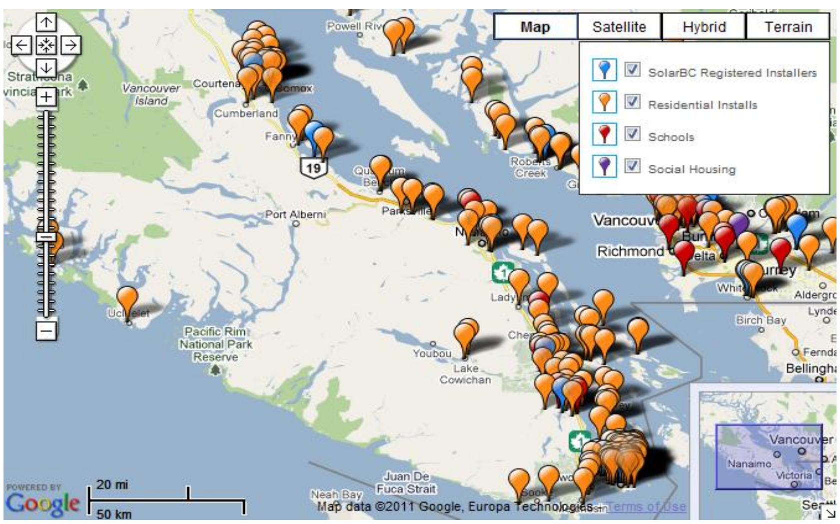

Figure 5: Google Map of Solar Hot Water Installations throughout Southern Vancouver Island

A pie chart was constructed to show the percentages of the different types of systems that were installed on southern Vancouver Island (Figure 6). This shows that 53.47% of the installations were of EnerWorks Systems products, with the next most popular brand being Globe Solar Energy (10.89%).

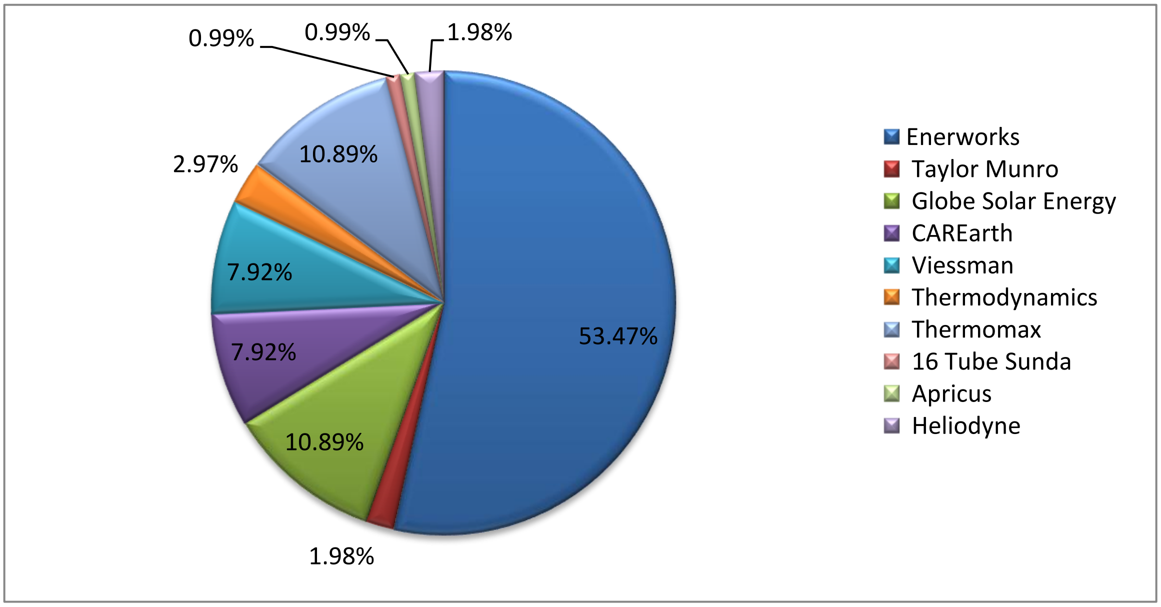

Figure 6: Distribution of the Brands of Solar Hot Water Systems Installed on Southern Vancouver Island.

5.1.6 Manufacturer Interview Results

After attending the session put on by Liz Kelly on behalf of Solar BC, the team was able to determine what the most commonly used system on southern Vancouver Island was. EnerWorks systems were seen to be the most commonly used systems on the island, and the next step was to research these systems to learn more about them. While researching, there were two systems that the team thought would be relevant to the local climate.

An email was sent to the Director of Applications Engineering at EnerWorks with a request for information regarding two different systems. In the email response the team was notified that of the two systems, one of the systems was inappropriate for the climate of southern Vancouver Island. The system that seemed to be the most commonly installed system was the EnerWorks Spectrum Preheat Appliance. A schematic of this system is shown in Figure 7. The Director of Applications Engineering was helpful in that he was able to provide a list of all of the parts to the system as well as their composition and their embodied energy coefficients. Once this datum was supplied, the team was able to complete the LCA.

Figure 7: Schematic Diagram of the EnerWorks Spectrum Preheat Appliance from: http://www.EnerWorks.com

5.1.7 Identification of a Typical Conventional Water Heating System

Upon consultation with our sponsors, it was deemed unnecessary to identify a typical hot water system that is currently used in Colwood, BC. As most of the installations will be done as retrofits, it is assumed that Colwood residents already own conventional hot water tanks and heating systems, and that they are faced with the decision of integrating a solar hot water system into their conventional system. When EnerWorks provided us with a detailed components list for their solar hot water system, they included information for a conventional hot water tank. This is because in colder climates, such as in Canada, they recommend that the system be installed in conjunction with a second, conventional hot water tank, which would heat the solar-heated water to domestic requirements. By using the embodied energy coefficients for the conventional tank supplied by EnerWorks, we can assume that the difference between a conventional hot water system and an EnerWorks solar hot water system is simply everything that is installed in addition to the conventional tank. This information made it unnecessary for us to identify a conventional hot water system that would commonly be used in Colwood.

Similarly, for completion of the BCA we were provided with information from City Green regarding the Canadian average home energy consumption for heating hot water by using electricity and gas. This gave us a better representative estimate of how much energy is involved in heating hot water, in comparison to selecting a singular conventional hot water tank and utilizing the manufacturer's projected energy inputs.

5.1.8 Embodied Energy Coefficient

Embodied energy is defined as the total input of energy consumed in the life time of a product, including the extraction of raw materials, fabrication, manufacturing, and transport (Hammond and Jones, 2011). A database of embodied energy values has been generated for various industrial materials, such as copper. The average embodied energy for copper taken from the database is consistent with the values supplied from EnerWorks. We have made the assumption that the embodied energy values supplied by EnerWorks for the specific components that make up the Spectrum Preheat Appliance include the extraction of resources, fabrication, manufacturing, and transport to produce the specific listed component. We arrived at this conclusion by observing the identical values in Hammond and Jones' database, and the definition of embodied energy presented.

5.2 Lifecycle Assessment

In this section the results of the LCA of the EnerWorks Spectrum Preheat Appliance has been outlined.

5.2.1 Goal Definition and Scope

The overall goal for performing the LCA is to provide information on the environmental impacts of installing, operating and the disposal of the solar thermal hot water system. This information will then be presented to Colwood homeowners to inform them of the economic, environmental, and social benefit costs.

In order to perform the above step, information was found for a solar hot water system as well as these factors below:

- Mining
- Manufacturing of the following components
    - Control Panel
    - Pump
    - Solar Panel
    - Water Tank
- Transportation
- Operation and emissions
- Recycling
- Disposal

Each factor has a limited depth and some assumptions were made due to the amount of time and information available. For example, it was not possible to determine the emissions required to mine and refine the resources. Without knowledge of the specific mining and manufacturing processes required to make the materials for the components of the system, making assumptions regarding these processes could introduce significant errors. Therefore, our focus for this section strictly focuses on the resources lost due to mining.

Manufacturing covers what types of materials and processes were required to make the four components that were chosen to complete the LCA. These are the control panel, pump, solar panel and water tank. Due to the time allotted, it was not be possible to study minor parts such as nuts, bolts and plumbing materials.

Transportation covers the transportation of the assembled systems to Vancouver Island. Some assumptions that were made include the size of the vehicle and the efficiency of the engine.

Information that was gathered included the type of fuel, and the distance travelled. The GaBi4 database includes information for a large variety of different vehicles that are used for transportation, so it is a matter of selecting the most representative one. We did not focus on the transportation or refining of the fuel. Another assumption that was made was that the route chosen was the most efficient, in terms of fuel cost.

Operation discusses which parts need to be replaced, the amount of energy used during the life span and other factors, such as maintenance. The operation was decided as 30 years for the life span of a solar thermal heating system. With the life span of the unit, it was possible to determine if there are environmental benefits through reduced energy consumption.

For recycling, we assumed that 100% of the recyclable material would be recycled. We chose to simplify this because a recycling process could have an LCA of its own.

Disposal assumed that the remaining material would end up in a landfill. This was simplified because it is not known what materials in the system would be recycled and disposed of, and how either of these processes would be accomplished. Once again, making assumptions on these processes could introduce errors. This simplified assumption also helped determine the environmental costs of the lost resource and what is added to the landfill. With the above information, it was possible to gain some understanding of the environmental impacts of installing a solar thermal heating system.

Due to the large number of assumptions inherent in the use of GaBi4 software, it was decided that it would no longer be used to complete the LCA portion of the deliverables. As the engineers at EnerWorks provided the embodied energy coefficients, the GaBi4 software was only used as a means to keep track of all the materials data.

5.2.2 Inventory Analysis

The datum to complete the LCA of the EnerWorks Spectrum Preheat Appliance System was supplied by the Director of Applications Engineering at EnerWorks. This included lists of the different components of the system, the composition of each of the components, and the embodied energy coefficients for each of the components. The components of the system include the Energy Pack, the HeatSafe Collector, mounting kits, and the water tank. The datum supplied by EnerWorks are attached in Appendix 5. All of these components were assessed for their environmental impacts, such as kg CO_2 that were created in the various manufacturing steps. These results can be seen below in Tables 1 to 4 in section 5.2.3.

5.2.3 Impact Assessment

In this section the contributions to the impact category, based on the results of the inventory analysis, are summarized. The conversions to masses of CO_2 from the embodied energy coefficients are detailed in Appendix 5 and summarized in Table 1. The conversions were calculated three different ways by assuming production of the components in three different Canadian provinces; British Columbia's conversion factor is quite small (0.027 kg CO_2/kWhr), because most of its electricity is generated hydroelectrically. In contrast, Alberta generates most of its energy by burning coal, which releases a much greater amount of CO_2, and Ontario represents a middle ground because it uses a combination of hydroelectric, coal, and nuclear (Table 5.2-1).

Table 5.2-1: Four components of the EnerWorks Spectrum Preheat Appliance and a comparison of the kg CO_2 that are created during the construction of the system, using different conversion factors for three different provinces, based on that province's method of generating electricity.

CO_2 released during manufacture (kg)

	Energy Pack	HeatSafe Collector	Mounting Kit	Water Tank	Total CO_2 (kg)
BC	3.995	12.374	4.532	70.337	91.238
Ontario	34.922	108.162	39.616	614.801	797.501
Alberta	135.395	419.358	153.597	2383.657	3092.007

Table 5.2-2: Conversion factors used to convert embodied energy coefficients for the components of the EnerWorks Spectrum Preheat Appliance in three different Canadian provinces.

Province	**Conversion Factors ($kg\ CO_2/kWh$)**
Alberta	0.915
Ontario	0.236
BC	0.027

Given the estimated 30 year lifespan of the product, we have assumed that the metal and glass components of the system will be recyclable at the end of the system's life, but the plastics will not (Tables 5.2-3 and 5.2-4).

Table 5.2-3: List of materials that are assumed to be recyclable at the end of the system's projected 30 year lifespan.

Component	**Mass (kg)**
Steel	144.34
Aluminum	7.52
Copper	3.18
Brass	2.30
Magnesium	1.81
Glass	30.76
Zinc	0.02
Total	189.93

Table 5.2-4: Materials that are assumed to be not recyclable at the end of the system's projected 30 year lifespan.

Component	Mass (kg)
Various plastics	46.32

The amount of CO_2 that would be generated during the transportation of the assembled components has been calculated, based on two modes of transportation from Toronto, Ontario (where EnerWorks is based) to Victoria, BC (Table 5.2-5). The conversion from litres of diesel fuel to kg CO_2 is detailed in Appendix 5 (Carbon Trust, 2011).

Table 5.2-5: The total amount of CO_2 produced when transporting the EnerWorks Spectrum Preheat Appliance by two different modes of transportation from Toronto to Victoria.

Mode of Transportation	Litres/100km	Litres of Diesel	Distance (km)	CO_2 Produced (kg)
Semi-Trailer	39.5	1698.5	4300	4538
Train (per tonne)	0.49	21.07	4300	56

5.2.4 Interpretation of Results (Summary of Environmental Impacts)

If the EnerWorks systems were manufactured and assembled in B.C., the carbon dioxide emissions would be minimal (91.24 kg per unit) since most of the energy comes from hydroelectric power. Manufacture and assembly in Alberta would produce the most CO_2 emissions due to the power mostly coming from the burning of coal. This would produce 3092 kg CO_2. As EnerWorks is based in Ontario, the most realistic scenario is manufacture and assembly in Ontario, which would produce 797.5 kg CO_2. EnerWorks has confirmed that the components are indeed assembled in Ontario, but we could not find information on where the components are originally manufactured.

Regarding transportation of the system from Ontario, if a semi-trailer truck were used, 4538kg CO_2 would be released. However, this number is for the entire truck, so the amount of CO_2 generated during transportation of a truckload of systems would likely be greatly reduced per system. Despite this, even a fully loaded truck cannot compare to the fuel efficiency of a freight train (Forkenbrock, 2001).

To combine the emissions of CO_2 from transportation and manufacturing/assembly, the numbers above can simply be added together. Assuming a fully loaded 36 tonne capacity semi trailer truck, the transportation from Ontario to Victoria would release approximately 31.5kg CO_2 per system. In comparison, a train would release only 14kg CO_2 per system. The total emissions are summarized in Table 5.2-6.

Table 5.2-6: Total CO_2 emissions related to the manufacture, assembly, and transportation of a single EnerWorks Spectrum Preheat Appliance, assuming manufacture, assembly and transportation in Toronto and transportation from Toronto to Victoria, BC.

Mode of Transportation	**kg CO_2 released**
Semi trailer truck	829
Freight train	811.5

The total amount of CO_2 saved during the lifetime of a solar hot water system, as compared to both the natural gas and the BC average for CO_2 emissions for fuel type is summarized in Table 5.2-7.

Table 5.2 -7: The amount of CO_2 saved during the operation use of the solar thermal heating unit. The amount of energy the unit saves per year 2235 kWh per year or 67050 kWh during its life time.

Source of Power	**Conversion Factor**	**Amount of CO_2 Saved (kg/year)**	**Amount of CO_2 Saved (kg/30 years)**
BC average	0.027	60.34	1810.35
Natural Gas	0.18523	413.98	12419.67

Conversion factors retrieved from Aube, (2001) and Carbon Trust (2011).

5.3 Benefit Cost Analysis

This section describes the results of the BCA for the EnerWorks Spectrum Preheat Appliance.

5.3.1 Qualitative List of Benefits and Costs

This section identifies the inputs and outputs of solar thermal heating and conventional water heating systems.

- Homeowner Benefits
    - Solar Colwood Rebate
    - LiveSmart BC Rebate
    - Energy savings
    - Personal satisfaction gained from reduction of GHGs and other environmental pollutants associated with energy production and use
    - Satisfaction of exemplary role modelling of environmental protection to the community
    - Increased awareness of water and energy consumption

- Homeowner Costs
    - Cost of the EnerWorks Spectrum Preheat Appliance
    - Installation costs
    - Cost of inspection by Colwood municipality home inspector
    - Risk of system failure or problems caused by installation, such as a leaking roof
    - Risk of improper installation of the solar thermal system

- Social and Environmental Benefits
    - Neighbourhood awareness of energy savings. A solar panel on an individual's roof promotes awareness of energy efficiency options throughout the neighbourhood
    - Reduction of GHGs and other airborne pollutants creates cleaner air for society
    - Participating in the Solar Colwood program creates a sense of community engagement

- Success of the Solar Colwood could influence other communities to facilitate and engage in a similar program
- Development of expertise and green job training. Installers become more proficient at installing solar thermal heating systems which lowers future costs of installing the systems
- A reduction in GHGs, from using less energy, is a mitigative action against climate change
- A reduction in other airborne pollutants is beneficial to the environment
- Awareness of water usage conserves water resources

- Social and Environmental Costs

- Solar Colwood rebate given to an individual comes from federal tax dollars, which translates to a cost incurred to society. This is also money that can no longer be spent on other federal programs
- LiveSmart BC rebate given to an individual comes from provincial tax dollars, which translates to a cost incurred to society and money that can no longer be spent on other provincial programs
- Non-renewable resources used in the production of the solar hot water system
- Release of GHGs in the production of the system (as determined in the LCA)

5.3.2 Evaluation of Benefits and Costs

Chosen Discount Rate

Based on rates provided by the Bank of Canada, the long-term real return bond rate is utilized as a discount rate. The real return bond rate is inflation-adjusted, and as of April 25, 2011, is 1.01%. The discount rate at which the benefit-cost analysis was performed was 1.0% (Bank of Canada, 2010).

Scenarios

Three scenarios were developed to cover a spectrum of potential real annual energy inflation, for electricity and natural gas, over the next 30 years. Within each scenario, the three remaining Solar Colwood incentives (Table 5.3-4) were applied. This was calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate, based on a 1% discount rate.

A fourth scenario based upon a discount rate of 0%, at a moderate rate of real annual energy inflation, was performed to represent the case that both current and future generations are valued equally. This was calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation. Found below is a summary of the four scenarios applied in the BCA, with the changing variables used within each scenario highlighted.

Scenario 1 (No Change)

Scenario 1 considers a real annual energy inflation rate of 0%, for both electricity and natural gas, over the 30 year project period with net benefits presented at the three remaining Solar Colwood incentive levels (2-4).

Scenario 2 (Moderate Increase)

Scenario 2 considers an annual real annual energy inflation rate of 3.0% for the rate of electricity, and 2.0% for the rate of natural gas over the project period of 30 years with net benefits presented at the three remaining Solar Colwood incentive levels (2-4).

Scenario 3 (High Increase)

Scenario 3 considers an annual real annual energy inflation rate of 5.0% for the rate of electricity, and 4.0% for the rate of natural gas over the project period of 30 years with net benefits presented at the three remaining Solar Colwood incentive levels (2-4).

Scenario 4 (0% Discount Rate at Moderate Increase)

Scenario 4 considers an annual real annual energy inflation rate of 3.0% for the rate of electricity, and 2.0% for the rate of natural gas over the project period of 30 years with net benefits presented at the three remaining Solar Colwood incentive levels (2-4).

Justification of Energy Inflation Rates

Natural Gas

The consensus forecast for the Intra-Alberta natural gas market indicates natural gas prices as increasing at 4.0% per annum, from 2010 to 2020 (NRC, 2011a). The Intra-Alberta market is Canada's natural market, and an inflation rate of 4.0% per annum is the nominal rate of natural gas inflation. Based on the data collected from the Intra-Alberta market, a real annual inflation rate of 2.0 % was used in scenario 2 to cover moderate increase, and a real annual rate of 4.0% for scenario 3 to cover the high end. This assumes an inflation rate of 2.0%, which was deducted from the nominal value of 4% to estimate the real annual rate of inflation (NRC, 2011b).

Electricity

Table 5.3-1: Estimated Real Annual Change (%) in Electricity Rate

2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021-2030**
5.5	11.4	3.5	6	5.5	5.4	3.4	1.5	2.3	2.8	0.9

(BC Hydro, 2011b).

Based on the data presented in Table 5.3-1, collected from BC Hydro's Integrated Resource Plan – Long Term Rate Forecast, the three electricity inflation rates were determined. Scenario 1 was run using a real annual energy inflation rate of 0%. Scenario 2 was run using a real annual energy inflation rate of 3%. This represents a moderate rate of energy price rises compared to the general rate of inflation, and was calculated based on energy inflation projections from 2011 to 2030. This energy inflation is estimated over a time frame that is closest to the duration of the project. Scenario 3 was run using a real annual energy inflation rate of 5%. This represents a high rate of projected inflation, and was calculated based on inflation projections from 2011 to 2020. This rate best reflects projected increases for the next decade due to projects BC Hydro are currently implementing, including the construction of a new dam. This rate however does not reflect preceding years beyond a ten year scope as inflation should subside once projects have been completed (BC Hydro, 2011b).

Table 5.3-2: EnerWorks Spectrum Preheat Appliance purchase and installation cost. Quotes were received from three installers for a two collector system. Installer names have been omitted by request.

Installer	Quote ($)
One	8500
Two	8500
Three	9700
Average	8900

A summary of the fixed variables used in the four BCA scenarios is provided in Table 5.3-3.

Table 5.3-3: Fixed variables applied to the four BCA scenarios.

Variable	Value
Discount Rate (%)	1.0 (scenario 1-3), 0 (scenario 4)
Cost of the EnerWorks Spectrum Pre-Heat Appliance, including installation ($)	8900
Inspection Cost ($)	55
Annual energy savings achieved by the system (kWh/yr)	2235*
Current cost of Electricity ($/kWh)[1]	0.0627
Current cost of Natural Gas ($/kWh)[2]	0.0515

(BC Hydro, 2011a)[1]
(Fortis BC, 2011)[2]

*The amount of energy (kWh) saved after implementation of the EnerWorks system was estimated to be approximately 2235 kWh. This annual energy savings value was determined based on data provided by Liz Kelly (personal communication, April 2011) collected through the SolarBC project. SolarBC data indicated that approximately 536,403 kWh of energy was displaced by the implementation of the EnerWorks system in 240 homes in one year. To determine the approximate energy savings of 2235 kWh; the overall energy savings of 536,403 kWh was divided by the 240 homes which had implemented the system. This estimate was used in the BCA as an estimate of the average energy savings the EnerWorks system can provide on a yearly basis, and is representative of real data collected within BC.

Table 5.3-4: Summary of the scenarios developed for the BCA.

Scenario	**1**	**2**	**3**	**4**
Electricity Inflation (%)	0	3	5	3
Natural Gas Inflation (%)	0	2	4	2
Solar Colwood Incentive Levels	2-4	2-4	2-4	2-4

Table 5.3-5: Solar Colwood incentive profile levels with LiveSmart BC solar thermal rebate as of June 28, 2011.

Level	**Solar Colwood ($)**	**(Over 6GJ) ($)**	**LiveSmart ($)**	**Total ($)**	**Notes**
1: First 10	3300	500	500	4300	Already gone
2: 200	2500	500	500	3500	
3: 350	2000	500	500	3000	
4: 320	1750	500	/	2250	

(Solar Colwood, 2011b)

5.3.3 Comparison of the Social Benefits and Costs

The net benefits for each of the four scenarios have been determined, for homes that currently use electricity or natural gas to heat water. A negative number indicates that the costs exceed the benefits.

Scenario 1

Table 5.3-6. Net present value of installing the EnerWorks Spectrum Preheat Appliance at real electricity and natural gas inflation rates of 0%, across the three remaining Solar Colwood incentive profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate.

	Incentive Profile ($)		
	3,500.00	3,000.00	2,250.00
Net Benefit (electricity)	-1,838.45	-2,338.45	-3,088.45
Net Benefit (gas)	-2,484.47	-2,984.47	-3,734.47

Scenario 2

Table 5.3-7. Net present value of installing the EnerWorks Spectrum Preheat Appliance at real electricity and natural gas inflation rates of 3% and 2% respectively, across the three remaining Solar Colwood incentive profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate.

	Incentive Profile ($)		
	3,500.00	3,000.00	2,250.00
Net Benefit (electricity)	156.28	-343.72	-1,093.72
Net Benefit (gas)	-1,496.73	-1,996.73	-2,746.73

Scenario 3

Table 5.3-8. Net present value of installing the EnerWorks Spectrum Preheat Appliance at real electricity and natural gas inflation rates of 5% and 4% respectively, across the three remaining Solar Colwood incentives profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate.

	Incentive Profile ($)		
	3,500.00	3,000.00	2,250.00
Net Benefit (electricity)	2,275.34	1,775.34	1,025.34
Net Benefit (gas)	-59.18	-559.18	-2,250.00

Scenario 4

Table 5.3-9. Net present value of installing the EnerWorks Spectrum Preheat Appliance at real annual electricity and natural gas inflation rates of 3% and 2% respectively, across the three remaining Solar Colwood incentives profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate based upon a discount rate of 0% (considers present and future generations are equivalent).

	Incentive Profile ($)		
	$ 3,500.00	$ 3,000.00	$ 2,250.00
Net Benefit (electricity)	1,211.96	711.96	-38.04
Net Benefit (gas)	-785.51	-1,285.51	-2,035.51

6.0 Discussion of Results

This section contains a discussion of results for both the LCA and BCA portions of the project.

6.1 LCA Results

The GaBi4 software was not used for the LCA model of the solar thermal heating unit because of the large number of assumptions that had to be made. Many of the materials in the lists supplied by EnerWorks were not listed in the GaBi4 database. As many of the materials and components can be produced by different methods, the selection of a particular material can apparently create very different results in the impact assessment. The scope our project did not include researching the different types of production processes, and the limited time for this project meant that we were unable to determine specific production processes and sources for the materials used in the components. Therefore, to use GaBi4, we would have made too many assumptions for it to be very accurate. The project shifted the LCA to focus on embodied energy, which is an estimate of the energy stored in the component from mining, refining and manufacturing (Hammond & Jones, 2011).

Using the embodied energy approach is advantageous over using the GaBi4 software, as we were required to make fewer assumptions about the data. The parts list from EnerWorks included embodied energy values for every component required to make the solar thermal heating unit. The information was cross-referenced with the literature (Hammond & Jones, 2011) to ensure that the numbers for embodied energy and the approach were valid. It should be noted that the estimates of embodied energy will themselves have some associated uncertainty, most likely as a result of averaging values for different processes. However, a strong advantage of the embodied energy approach is that the values can be easily converted into kg CO_2. Converting embodied energy into kg CO_2 also allowed us to determine how much CO_2 is saved during the operation of the solar thermal unit; this is something that would have been difficult to show in GaBi4. The disadvantage of using only the embodied energy is that other emissions and pollutants, such as heavy metals, volatile organic compounds, and acid rain could not be accounted for, which limits the environmental impact assessment to just CO_2. However, it was decided that the embodied energy approach was still preferable to using GaBi4.

The EnerWorks system would produce a minimal amount of CO_2 if the parts were made and assembled in British Columbia; there would be a release of 91.24 kg $CO_{2,}$ which is a lower impact compared to having the systems produced in Alberta (3092.01 kg CO_2). The EnerWorks systems were assembled in Ontario, meaning 797.50 kg CO_2 were produced. An assumption that was made is that the components were also manufactured in Ontario; in actuality the materials and resources would likely be sourced from all over the world.

As the EnerWorks systems are assembled in Ontario, the transportation to Vancouver Island became a consideration. If the mode of transportation is assumed to be semi-trailer truck, the amount of CO_2 produced would be 4538 kg. This impact is quite large but it should be noted that this number is for only one system being transported by this method, whereas in reality a semi-trailer truck would be loaded, which would reduce the emissions per system. The emissions could be further reduced by using a freight train, which has a much smaller impact than a semi-trailer truck, at only 56 kg CO_2 per tonne. The LCA model covers the transportation of just the finished product from Toronto to Victoria, it does not cover the transportation of the parts from all over the globe. No information could be gathered on the fuel consumption of ferries so the assumption was made that the distance transported across the Georgia Strait was from either semi-trailer truck or the freight train. The transportation efficiencies used averages for the year, whereas realistically the season would also change the efficiency of the vehicle. According to National Resources Canada (NRC, 2009), seasonal variations can cause the efficiency to vary between 3-5 L/100 km.

The total amount of CO_2 released is 829 kg if a semi-trailer truck is used and 811.5 kg if a freight train is used. The amount of CO_2 released is small compared to the amount of CO_2 that can be saved from installing one of these systems.

During the operation of the solar thermal heating unit, it will save 67050 kWh of energy in its life time which saves 1810.35 kg CO_2 using the B.C. averages. If natural gas was used, it would save 12419.67 kg $CO_{2.}$ This value is greater than the amount of CO_2 emitted from producing and transporting the systems; the difference is approximately 1 tonne. Our model focused on the energy saved by using the solar thermal heating unit, it did not consider other things such as decreased efficiency over time, maintenance and replacement parts, which are assumed to have negligible impacts.

For recycling of the solar thermal heating unit, it was assumed that all the metals, which by weight are the major materials, can be recycled and all the plastics will be disposed in a landfill. This brings environmental benefits because fewer metals need to be mined and refined. The plastics make up a smaller amount of the mass and these materials will most likely not be recycled after the projected 30 year life of the unit. This is a realistic assumption because the plastics will most likely be broken down by sunlight and weathering to the point where they cannot be recycled.

The amount of CO_2 released from manufacturing and the transportation of the solar thermal heating unit is, under the best conditions, less than the amount of CO_2 that is saved during its operation over 30 years. The amount of CO_2 saved can range from 1810.35 kg to 12419.67 kg. The majority of the materials can be recycled which lowers the impacts of subsequent goods that use these recycled materials.

6.2 BCA Results

A BCA for the EnerWorks Spectrum Preheat Appliance was generated to present financial information to Colwood homeowners who are considering implementing a solar thermal system under the Solar Colwood project. The EnerWorks Spectrum Preheat Appliance was deemed a representative system that has a high degree of potential of being installed during the Solar Colwood program. It was important to run the BCA using a variety of different factors to estimate the potential future changes in the economic environment of British Columbia. Comprehensive estimates were illustrated in the presentation of four BCA scenarios.

The BCA showed that, from a purely economic position, there is not a strong incentive to install a solar thermal heating system. Evaluating the results of scenario 1, for all incentive levels of the Solar Colwood project, the net benefit of installing a solar thermal heating system was negative for both electrical and natural gas hot water heating. Scenario 1 considers an annual real energy inflation rate of 0% over the next 30 years, which is unlikely to occur since analyst estimates indicate that the real price of electricity and natural gas will increase into the future (BC Hydro, 2011b; NRC, 2011a). Taking future energy forecasts into consideration, the results generated for scenario 1 do not significantly represent the homeowner’s net benefit of installing a solar thermal heating system; the reason for completion of scenario 1 was to provide a comprehensive estimate of potential net benefits.

Reviewing the net benefits generated under the parameters of scenario 2 that consider real annual energy inflation rates of 3% and 2% for electricity and natural gas respectively, the overall net benefits for installing a solar thermal heating system were negative; except for water heating via electricity, at a Solar Colwood incentive level of $3500, which had a positive net benefit over the 30 year period of $156.28. Scenario 2 provides a more representative estimate of the net benefits of installing a solar thermal heating system since it takes into consideration future annual increases in energy costs over a time frame closest to the duration of the solar thermal heating system project of 30 years; rates were based on BC Hydro estimates for electricity (2011b) and consensus forecasts made by the Intra-Alberta (NRC, 2011a) natural gas market over the next 20 years.

Evaluating the net benefits determined under the parameters of scenario 3, that consider real annual energy inflation rates of 5% and 4% for electricity and natural gas respectively, supplementing the cost of heating water by electricity with solar thermal energy produced positive net benefits across the three remaining Solar Colwood incentives; net benefits ranged from $2,275.43 to $1,025.34. Supplementing the cost of heating water using natural gas with solar thermal energy generated negative net benefits across the three remaining Solar Colwood incentives (Table 5.3-8). Scenario 3 considers real annual energy inflation rates at the high end of the energy inflation spectrum, with the rates estimated as slightly increased in comparison to BC Hydro and Intra-Alberta natural gas market future forecasts for real annual energy inflation. Scenario 3, like scenario 1, was completed to provide a comprehensive estimate of the net benefits of installing a solar thermal heating system.

The final scenario that was applied in the BCA used a discount rate of 0%, which takes into consideration that future generations are as important as today's, since benefits received in the future are equivalent to benefits received today. Scenario 4 was completed using real energy inflation rates of 3% and 2% for electricity and natural gas respectively, because these two rates are forecasted over a time frame that is closest to the duration of the thirty-year project period applied in the BCA. Scenario 4 had positive net benefits of installing a solar thermal heating system across the three remaining Solar Colwood incentive levels. Again, the net benefits across all three Solar Colwood levels for supplementing heating water by natural gas with solar energy were negative.

The largest net benefit recorded was generated under scenario 3, considering a real annual energy inflation rate for electricity of 5%. Under this scenario, the net benefit of installing a thermal solar heating system was $2275.34 received over the estimated thirty-year life span of the system. It was also under these conditions that natural gas came the closest to having a positive net benefit over the thirty-year period, in which the net benefit received was -$59.18. The discrepancy between the net benefit of supplementing hot water heating by either electricity or natural gas with solar energy is that the current rate of natural gas per kWh is cheaper than electricity, and the real annual energy inflation forecasts for natural gas are lower in comparison to real annual energy inflation forecasts for natural gas.

The BCA is a subjective estimate of the benefits that may be received by Solar Colwood homeowners who install a solar thermal heating system. From a homeowner's perspective, the EnerWorks Spectrum Pre-heat Appliance was used as a representative system that may be applied in the Solar Colwood project, and as a result the purchase and installation cost of the system used in the BCA is a representative cost of what a homeowner participating in the Solar Colwood program may expect to pay. It is probable that a Solar Colwood participant would select a system other than the EnerWorks Spectrum Preheat Appliance, which would change their present net benefits determined through the four applied scenarios with the potential of increasing or decreasing their net benefits. Likewise, it is up to the homeowner’s discretion to decide how energy rates may change into the future, and decide which scenario they feel is most likely to occur. The initiative taken by Colwood residents to participate in the Solar Colwood program will dictate which incentive packages are available; this is a variable that significantly influences the net benefit of installing a solar thermal system, as the incentives drop as more people sign up. Finally, there are a significant number of social and environmental benefits that were not factored into the Colwood homeowner’s net benefit of installing a solar thermal heating system, but can be as equally important to the monetary benefits, and therefore should not be ignored when deciding whether or not to purchase and install a solar thermal system.

There are a multitude of social benefits associated with the implementation of a solar thermal heating system. Social benefits include utilizing other energy saving measures, spreading energy awareness throughout the neighbourhood, becoming a role model to other individuals and future generations, fostering community engagement, the promotion of energy-saving programs in other municipalities, and the transfer of jobs into the green sector. The implementation of a solar thermal system not only saves energy but promotes the use of other energy-saving techniques. Tracking your energy savings becomes an exciting task, and may encourage one to see how much can be saved. For example, after installing a solar hot water system, a household might then adopt low flow shower heads to reduce water consumption, or may begin to take shorter showers. This behaviour has been observed in the T'Sou-ke First Nations in Sooke, BC; community member Andrew Moore commented that energy consumption was reduced by 30% through the implementation of solar thermal heating, while an additional 30% was reduced through further energy saving techniques adopted by the community. Furthermore, the addition of two solar panels on the roof of a house will likely generate conversation throughout the neighbourhood. By discussing with your neighbours the choice of implementing this new system, others could be encouraged to participate in saving energy; people are influenced by the choices of others; if the homeowner discusses the choice made to implement the system, for either economic, environmental or social reasons, others could be influenced to participate in the Solar Colwood program. Admiration of action is another social benefit associated with installing a solar thermal heating system. At this point in time, it has been deemed unequivocal by scientists that climate change is occurring. This finding however has not had a strong influence on the choices and policies made by our governing officials. It is now common to see individuals making personal choices in regards to preserving the environment and limiting carbon dioxide emissions, for example via the purchase of hybrid cars. It is common to look at these individuals with admiration for they are at the forefront of fighting climate change on a personal level. It is with this in mind that it can be said that an individual taking the initiative to implement a solar thermal heating system, which has the capability of reducing carbon emissions, will be admired by the community for doing their part. This can also tie into encouraging energy savings throughout the neighbourhood. In addition, neighbourhood communication about the system within the community promotes community engagement. The structure and social interactions of a community have slowly disintegrated due to urbanization and cultural and lifestyle changes in the past decades. By bringing the community together through conversation on the street about energy savings, meetings at the town hall to discuss the project, and press releases promoting the community, the community has a chance of interacting, and perhaps working together to create other initiatives. Not only will Solar Colwood promote community engagement, but it has the potential to promote other municipalities to adopt energy saving programs. The success of the Solar Colwood project will stimulate the solar thermal market, increasing the amount of trained individuals, which could decrease installation costs in the future.

In contrast, the costs associated with implementing a solar thermal system under the Solar Colwood program include costs to society and the opportunity cost of both federal and provincial tax dollars. As the Solar Colwood project received funds by Natural Resources Canada, a federally funded sector of the Government of Canada, the funding is coming out of the pockets of the citizens of Canada. It is a relocation of money from one potential project to another. The same concept applies for funding provided by the LiveSmart program, which is a provincially funded program. This means that the community of Colwood is benefitting from a cost placed on the provincial and federal tax payers. As well, there is an opportunity cost for the citizens of both BC and Canada, associated with Solar Colwood's funding. The federal and provincial government has decided to allocate funding to these programs at an opportunity cost to society. This means that by allocating money to these programs, funding could not be provided to other projects or sectors of government including healthcare, education, etc.

There are environmental benefits associated with the implementation of a solar thermal system, apart from those that stem the from social benefits outlined above. For example, there is a reduction in greenhouse gases (GHG) emissions generated by supplementing the consumption of natural gas, or electricity with solar energy. Reducing GHG emissions is an environmental benefit as it is mitigative action against climate change. The environmental cost associated with the implementation of this system is the energy used and emissions generated through the production of the solar thermal heating system, as was discussed in detail in the LCA portion of this report.

One factor of economic uncertainty in the future which could significantly affect Colwood homeowner's net benefits of the system is the potential implementation of a homeowner carbon tax. A carbon tax is a value placed on one tonne of carbon dioxide emitted (Carbon Tax Center, 2009). Initiation of this tax would require the homeowner to pay the government for each tonne of carbon emitted from their residence based on their energy bills. This tax could be used to fund green initiatives in Canada. The implementation of such a tax would produce greater net benefits for the installation of a solar thermal heating system, especially for homeowners who are currently generating hot water by using natural gas. By increasing the costs of emitting carbon dioxide, the net benefits will increase as the production of carbon decreases through the use of the system. BC is a leader amongst Canadian provinces for implementing green initiatives; it was the second province, after Quebec, to implement a carbon tax on fuel. There is political discussion in Europe of adopting a carbon tax for homeowners based on energy bills (Solar-Help, 2010). With this in mind, it is conceivable that BC would be an early adopter of the tax. Any future BCA analyses performed on the benefits of installing a solar thermal heating system should take a potential residential home energy carbon tax into consideration.

7.0 Recommendations

CO_2 Emissions

An LCA is an attempt to model the interactions between a product and the environment. Even simple products could have a multitude of interactions, many of which produce environmental impacts, which can lead to very complex models. In our efforts to determine the environmental impacts of making and using a solar hot water system, we have had to make a very simplified model that instead of considering all of the processes involved in the production of the components, used only the embodied energy coefficients that were supplied by the manufacturer of the chosen system. Simplifying the model in this way allowed us to avoid making many assumptions, which it was felt could weaken the validity of the results. As a result of this simplified approach, the only environmental impact that we have been able to assess is the emissions of CO_2. It was found that over the projected lifespan of the system, the amount of CO_2 saved by its operation is greater than the amount of CO_2 released during its manufacture and transportation to Victoria, even when the fuel source that it is replacing/supplementing is assumed to be the least polluting (hydroelectric).

As it was assumed that the key difference between a solar hot water system and conventional water heating system is only the components that are supplementary to the latter (including such things as the collector panels), the difference in the amount of CO_2 released over the 30 year time period would be 1.8 tonnes if the conventional system uses electricity, and 12.4 tonnes if the conventional system uses natural gas. Based on these results, if a reduction in CO_2 emissions is desired, then it is recommended to install a solar hot water system. The reductions in CO_2 emissions would be even more significant if the installation occurs in a place where the method of electricity generation is more polluting than BC’s hydroelectric dams (e.g. coal-fired power plants in Alberta).

Financial Considerations

Based on the results of the various calculations used in the BCA, there is not a strong economic incentive to install a solar hot water system in the Solar Colwood program. It should be noted that there are a number of variables in the calculations that are not very easy to predict, namely the real energy inflation rates for electricity and natural gas. Future energy cost forecasts were taken into account, yet there is a fair amount of uncertainty in them. Four scenarios were developed to conduct the BCA, and each used different values for such things as fuel cost inflation rates and discount rates.

The results of all four scenarios show that if the home currently uses natural gas, there are net negative benefits to installing a solar hot water system, even at the highest remaining incentive level. The results for a home that currently uses electricity to heat water are more favourable, as some of the scenarios generated net positive benefits; under scenario 3 there are positive benefits of at least $1000 for all three remaining incentive levels.

It should be noted that the results of the BCA are speculative, as the fuel cost inflation rates are very difficult to predict for a 30 year period, which is the projected life of a solar hot water system. For example, very low inflation rates do not make the installation an attractive option, whereas higher rates do. Considering the uncertainty in the forecasts, it is difficult to make specific recommendations to Colwood residents.

Apart from the financial considerations, there are considerable environmental benefits to installing a solar hot water system. These were not assigned monetary values in the BCA calculations, but for some they may be quite important. It is recommended that the importance of these benefits be compared to the financial considerations by each homeowner considering participating the Solar Colwood program.

Further LCA Studies

Regarding the use of an LCA to determine the environmental impacts of a solar hot water system, it is recommended that a more complete study be conducted. This could be accomplished by using the same framework set out in this project, but with more detail regarding the materials and processes used in the manufacture of the components. This would require extensive research into the origins of all of the materials; to handle the large amount of information the GaBi4 system is recommended; however, the professional license would be preferable to the student license as it would allow access to the GaBi4 support forums. The use of GaBi 4would allow other environmental impacts to be assessed, potentially including pollution related to emissions of such things as heavy metals, volatile organic compounds, inorganic gases, and wastewater.

In addition to looking at the impacts associated with manufacture and transportation, a detailed examination of the impacts related to the recycling processes is also recommended. Whether or not a material is recycled or disposed of could significantly alter the results; consider aluminum, for example, which is very energetically expensive to make from mined alumina, and so the recycling of it is preferable, in terms of energy use and pollution. These LCA studies could be used to gain a more complete picture of the environmental impacts related to the production and use of a solar hot water system.

8.0 References

AAR. (2011). The Environmental Benefits of Moving Freight by Rail, Association of American Railroads. Retrieved from: http://www.aar.org/~/media/aar/Background-Papers/The-Environmental-Benefits-of-Rail.ashx

Aube, F. (2001). *Guide for Computing CO_2 Emissions Related to Energy use.* CANMET Energy Diversification Research Laboratory. Retrieved From: http://canmetenergy anmetenergie.nrcan- ncan.gc.ca/fichier.php/codectec/En/2001-66/2001-66e.pdf

Baird, G., Alcorn, A., Haslam, P. (1997). The energy embodied in building materials – updated New Zealand coefficients and their significance. *IPENZ Transactions*; 24(1). Retrieved online on May 10, 2011 from: http://www.ipenz.org.nz/ipenz/publications/transactions/Transactions97/civil/7baird.PDF

Bank of Canada. (2005-2010). Real return bond, long term, *Interest rates*. Retrieved on April 26, 2011 from: http://bankofcanada.ca/en/rates/bonds.html

BC Hydro. (2011a). Residential conservation rate. Retrieved July 5, 2011 from: https://www.bchydro.com/youraccount/content/residential_rates.jsp#my_bill

BC Hydro. (2011b). Table 2: Estimated Real Changes in Rates, Forecast Changes in rates (Table 2): *Integrated Resource Plan.* Retrieved July 5, 2011 from: http://www.bchydro.com/etc/medialib/internet/documents/planning_regulatory/iep_ltap/ror/irp_tac_mtg01_summarybrief1.Par.0001.File.IRP_TAC_Mtg01_SummaryBrief_LongTermRateForecast_FINAL_2010-12-22.pdf

Bureau of Labour Statistics. (2011). United States Inflation Rate. Retrieved on April 19, 2011 from: http://www.tradingeconomics.com/economics/inflation-cpi.aspx?Symbol=USD

Carbon Tax Center. (2009). What's A Carbon tax; *Introduction*. Retrieved on July 12, 2011 from: http://www.carbontax.org/introduction/

Carbon Trust (2011). *Resources Conversion Factors.* Carbon Trust. Retrieved from: http://www.carbontrust.co.uk/cut-carbon-reduce-costs/calculate/carbon-footprinting/pages/conversion-factors.aspx

City of Colwood (January 2011). Home Retrofits: Energy Efficiency and Renewable Energy. *Solar Colwood*. pp.1-8. Retrieved from: http://www.solarcolwood.ca/docs/SolarColwoodJan2011FinSm.pdf

Environmental Protection Agency (EPA). (2011). Life-Cycle Assessment (LCA). *Lifecycle Assessment Research.* Retrieved from: http://www.epa.gov/nrmrl/lcaccess/index.html

Field, B., Olewiler, N. (2005). *Environmental Economics UPDATED Second Canadian Edition.* Toronto, Ontario, Canada. McGraw-Hill Ryerson. pp 9-10

Forkenbrock, D. (2001). Comparison of external costs of rail and truck freight transportation. *Transportation Research Part A 35*, pp. 321-337

Fortis BC. (2011). Current Vancouver Island/Sunshine Coast service area (effective October 10, 2010). Retrieved July 5, 2011 from: http://www.fortisbc.com/NaturalGas/Homes/Rates/Pages/Vancouver-Island.aspx.

GaBi Software (*n.d.*). GaBi 4 Professional. Retrieved online on May 3, 2011 from: http://www.gabi-software.com/america/software/gabi-4/

Hammond, G. & Jones, C. (2011). Inventory of energy and carbon (ICE) version two. *Sustainable Energy Research Team (SERT) Department of Mechanical Engineering*. University of Bath, UK. Retrieved from: http://www.bath.ac.uk/mech-eng/sert/embodied/

Natural Resources Canada (January 24, 2011). Government of Canada Invests in B.C. Solar Energy Project. From *Natural Resources Canada- News Release.* pp. 2-3

NRCan. (2009). Fuel Efficiency Benchmarking in Canada's Trucking Industry Results of an Industry Survey March 2000, Natural Resources Canada, Ottawa ON, Canada. Retrieved From: http://oee.nrcan.gc.ca/publications/infosource/pub/transportation/fuel_effic_benchm_truckE.cfm?attr=16

Natural Resources Canada [NRC] (2011a). Energy sources: Outlook to 2020. Retrieved from: http://www.nrcan.gc.ca/eneene/sources/natnat/revrev-2020-eng.php

Natural Resources Canada [NRC] (2011b). North American Natural Gas - Heating Season and Winter Update; from *The Government of Canada*. Retrieved July 5, 2011 from: http://www.nrcan.gc.ca/eneene/sources/natnat/shocou-eng.php

Olewiler, N. & Field, B. (2002). Choice of the Discount Rate: *Environmental Economics, 2nd Canadian Edition* (pp.114-115). McGraw-Hill Ryerson Limited; Toronto, Ontario.

Patterson, J., Olsen, S. (2008). Single-tank Solar Water Systems. *Home Power* (124). pp 42-46.

Product Ecology Consultants (2011). The SimaPro Family. Retrieved online on May 30, 2011 from: http://www.pre.nl/content/the-simapro-family

Rebitzer, G., Ekvall, T., Frischknecht, R., Hunkeler, D., Norris, G., Rydberg, T., Schmidt, W., Suh, S., Weidema, B. & Pennington, D. (2004). Life cycle assessment Part 1: Framework, goal and scope definition, inventory analysis, and applications. *Environment International 30.* DOI: 10.1016/j.envint.2003.11.005.

Royal Roads University, (February 25, 2011). *Researching interest and uptake of solar thermal systems.* Retrieved from *Roadspiel* on April 5, 2011: http://sustainability.royalroads.ca/newsstory/researching-interest-uptake-solar-thermal-hot-water-systems

Royal Roads University (2011). Staff and Faculty Bios. From *The University* retrieved online on April 5, 2011 from: http://www.royalroads.ca/about-rru/the-university/staff-faculty-bios/k/krusekopf-charles.htm

SolarBC. (2008). *Learn about solar hot water.* Retrieved from: http://www.solarbc.ca/learn

Solar B.C. (2008). View Installations Across B.C. Viewed online on the *Solar BC* website. Retrieved on April 12, 2011 from: http://www.solarbc.ca/view-installations-across-bc

Solar-Help. (2010). Carbon Tax to Increase Energy Bills for Homeowners. Retrieved on July 12, 2011 from: http://www.solar-help.co.uk/blog/2011/solar-panels/carbon-tax-to-increase-energy-bills-for-homeowners

The Department of the Treasury. (2011). Daily Treasury Yield Curve Rates: Resource Center. Retrieved on April 19, 2011 from: http://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/TextView.aspx?data=yieldYear&year=2010

T'Sou-ke Nation (2009). T'Sou-ke Solar Forum and Gathering. From *T'Sou-ke Nations Website*. Retrieved online on February 13, 2011 from: http://www.tsoukenation.com/

Whitehead, J. (2005). Discount rates for benefit-cost analysis: *Environmental Economics*. Retrieved on April 19, 2011 from: http://www.env-con.net/2005/08/discount_rates_.html

9.0 Appendices

The following appendices were used in the research stages of the project.

9.1 Appendix 1: Ethical Review Application

Royal Roads University

Request for Ethical Review

For Research Involving Humans

Revision of the Form
Approved by RRU Academic Council
17 January, 2007

If your research involves human subjects then it most likely requires an ethical review by the Royal Roads University Research Ethics Board (or one of its subcommittees). Please refer to the *Royal Roads University Research Ethics Policy* (**17 January, 2007**) for specific guidance on identifying research that requires ethical review.

Reference to the *Royal Road University Research Ethics Policy* will assist you in understanding the questions below and will help you formulate your responses. If you have additional inquires, contact your Faculty Project Supervisor, the Dean of your Division, the School Director, the Associate Vice President Research, or the Research Ethics Coordinator.

Research involving human subjects cannot be initiated until the Request for Ethical Review has been approved.

Please have your academic supervisor submit the completed form, via email, to colleen.hoppins@royalroads.ca.

Please allow four weeks for the decision of the Research Ethics Board.

Please do **not** delete any of the questions or prefatory materials**.**

1. Principal Investigators: Division: BSc. Environmental Science

Jari Eikenaar, Brooke Davidson, Kate Fonteyne,

Brandon Leong, Matt Girard

Faculty: ☐ **Graduate Learner** ☐ **Undergraduate Learner** ☐ **Staff** ☐

Other ☐ **Specify:**

Address: Jari Eikenaar, 1234 Dallas Rd, Victoria, BC, V8V 1C3
Telephone: 250.477.1130

Mail Correspondence and/or approval to: Jari Eikenaar

Fax: Email: jeikenaar@gmail.com

[please use current email address which you are checking regularly]

If learner, specify Faculty Project Supervisor/Advisor and Sponsor/Client.

Faculty Project Supervisor/Advisor: Dr.Jonathan Moran

Telephone: 250-391-2600 ext. 4314

E-Mail address: jonathan.moran@royalroads.ca

Project/Thesis Sponsor/Client: Dr.Charles Krusekopf, Dr. Chris Ling

Sponsor contact name: Dr.Charles Krusekopf

Telephone: 250-391-2600 ext. 4421

E-Mail Address: chris.ling@royalroads.ca, charles.krusekopf@royalroads.ca

Co-Investigators (name, position, Division or other institution, mailing address, e-mail address, and telephone)

Brooke Davidson - brooke.r.davidson@gmail.com

Matthew Girard - Matthew.Girard@royalroads.ca

Brandon Leong - Brandon.Leong@royalroads.ca

Kate Fonteyne - Kate.Fonteyne@royalroads.ca

II. Short Title of Project (no more than 10 words)

Lifecycle Assessment – Understanding the Full Benefits and Costs of Solar Thermal Systems

Keywords

Provide 4 keywords/key phrases that describe this project.

1. Lifecycle Assessment
2. Solar thermal heating system
3. Benefit/Cost Analysis
4. Solar Colwood Initiative

III. Summary of Proposed Research

Provide a brief but complete description, in non-technical language, of the purpose, objectives and research questions of the project (USE NO MORE THAN ONE PAGE).

A. Purpose

The purpose of this project is to conduct a Lifecycle Assessment (LCA) of a solar thermal heating system. The results of the LCA will be used in a Benefit/Cost Analysis that may be used in Colwood, BC, as part of their project to implement solar thermal heating systems in homes within the community.

B. Objectives

The project will provide analysis and recommendations regarding the full environmental, economic and social benefits and costs of solar thermal systems on Southern Vancouver Island, BC. The information gathered will be used to help evaluate solar thermal system potentials for homeowners and institutional applications, such as the solar thermal installations planned for Royal Roads University and in Colwood, BC.

C. Research Questions

Regarding the Lifecycle Assessment, we will determine the energy inputs and outputs of all the materials and processes involved in the manufacturing of the solar thermal cell. We will ask questions regarding the materials and processes, the costs of installing and maintaining the solar thermal heating systems, and the energy savings achieved following installation.

IV. Summary of Methodology and Procedures

Provide a brief but complete description, in non-technical language of the methodology and procedures. USE NO MORE THAN ONE PAGE.

Three different groups will be interviewed: homeowners, contractors, and manufacturers.

For homeowners, we will contact them by telephone after identifying them as subjects of interest. After describing to them the purpose of the interview and our project, as well as informing them of their rights, we will ask them questions related to their reasons for installing the solar thermal heating system, the financial or other benefits, and the costs and disadvantages of the system.

For contractors, we will contact them by telephone after identifying them as subjects of interest. After describing to them the purpose of the interview and our project, as well as informing them of their rights, we will ask them questions about the installation and maintenance of the solar thermal systems.

For manufacturers, once we have determined the exact system that we will research, we will contact the manufacturer by email to ask them questions regarding the materials and processes required to make the solar thermal units. We will again inform them of our project and their rights.

V. Description of Population

A. How many subjects/participants will be used?
Manufacturer – only one manufacturer will be contacted as we will only be conducting the LCA on one model of a solar thermal heating system to be determined.
Contractors - less than 5
Homeowners - less than 5

B. Who is being recruited and what are the criteria for their selection?

> (Justify any exclusion of prospective or actual research subjects on the grounds of attributes such as race, sex, age, culture, race, and mental or physical disability.)

Subjects of interest include home owners who are early adopters of thermal heating systems. Interest will be interviewed on their motivations for installing the system as well as additional information of benefits they have received to date.
The manufacturer of the solar thermal heating system chosen will be recruited.
Contractors who have installed similar systems are also subjects of interest.

VI. Recruitment and Withdrawal

A. How are the subjects being recruited?

- ☐ By letter (enclose a copy)
- ☒ By telephone (If yes, complete "Telephone Contact Form")
- ☐ Advertisement, poster, flyer (enclose a copy)
- ☒ Other (explain)

Homeowners and contractors of interest will be contacted by telephone for their participation in our research. We have received information regarding potential candidates through our sponsor Charles Krusekopf as well through contact with Nancy Wilkin of the University's Office of Sustainability.

The manufacturer of the solar thermal heating system will be contacted by e-mail.

B. How and when are subjects informed of the right to withdraw?

Subjects will be informed of their right to withdraw from answering individual questions or the entire interview before the interview commences on the telephone. Emails will also indicate that the subject has the right to withdraw from individual questions or the interview.

C. What procedures will be followed for subjects who wish to withdraw at any point during the study?

If a subject wishes to withdraw from answering individual questions or the entire survey, they will not be pressured into continuing against their will. If they so desire, their answers to previous questions will be eliminated from the study.

VII. Research Project Details

A. Where will the project be conducted?
The majority of this project will be conducted at Royal Roads University with utilization of university library and break-out rooms, with some off campus research taking place in Sooke and Colwood.

B. Does your sponsoring organization or any of the organizations involved in your research require an ethical review?

Yes ☐ No ☒

If yes, has approval been granted?

Yes ☐ No ☐

Once you receive feedback from ethical review processes at other institutions, please forward that information to via email to colleen.hoppins@royalroads.ca **or** by surface mail to: Colleen Hoppins, Office of Research, Royal Roads University, 2005 Sooke Road, Victoria, BC, V9B 5Y2 **or** by fax to 250-391-2500.

C. For research in other countries, indicate how the research will conform to the laws and customs of that country.

No research will be conducted in other countries.

D. Is this an amendment from a previously approved protocol?

Yes ☐ No ☒ Date:

VIII. Involvement of Aboriginal Individuals or Communities

Will the research involve aboriginal individuals? Yes

If yes, will any of the following considerations apply? (Provide a brief explanation of any relevant considerations and indicate how approval of the community as a whole will be obtained.)

☒ Property or private information belonging to an aboriginal group as a whole will be studied or used.

☒ Leaders of the group will be involved in the identification of potential participants.

☐ The research is designed to analyze or describe characteristics of the group.

☒ Individuals are selected to speak on behalf of, or otherwise represent, the group.

We intend to speak to members of the T'Sou-ke Nation of Sooke, BC about their recent installation of solar thermal heating systems in their community, including the Chief. We will not ask questions regarding their culture or any other potentially sensitive subjects, and we hope that in speaking to the Chief and other community leaders we will have the approval of the community as a whole.

IX. Free and Informed Consent

Evidence of free and informed consent by the subject or authorized third party should ordinarily be obtained in writing. (See Checklist for Consent Form and include a copy of the consent form or other format by which you will obtain consent in writing). Obtaining informed consent from your research subjects is mandatory; however, the method by which the informed consent is obtained may vary. For example, in completing a survey, one method of handling the need to inform research subjects is to include, as a preface or preamble to the survey, the same sort of information that would otherwise be included in a consent form.

A. Have you included, attached to this "Request for Ethical Review," a sample consent form?

Yes ☐ No ☒

If no, document the procedure by which free and informed consent will be obtained.
Free and informed consent will be obtained verbally in the case of a telephone interview or as part of the email letter response.

B. Will the subjects have any problem giving free and informed consent on their own behalf? (Consider physical or mental condition, age [e.g., under 18], language, incarceration or other barriers.)

Yes ☐ No ☒

C. Are subjects **competent** to give free and informed consent?

Yes ☒ No ☐

If no, who is empowered to give consent on the subject's behalf? What is the process for seeking this consent?

D. Is any form of deception of subjects part of the research design?

Yes ☐ No ☒

If yes, describe and justify the proposed deception.

X. Risks

A. Does the research in your view conform to the standard of "minimal risk"?

"Minimal Risk": if potential subjects can reasonably be expected to regard the probability and magnitude of possible harms implied by participation in the research to be no greater than those encountered in those aspects of his or her everyday life that relate to the research, then the research can be regarded as within the range of minimal risk.

Yes ☒ No ☐

If No, please explain how it exceeds minimal risk.

B. Describe the potential and anticipated risks of the proposed research.
The only anticipated risks could include the unauthorized disclosure of personal or product information. These risks will be minimized by acquiring approval to disclose this information within our study, and great focus will be placed on ensuring this information is treated sensitively and securely.

C. What inducements (monetary or otherwise) will be offered to prospective subjects? If payment is to be made, provide details or amounts, payments schedules and other relevant details.
None.

D. How much time will a subject be expected to dedicate to the project?

Each subject will be required to dedicate between one to two hours on this project.

XI. Benefits

The likely benefits that justify asking subjects to participate

A. Benefits to Researcher: Collecting necessary information to complete a LCA, as well as a cost/benefit analysis to complete our undergraduate thesis.

B. Benefits to Subjects: Subjects will be exposed to the costs and benefits of their system that they may not have otherwise been aware of. With their approval they will be noted within our report and will receive social benefits through identification as environmentally friendly households. Benefits to the manufacturer include an in-depth LCA of their product as well as advertising within the Colwood region. The contractor may benefit by gaining publicity for their work and knowledge of the solar thermal systems.

C. Benefits to Sponsor: Sponsor will receive complete thesis report outlining an LCA as well as a cost/benefit analysis of a solar thermal heating system. These results will be utilized for marketing within the Solar Colwood project to address the benefits for potential homeowner adapters of the system.

D. Benefits to Society: The people of Colwood will gain knowledge of the costs and benefits of installing a solar thermal heating system, to themselves and their community.

XII. Privacy, Confidentiality and Anonymity

A. Have you completed a privacy research agreement, if required by any privacy legislation or regulations governing the organization in which you will be conducting your research?

Yes ☐ No ☒

If no, please provide an explanation of why a privacy research agreement is not required.

Royal Roads University does not require us to complete a privacy research agreement.

B. Will the project obtain information from research subjects which is not available through publicly available sources? (For example, are names, ages, opinions, views, etc. to be collected?)

Yes ☒ No ☐

C. Will such information be obtained only from publicly available information (e.g., from existing books or Stats Canada information) or materials?

Yes ☐ No ☒

If No, describe methods for obtaining and handling data, including the following:

a. The type of data to be collected

We require data for the Lifecycle Assessment, data for a Benefit/Cost analysis, household energy usage, and demographics such as number of people per house and their ages.

b. The purpose for which the data will be used

The data collected will be utilized only to complete our major project.

c. Limits on the use, disclosure and retention of the data

Data collected will only be used within the constraints of our major project. Disclosure is restricted to three term presentations to fellow classmates and sponsors as well as a final project report.

d. Appropriate safeguards for confidentiality and security (If you are using US software to warehouse your data, you will need to make your research subjects aware that the information they share with you may be subject to the Patriot Act).

All data from interviews and surveys will be stored in a password-protected folder on one computer.

e. Any modes of observation (e.g. photographs or videos) or access to information (e.g. sound recordings) that allow identification of particular subjects
None.

f. Any anticipated linkage of data gathered in the research with other data about subjects whether those data are contained in public or personal records
None.

g. Provision for confidentiality of data resulting from the research

Yes - the option to remain anonymous will be given.

h. Is secondary use of identifiable data anticipated? (I.e. do you plan to use identifiable information that you gather in the course of your research project for a purpose other than your research project?)

Yes ☐ No ☒

If yes, describe methods for obtaining and handling data, including the following:

i. Why identifying information is essential to the research

ii. What measures will be taken to protect the privacy of individuals

iii. Proposed methods of obtaining informed consent of those who contributed the data or of authorized third parties

XIII. Feedback to Subjects

Will the subjects be debriefed at the end of the research project?

☒ Yes. Explain how this will be done.

A copy of the project, if agreed to by the project sponsors, will be made available to the subjects.

☐ No. Explain why not.

XIV. Conflict of Interest

Provide full details of any actual, perceived, or potential conflict of interest, economic, family-related or otherwise, on the part of the principal investigator and co-investigators. (For example, if you are the teacher of students or the employer or manager of employees who you will be inviting to be part of your research, that would be a conflict of interest situation which would need to be addressed. Are you an employee of an organization where your fellow employees will be potential research subjects? That too would be a conflict of interest situation.) Indicate how this conflict of interest will be addressed with your research subjects. What measures will you be taking to ensure that your research subjects are apprised of the conflict of interest? Any and all conflicts of interest must be disclosed in your consent documentation (as outlined in Question IX).

Do you have a conflict of interest in any way type of question will be asked in the survey?

No.

Do you have a supervisory or role of possible influence over the individuals in the study? If so, please explain how you would mediate undue influence or coercion for participants to "participate" in the study?

No.

Is there any possibility that the activities or results of your study could impact negatively on the organization? If so, please explain how you would mediate this impact.

No.

XV. Compliance

I understand that the Royal Roads University Research Ethics Board may request from me my research documentation and my research results to demonstrate compliance with the Royal Roads University Research Ethics Policy and to demonstrate my compliance with my approved request for ethical review.

Please check here: ☐

XVI. Signatures

For electronic submissions, the researcher's supervisor/advisor can email his/her approval to ethicalreview@royalroads.ca or fax the signed signature page, attention Research Ethics Coordinator, Office of Research, to 250-391-2500.

All applicants:

______________________________ ______________

Principal Investigator **Date**

______________________________ ______________

Principal Investigator **Date**

______________________________ ______________

Principal Investigator **Date**

______________________________ ______________

Principal Investigator **Date**

______________________________ ______________

Principal Investigator **Date**

If learner:

________________________________ ______________

Faculty Project Supervisor/Advisor **Date**

If faculty member or other:

______________________________ _____________

Dean **Date**

Where the Dean is the Principal Investigator, the signature of the Vice President Academic is required.

______________________________ _____________

Vice President Academic **Date**

9.2 Appendix 2: Surveys and Questionnaires

Contractor Contact Template:

Good morning/afternoon,

My name is (one of: Jari Eikenaar; Brooke Davidson; Matthew Girard; Brandon Leong; Kate Fonteyne). I am contacting you on behalf of the BSc-ES major project team at Royal Roads University. Our major project is to conduct a life cycle assessment of a solar thermal heating system and a benefit-cost analysis of installing solar thermal units for the City of Colwood.

With your consent, we would like to ask you some questions about the solar thermal systems regarding installation costs and maintenance. Please do not feel that every question must be answered and at any point you can withdraw from the survey, either in part or in full. At your request you may remain anonymous and your name will not be published. All data from this interview will be kept confidential and secure.

If you have any questions about any of this, please feel free to ask at any time. To verify the authenticity of this interview, you can also contact Dr. Jonathan Moran, **School of Environment and Sustainability, 250-391-2600 ext 4314. If you would like a copy of what we have shared with you verbally, we would be happy to email this to you.**

1. What are the installation costs of the solar system for most of your projects?

2. What materials, how much time, and how much labour is required to complete most projects?

3. Which system or brand do you prefer to install? Which one is the most commonly asked for?

4. What is the typical house size that you install these systems for?

5. Where are most of the installations that you have worked in (which community/area), and are they retrofits or new homes?

6. What is the maintenance required for these solar systems? Would it mostly be parts or labour?

7. Could the home owner potentially fix the systems themselves or would it require a contractor every time?

8. Are the projects complicated and do they require many different types of labourers?

9. Are additional parts required to install a solar thermal heating system that need to be bought externally?

10. Is there any method to improve a system once it has been installed, in case the home owner wants to upgrade as technology does? Would this be expensive?

Homeowner Contact Template

Good morning/afternoon,

My name is (one of: Jari Eikenaar; Brooke Davidson; Matthew Girard; Brandon Leong; Kate Fonteyne). I am contacting you on behalf of my BSc-Environmental Science major project team at Royal Roads University. We are working on our undergraduate thesis to determine the benefits and costs of solar thermal heating systems, as well as complete a lifecycle assessment on a solar thermal unit. With your verbal agreement and consent, we would like to ask you a series of questions related to your home heating system. Please do not feel as if you have to answer every question that is asked, and if at any point you feel uncomfortable with a question, please let me know. You have the right to withdraw from the survey at any point if you feel it is necessary. At your request you may remain anonymous and your name will not be published. All data from this interview will be kept confidential and secure. If you have a conflict of interest please inform us.

If you have any questions about any of this, please feel free to ask at any time. To verify the authenticity of this interview, you can also contact Dr. Jonathan Moran, **School of Environment and Sustainability, 250-391-2600 ext 4314. If you would like a copy of what we have shared with you verbally, we would be happy to email this to you.**

Would you be willing to participate in our survey?

1. What heating system are you using now and what were you using before?

2. What are/were the monthly energy bills and costs of upkeep of the system?

3. What were your reasons for installing the solar thermal system?

4. In your choice to move to solar thermal heating, which system did you select, and how did you choose it?

5. What are the pros and cons of this system?

6. Since the installation of your solar thermal heating system, how much have you saved on heating bills?

7. Has changing heating systems changed your water usage habits?

8. Are you aware whether or not your decision has affected other residents' decisions to install similar heating systems?

9. Prior to the installation of your solar thermal heating system, had you participated in any other energy savings initiatives? What about since installing it?

10. Would you be alright with us using your name in our thesis project? If not, we can keep you anonymous.

Manufacturer Contact Template

Dear Sir/Madam,

My name is (one of: Jari Eikenaar; Brooke Davidson; Matthew Girard; Brandon Leong; Kate Fonteyne). We are undergraduate BSc. Environmental Science students at Royal Roads University in Victoria, BC, Canada, and we are currently conducting a Lifecycle Assessment Analysis (LCA) of your product model____________________ solar thermal heating system.

Your model has been chosen as we have concluded, via research in Colwood, BC, Canada, that it is a popular option for solar thermal heating systems. The LCA of your system will be utilized in the completion of our thesis entitled "**Lifecycle Assessment – Understanding the Full Benefits and Costs of Solar Thermal Systems"**. The goal of our project is to provide information to a Victoria, BC area initiative to implement solar thermal heating systems as part of a community "greening" initiative. Information provided by your company on model materials, focusing on origin and transportation information, will be a great asset in completing an accurate LCA. The information provided to us will be used to complete our project, and the final report will not be made available to the general public. However, there is a possibility that the report will be used to give homeowners detailed information about solar thermal heating systems, in which case your company name and the specific product will be mentioned, should you wish.

We request your help in this project by answering some questions primarily about the materials used in the unit. By responding to this email you provide consent that the information provided may be used in our thesis document. If there are certain questions that you do not wish to answer, either in part or in full, then please leave them blank. If, at any time after answering these questions you wish us not to use the information provided, or wish to remain anonymous, then we will abide by your wishes. All data from this interview will be kept confidential and secure.

If you have any questions about any of this, please feel free to ask at any time. To verify the authenticity of this interview, you can also contact Dr. Jonathan Moran, **School of Environment and Sustainability, 250-391-2600 ext 4314. If you would like a copy of what we have shared with you verbally, we would be happy to email this to you.**

1. Could you provide a detailed list of materials or a schematic breakdown of the components of the model________________solar thermal heating system?

2. For each raw component could you provide the source, supplier, and mode of transportation for delivery?

3. Could you provide detailed breakdown of manufacturing costs?

4. Where is the unit assembled, and how would it normally be shipped to Victoria, BC, Canada?

9.3 Appendix 3: Local Publicity for Hatley Park Environmental Consulting

a) Youtube link to an ANews story about Royal Roads' Students Impact on the Community: http://www.youtube.com/watch?v=aTSG3ZWXVWE

b) Link to Royal Roads University Alumni article concerning solar studies: http://alumni.royalroads.ca/in-roads/rru-students-infuse-data-solar-study

c) Newspaper article published in the Goldstream Gazette:

Academics plan for sunny days

Colwood becomes a real-time classroom for Royal Roads University students

TRAVIS PATERSON
BLACK PRESS

Beyond the academic impact, the number of Greater Victoria educational institutions in itself has a sizable economic impact.

And it's not just the dollars generated by the University of Victoria and Camosun College – though they are grand in scale, with an estimated $2 billion value to the local economy.

In Colwood, students of the region's third biggest school, Royal Roads University, are helping to shape their city's future in what's become a symbiotic relationship with the municipality.

"We have an opportunity that many cities (our size) don't have, a university with students and professors focused on city issues," Colwood Mayor Dave Saunders says.

"RRU has brought forward a lot of ideas to open up our municipality as a real-time classroom."

Kate Fonteyne is the spokesperson for Hatley Park Environmental Consulting – one of two student groups in RRU's environmental sciences program currently doing research for the Solar Colwood initiative. It's exploring the integration of solar energy as a sustainable option for the city.

"We'll put a report together for August that Colwood residents will be able to use as a resource to put a solar heating system in their house," Fonteyne explains.

The Hatley consulting report will educate citizens about the life cycle expectations for a typical solar thermal system used to heat water in a Colwood household.

"We look at the financial cost and environmental (footprint) of the materials used to compare the solar (heating) system to a hot water system commonly found in a house right now."

Much like a real consulting group, Fonteyne's partners bid for the project, one of many research topics up for selection.

"We talked to Colwood councillor Judith Collingwood who is very involved with Solar Colwood and she told us what they expect from our team."

Fonteyne's group is encouraged to value their work with a dollar figure, though they have yet to do that.

By comparison, a finalized consulting report by RRU's masters of business administration comes in at $40,000.

Don Caplan is the person who evaluates the organization management projects (OMPs), the "capstone" of the MBA program.

He's overseeing 260 of them.

"When our learners do a project we bring it to the point of recommendation, a 400-hour piece of work in a 15,000 to 20,000 word document," he says.

"Not all recommendations are taken into account but many are used. When I get feedback, it is always great. The awareness is spawning more and more projects all the time."

sports@vicnews.com

Figure A: Newspaper Article Scanned in from the Goldstream Gazette regarding the project that Hatley Park Consulting is completing on behalf of Royal Roads University

9.4 Appendix 4: Determination of Most Common Solar Thermal System

Table A: List of Residential Locations around Southern Vancouver Island that have installed Solar Thermal Hot Water Systems, including the contractor who completed the installation and the type of system installed.

Location	System	Contractor	Panel/Type	Website
Lake Cowichan	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Lake Cowichan	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Nanaimo	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Nanaimo	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Nanaimo	EnerWorks	Wizards 4 Environmental	2 panel	http://www.solarbc.ca/learn/installers/wizards-4-environmental-technology
Nanaimo	Taylor Munro Suncoil System	Taylor Munro Energy Systems Inc		http://www.taylormunro.com/
Nanaimo	EnerWorks	TerraTek Energy	2 panel, new	http://www.solarbc.ca/learn/

		Solutions	build	installers/terratek
Nanaimo	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Gabriola Island	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Gabriola Island	Globe Solar Energy 1p-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar
Ladysmith	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Thetis Island	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Chemainus	CAREarth evacuated tube system	Ambient Source Energy Systems		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Galiano Island	Swiss Sol Veissman System	Pacific Solar Smart Homes Inc.	2 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Saltspring Island	Globe Solar Energy 1P-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar

Saltspring Island	Globe Solar Energy 1p-195 system	Globe Solar Energy (Western) Inc.		http://www.solarbc.ca/learn/installers/jb-solar
Saltspring Island	CAREarth evacuated tube system	Ambient Source Energy Systems		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Saltspring Island	Thermodynamics system	Ark Homeworks	1 panel	http://www.solarbc.ca/learn/installers/ark-homeworks
Saltspring Island	EnerWorks	Island Energy	1 panel	http://www.solarbc.ca/learn/installers/island-energy
Saltspring Island	Globe Solar Energy 1P-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar
Mayne Island	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek	1 panel	http://www.solarbc.ca/learn/installers/terratek
Mayne Island	Taylor Munro Suncoil System	Taylor Munro Energy Systems Inc		http://www.taylormunro.com/
Duncan	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek

Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Duncan	Veissmann system	Pacific Solar Thermal Smart Homes Inc.	1 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	2 panel	http://www.solarbc.ca/learn/installers/terratek
Duncan	EnerWorks Cowichan/Ucluelet Bulk Buy	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek

Duncan	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Cowichan Bay	30 Tube Thermomax system	G.E.T Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
Cobble Hill	CAREarth Evacuated Tube System	Don Skerik Electric		http://www.solarbc.ca/learn/installers/don-skerik-electric
Shawnigan Lake	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Cobble Hill	CAREarth Evacuated Tube System	Ambient Source Energy Systems		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Mill Bay	Thermomax System	G.E.T Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
Cobble Hill	CAREarth Evacuated Tube System	Ambient Source Energy Systems		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Mill Bay	EnerWorks	Island Energy Inc.	1 panel	http://www.solarbc.ca/learn/installers/island-energy
North Sannich	90 Tube Thermomax System	Island Energy Inc.		http://www.solarbc.ca/learn/installers/island-energy

North Sannich	EnerWorks	Island Energy Inc.	1 panel	http://www.solarbc.ca/learn/installers/island-energy
North Sannich	Thermomax System	G.E.T Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
North Sannich	20 Tube Thermomax System	G.E.T Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
North Sannich	EnerWorks	Island Energy Inc.	1 panel	http://www.solarbc.ca/learn/installers/island-energy
North Sannich	Globe Solar Energy 1P-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar
Brentwood Bay	EnerWorks	Island Energy	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Sannich	EnerWorks	Pacific Solar Smart Homes Inc.	2 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Sannich	Veissman	Pacific Solar Smart Homes Inc.	1 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Sannich	Globe Solar Energy 1P-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar
Sannich	EnerWorks	Island Energy	1 panel	http://www.solarbc.ca/learn/installers/island-energy

Sannich	Swiss Sol-Veissmann system	Pacific Solar Thermal Smart Homes Inc.		http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Sannich	EnerWorks	Pacific Solar Thermal Smart Homes Inc.	1 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Sannich	Thermomax System	G.E.T Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
Victoria	EnerWorks	Island Energy	1 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	Globe Solar Energy 1P-195 system	Globe Solar Energy (Western) Inc.		http://www.solarbc.ca/learn/installers/globe-solar-energy-inc
Victoria	CAREarth Evacuated Tube System	Ambient Source Energy System		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Victoria	EnerWorks	Island Energy Inc.	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	EnerWorks	JB Solar	2 panel	http://www.solarbc.ca/learn/installers/jb-solar
Victoria	EnerWorks	Pacific Solar Thermal Smart Homes	1 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc

		Inc.		
Victoria	EnerWorks	Island Energy Inc.	1 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	EnerWorks	JB Solar	1 panel	http://www.solarbc.ca/learn/installers/jb-solar
Victoria	EnerWorks	Ark Homeworks	1 panel	http://www.solarbc.ca/learn/installers/ark-homeworks
Victoria	EnerWorks	Island Energy Inc.	1 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	16 Tube Sunda System	Ambient Source Energy System		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Victoria	Thermomax System	G.E.T Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
Victoria	EnerWorks	Island Energy Inc.	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	Thermomax System	Island Energy Inc.		http://www.solarbc.ca/learn/installers/island-energy
Victoria	Swiss-Sol Veissmann system	Pacific Solar Thermal Smart Homes Inc.	1 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Victoria	Swiss-Sol Veissmann	Pacific Solar Thermal Smart Homes	2 panel	http://www.solarbc.ca/learn/installers/pacific-solar-

	system	Inc.		smart-homes-inc
Victoria	EnerWorks	Island Energy Inc.	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	EnerWorks	JB Solar	2 panel	http://www.solarbc.ca/learn/installers/jb-solar
Victoria	Swiss-Sol Veissmann system	Pacific Solar Thermal Smart Homes Inc.	2 panel	http://www.solarbc.ca/learn/installers/pacific-solar-smart-homes-inc
Victoria	EnerWorks	Island Energy Inc.	1 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	EnerWorks	Island Energy Inc.	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	EnerWorks	Island Energy Inc.	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	CAREarth Evacuated Tube System	Ambient Source Energy Systems		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Victoria	Apricus System	Via Solar		http://www.solarbc.ca/learn/installers/solar
Victoria	EnerWorks	TerraTek Energy Solutions	1 panel	http://www.solarbc.ca/learn/installers/terratek
Victoria	Heliodyne	G.E.T. Solar		http://www.solarbc.ca/learn/

	System	Solutions		installers/get-solar
Victoria	Globe Solar Energy 1P-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar
Victoria	Heliodyne System	Via Solar	2 panel	http://www.solarbc.ca/learn/installers/solar
Victoria	20 Tube Thermomax System	Island Energy		http://www.solarbc.ca/learn/installers/island-energy
Victoria	CAREarth Evacuated Tube System	Ambient Source Energy Systems		http://www.solarbc.ca/learn/installers/ambient-source-energy-systems
Victoria	EnerWorks	Island Energy	1 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	EnerWorks	Island Energy	1 panel	http://www.solarbc.ca/learn/installers/island-energy
Victoria	Globe Solar Energy 1P-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar
Victoria	Globe Solar Energy 1P-195 system	JB Solar		http://www.solarbc.ca/learn/installers/jb-solar
View Royal	EnerWorks	JB Solar	1 panel	http://www.solarbc.ca/learn/installers/jb-solar

View Royal	EnerWorks	Island Energy	1 panel	http://www.solarbc.ca/learn/installers/island-energy
View Royal	20 Tube Thermodynamics	Island Energy		http://www.solarbc.ca/learn/installers/island-energy
View Royal	EnerWorks	Island Energy	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Langford	EnerWorks	Island Energy	2 panel	http://www.solarbc.ca/learn/installers/island-energy
Langford	Thermomax System	G.E.T. Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
Colwood	Thermomax System	G.E.T. Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
Colwood	Thermomax System	Island Energy Inc.		http://www.solarbc.ca/learn/installers/island-energy
Metchosin	Globe Solar Energy 1P-195 system	Globe Solar Energy (Western) Inc.		http://www.solarbc.ca/learn/installers/globe-solar-energy-inc
Sooke	Veissmann System	G.E.T. Solar Solutions		http://www.solarbc.ca/learn/installers/get-solar
Sooke	Thermodynamics system	Ark Homeworks	2 panel	http://www.solarbc.ca/learn/installers/ark-homeworks
Ucluelet	EnerWorks	Wizards 4 Environmental	2 panel	http://www.solarbc.ca/learn/installers/wizards-4-

				environmental-technology

The determination of the system, contractor, and panel types were determined from the Google map found on the SolarBC website.

9.5 Appendix 5: Supplied Parts Data from EnerWorks

The data seen in this section is the data supplied from the Head of Applications Engineering at EnerWorks. This appendix contains six different tables copied and pasted from MS Excel spreadsheets. The information being represented contains supplied datum for the Energy Pack, HeatSafe Collector, Mounting Kits, and Water Tank. Each of these tables contains masses and embodied energy coefficients for the separate components of the system.

Table B: Supplied Information from EnerWorks regarding the Energy Pack - Embodied Energy from Materials

Item	Description	Qty.	Total Mass (lb)	Coef. Of Energy Embodied (MJ/kg)	Energy Embodied per Components (MJ)	Ref. used	Mass of components (Kg)	Mass Of Individual Component (kg)	mWh	Tonnes CO_2 British Columbia	Tonnes CO_2 Ontario	Tonnes CO_2 Alberta
CAA318-R3 -	Bracket - Back Plate, 16 Guage CRS Steel	1	6.4000	10.1	29.3205	4	2.9030	2.9030	0.0081	0.000219906	0.001922138	0.007452356
	Back plate paint	1			0.0000		0.0000	0.0000	0.0000	0	0	0
XAA081 -	Single Wall Heat Exchanger	1	3.6500				1.6556	1.6556	0.0000	0	0	0
	Stainless Steel	1	2.7000	68.3	83.6478	4	1.2247	1.2247	0.0232	0.000627364	0.005483624	0.02126066
	Copper	1	0.9500	70	30.1642	4	0.4309	0.4309	0.0084	0.000226233	0.001977447	0.007666796
XAA062 -	Pressure Guage, Indicated 40 psi Max	1	0.2000				0.0907	0.0907	0.0000	0	0	0
	Steel	1	0.0300	10.1	0.1374	4	0.0136	0.0136	0.0000	1.03081E-06	9.01002E-06	3.49329E-05
	Brass	1	0.1500	62	4.2185	4	0.0680	0.0680	0.0012	3.16386E-05	0.000276545	0.001072199
	Plastic	1	0.0200	103	0.9344	4	0.0091	0.0091	0.0003	7.00813E-06	6.12562E-05	0.000237498
CAA315-R1 -	Manifold Alignment Plate	1	0.2100	12.9	1.2288	4	0.0953	0.0953	0.0003	9.21603E-06	8.05549E-05	0.000312321
HAA224 -	Rivet (Closed) - 3/16 X 3/8 Head x 1/8 - 1/4 Grip	4	0.0400	8.1	0.5879	4	0.0181	0.0045	0.0002	4.409E-06	3.85379E-05	0.000149416
HAA242 -	Free End Clip, 1/4" Wide, Stainless Steel (Band-It P/N - C252)	2	0.0083	68.3	0.5163	4	0.0038	0.0019	0.0001	3.87262E-06	3.38495E-05	0.000131239
HAA243 -	Banding, 1/4" Wide x 0.020" thk, Stainless Steel, Band-It P/N - C202	2	0.0553	68.3	3.4276	4	0.0251	0.0125	0.0010	2.57076E-05	0.000224703	0.000871201
HAA213 -	Steam Bumper P/N RB-49	6	0.0724	110	21.6788	4	0.0328	0.0055	0.0060	0.000162592	0.001421178	0.005510075
HAA251 -	#8 x 3/8" Phillips Drive Pan Head-Thread Cutting Screw , Type F (Steel)	6	0.0300	10.1	0.8246	4	0.0136	0.0023	0.0002	6.18484E-06	5.40601E-05	0.000209598
BAA133-R1 -	Energy Cover Assembly, 22 Guage CRS (Pow der Coated Steel)	1	5.6000	10.1	25.6554	4	2.5401	2.5401	0.0071	0.000192417	0.001681871	0.006520812
	Cover Assembly Paint	1			0.0000		0.0000	0.0000	0.0000	0	0	0
CAA320-R1 -	Tank Bracket (Steel)	4	0.5455	12.9	12.7667	4	0.2474	0.0619	0.0035	9.5751E-05	0.000836934	0.003244894
HAA134 -	Cable Clamp, 3/8" Cord (Plastic)	2	0.0120	148	1.6112	4	0.0054	0.0027	0.0004	1.20839E-05	0.000105622	0.000409511
HAA225 -	GB-207560s Grommet Bumper (rubber)	1	0.0050	110	0.2495	4	0.0023	0.0023	0.0001	1.8711E-06	1.63548E-05	6.34096E-05
HAA226 -	Grommet 3/8" ID x 5/8" OD Spaenaur P/N 315-259 (Rubber)	2	0.0040	110	0.3992	4	0.0018	0.0009	0.0001	2.99376E-06	2.61677E-05	0.000101455
HAA250 -	#8 x 1" Phillips Drive Pan Head-Thread Cutting Screw , Type F (Steel)	1	0.0059	10.1	0.0269	4	0.0027	0.0027	0.0000	2.02119E-07	1.76667E-06	6.84959E-06
HAA193 -	Plug, Plastic, 3/4" Pipe NPT Threaded Plug	1	0.0086	103	0.4005	4	0.0039	0.0039	0.0001	3.00348E-06	2.62527E-05	0.000101785
HAA216 -	Cap, Vinyl, Black 3/4" NPT	2	0.0167		0.0000		0.0076	0.0038	0.0000	0	0	0
RAA032-R0-10 -	Closed Cell Foam 1/2" Wide x 1/8" THK Weather Stripping w ith PSA back	1	0.0021		0.0000		0.0009	0.0009	0.0000	0	0	0
HAA202 -	Hex Socket Cap Screw M5 x 15mm	2	0.0167	68.3	1.0327	4	0.0076	0.0038	0.0003	7.74523E-06	6.76991E-05	0.000262477
HAA205 -	Jam Nut, 5/8" - 18 x 3/8" Thk Max, Brass	2	0.1000	62	5.6246	4	0.0454	0.0227	0.0016	4.21849E-05	0.000368727	0.001429598
HAA201 -	Oring Metric - 18mm ID x 3.55 Width EPDM (Fugas CODE D0060)	4	0.0080	110	1.5967		0.0036	0.0009	0.0004	1.19751E-05	0.000104671	0.000405821
HAA233 -	Washer 1/8" THK x 5/8" ID x NOM 1 1/8"	2	0.0500	12.9	0.5851	4	0.0227	0.0113	0.0002	4.38859E-06	3.83595E-05	0.000148724
HAA114 -	8/32 x 1" Hex Socket Cap Screw , Zinc Plated	6	0.0400	12.9	1.4043	4	0.0181	0.0030	0.0004	1.05326E-05	9.20628E-05	0.000356938
HAA200 -	Oring - Imperial AS 568 - 010 EPDM Nom. 1/4" ID, 3/8" OD, 1/16" W	2	0.0004	110	0.0399	4	0.0002	0.0001	0.0000	2.99376E-07	2.61677E-06	1.01455E-05
HAA197 -	Dow el Pin 1/8" x 3/8"	2	0.0030	68.3	0.1859	4	0.0014	0.0007	0.0001	1.39414E-06	1.21858E-05	4.72459E-05
CAA311-R0 -	Low er Manifold w ith Filter Housing (DWG-137) - Brass	1	1.7000	62	47.8091	4	0.7711	0.7711	0.0133	0.000358571	0.003134179	0.012151583
XAA094 -	Pressure Relief Valve, set to 50 psi Watts P/N 1/2 53 Z13 050 - Brass	1	0.3500	62	9.8431	4	0.1588	0.1588	0.0027	7.38235E-05	0.000645272	0.002501797
CAA282-R1 -	Filter 100 Micron - Stainless Steel	1	0.0067	68.3	0.2065	4	0.0030	0.0030	0.0001	1.54905E-06	1.35398E-05	5.24955E-05
CAA283-R0 -	Compression Spring - Steel	1	0.0050	32	0.0726	4	0.0023	0.0023	0.0000	5.44321E-07	4.75777E-06	1.84464E-05
HAA191 -	1/8" NPT Hex Nipple x 1", Brass	2	0.0400	62	2.2498	4	0.0181	0.0091	0.0006	1.68739E-05	0.000147491	0.000571839
HAA179 -	Quick Connect Nipple 1/8", Brass, With EPDM Seal	2	0.1100	62	6.1871	4	0.0499	0.0249	0.0017	4.64033E-05	0.0004056	0.001572558
HAA204 -	Oring Metric, 16.1mm ID x 1.6mm Width, EPDM	2	0.0040	110	0.3992	4	0.0018	0.0009	0.0001	2.99376E-06	2.61677E-05	0.000101455
XAA083 -	Oring Port Plug m18 x 1.5, Fugas P/N 10.0290	2	0.0833	12.9	0.9752	4	0.0378	0.0189	0.0003	7.31432E-06	6.39325E-05	0.000247874
CAA128-R2 -	Adapter Coupling, MG Series pump to Oriental Motor	1	0.4000	191	34.6548	4	0.1814	0.1814	0.0096	0.000259913	0.002271834	0.008808169
XAA042 -	Induction Motor With Capacitor (Oriential Motors P/N 21K6A - AWU)	1	1.6500				0.7484	0.7484	0.0000	0	0	0
	Steel - Shaft & bearings	1	0.9000	32	13.0636	4	0.4082	0.4082	0.0036	9.79777E-05	0.000856398	0.003320357
	Alluminium Case	1	0.3000	199	27.0797	4	0.1361	0.1361	0.0075	0.0002031	0.001775242	0.006882823
	Copper	1	0.4500	70.6	14.4108	4	0.2041	0.2041	0.0040	0.000108082	0.000944714	0.003662769
XAA076 -	Magnetic Coupling, 6mm Shaft (Steel)	1	0.1833		0.0000		0.0832	0.0832	0.0000	0	0	0
HAA116 -	#8 Nylock Nut	4	0.0180	68.3	2.2306	4	0.0082	0.0020	0.0006	1.67297E-05	0.00014623	0.000566951
XAA075 -	Pump-MG209 Gear Manifold Mount (mostly stainless steel)	1	0.8500	68.3	26.3336	4	0.3856	0.3856	0.0073	0.000197503	0.001726326	0.006693171
HAA218 -	Screw , 4/40 x 1/4" hex socket cap screw , Zinc-Bright, Steel	6	0.0090	12.9	0.3160	4	0.0041	0.0007	0.0001	2.36984E-06	2.07141E-05	8.03111E-05
CAA312-R0 -	Upper Manifold (Brass)	1	1.8500	62	52.0276	4	0.8391	0.8391	0.0145	0.00039021	0.003410724	0.013223782
BAA144-R1 -	Expansion Tank Elbow Assembly (Brass)	1	0.5000	62	14.0615	4	0.2268	0.2268	0.0039	0.000105462	0.000921817	0.003573995
CAA341-R0 -	Adaptor 1" Female NPT to 1/2" Copper	1	0.1600	70	5.0803	4	0.0726	0.0726	0.0014	3.81025E-05	0.000333044	0.00129125
XAA082 -	Expansion Tank - 1 Litre, 1" NPT SS Connection Flexcon Model PW2	1	2.1000				0.9525	0.9525	0.0000	0	0	0
	Rubber	1	0.3000	110	14.9687	4	0.1361	0.1361	0.0042	0.000112266	0.000981289	0.003804575
	Steel Case	1	1.8000	10.1	8.2464	4	0.8165	0.8165	0.0023	6.18484E-05	0.000540601	0.002095975
CAA242-R2 -	Valve Body - (Nylon)	1	0.0060		0.0000		0.0027	0.0027	0.0000	0	0	0
HAA178 -	Dow el Pin - DP100 2.5mm x 20mm Steel	1	0.0030	68.3	0.0929	4	0.0014	0.0014	0.0000	6.97071E-07	6.09292E-06	2.3623E-05
HAA050 -	Ball-Plastic SG=1.4 7/16 Diameter, White Plastic, Derlin	1	0.0040		0.0000		0.0018	0.0018	0.0000	0	0	0
CAA290-R2 -	Electrical Bracket - 18 Guage (Steel)	1	0.7500	12.9	4.3886	4	0.3402	0.3402	0.0012	3.29144E-05	0.000287696	0.001115432
XAA080 -	Step Dow n Transformer 120VAC - 24VAC	1	0.7000				0.3175	0.3175	0.0000	0	0	0
	Iron / steel	1	0.4000	10.1	1.8325	4	0.1814	0.1814	0.0005	1.37441E-05	0.000120134	0.000465772
	Plastic	1	0.0500	103	2.3360	4	0.0227	0.0227	0.0006	1.75203E-05	0.000153141	0.000593744
	Copper	1	0.2500	70.6	8.0060	4	0.1134	0.1134	0.0022	6.00454E-05	0.000524841	0.002034871
CAA313-R2 -	Controller Mount (Steel)	1	0.8000	12.9	4.6811	4	0.3629	0.3629	0.0013	3.51087E-05	0.000306876	0.001189795
XAA067 -	Customized D-155 Controller Pkg (mostly plastic)	1	0.3333		0.0000		0.1512	0.1512	0.0000	0	0	0
HAA251 -	#8 x 3/8" Phillips Drive Pan Head-Thread Cutting Screw , Type F	1	0.0035	12.9	0.0205	4	0.0016	0.0016	0.0000	1.53601E-07	1.34258E-06	5.20535E-06
HAA257 -	3/8" Flare Fitting Cap (Brass)	1	0.0350	62	0.9843	4	0.0159	0.0159	0.0003	7.38235E-06	6.45272E-05	0.00025018
HAA269 -	1/4" Female x 1/8" Male Reducing Elbow - Brass for Upper Manifold of Energy Pack	1	0.0667	62	1.8749	4	0.0302	0.0302	0.0005	1.40616E-05	0.000122909	0.000476533
		Total Embodied Energy			**532.70**				0.1480	0.003995271	0.034921626	0.135395288
									Total Mass k	3.995270807	34.92162631	135.3952885

Table C: Supplied from EnerWorks - Energy Pack - Embodied Energy from Transportation				Total Mass	Distance	Energy Intensity	Enrgy (MJ)
Item	Description	Qty.	Mass (lb)	(Kg)	Traveled (Km)	(MJ/Net.T.km)	
CAA318-R3 -	Bracket - Back Plate, 16 Guage CRS	1	6.4000	2.9030	90	2.5000	0.6532
XAA081 -	Single Wall Heat Exchanger	1	3.6500	1.6556	5450 / 1230	1.4 / 2.5	17.9321
XAA062 -	Pressure Guage, Indicated 40 psi Max	1	0.2000	0.0907	100	2.5000	0.0227
CAA315-R1 -	Manifold Alignment Plate	1	0.2100	0.0953	90	2.5000	0.0214
HAA224 -	Rivet (Closed) - 3/16 X 3/8 Head x 1/8 - 1/4 Grip	4	0.0100	0.0181	20	2.5000	0.0009
HAA242 -	Free End Clip, 1/4" Wide, Stainless Steel (Band-It P/N - C252)	2	0.0042	0.0038	20	2.5000	0.0002
HAA243 -	Banding, 1/4" Wide x 0.020" thk, Stainless Steel, Band-It P/N - C202	2	0.0277	0.0251	20	2.5000	0.0013
HAA213 -	Steam Bumper P/N RB-49	6	0.0121	0.0328	100	2.5000	0.0082
HAA251 -	#8 x 3/8" Phillips Drive Pan Head-Thread Cutting Screw , Type F	6	0.0050	0.0136	20	2.5000	0.0007
BAA133-R1 -	Energy Cover Assembly, 22 Guage CRS (Pow der Coated)	1	5.6000	2.5401	90	2.5000	0.5715
CAA320-R1 -	Tank Bracket	4	0.1364	0.2474	90	2.5000	0.0557
HAA134 -	Cable Clamp, 3/8" Cord	2	0.0060	0.0054	90	2.5000	0.0012
HAA225 -	GB-207560s Grommet Bumper	1	0.0050	0.0023	90	2.5000	0.0005
HAA226 -	Grommet 3/8" ID x 5/8" OD Spaenaur P/N 315-259	2	0.0020	0.0018	100	2.5000	0.0005
HAA250 -	#8 x 1" Phillips Drive Pan Head-Thread Cutting Screw , Type F	2	0.0059	0.0053	20	2.5000	0.0003
HAA193 -	Plug, Plastic, 3/4" Pipe NPT Threaded Plug	1	0.0086	0.0039	120	2.5000	0.0012
HAA216 -	Cap, Vinyl, Black 3/4" NPT	2	0.0083	0.0076	180	2.5000	0.0034
RAA032-R0-10 -	Closed Cell Foam 1/2" Wide x 1/8" THK Weather Stripping w ith PSA back Spaenaur 892-360	1	0.0021	0.0009	90	2.5000	0.0002
HAA202 -	Hex Socket Cap Screw M5 x 15mm	2	0.0083	0.0076	20	2.5000	0.0004
HAA205 -	Jam Nut, 5/8" - 18 x 3/8" Thk Max, Brass	2	0.0500	0.0454	20	2.5000	0.0023
HAA201 -	Oring Metric - 18mm ID x 3.55 Width EPDM (Fugas CODE D0060)	4	0.0020	0.0036	7428	3.4300	0.0925
HAA233 -	Washer 1/8" THK x 5/8" ID x NOM 1 1/8"	2	0.0250	0.0227	20	2.5000	0.0011
HAA114 -	8/32 x 1" Hex Socket Cap Screw , Zinc Plated	6	0.0067	0.0181	20	2.5000	0.0009
HAA200 -	Oring - Imperial AS 568 - 010 EPDM Nom. 1/4" ID, 3/8" OD, 1/16" W	2	0.0002	0.0002	20	2.5000	0.0000
HAA197 -	Dow el Pin 1/8" x 3/8"	2	0.0015	0.0014	175	2.5000	0.0006
CAA311-R0 -	Low er Manifold w ith Filter Housing (DWG-137)	1	1.7000	0.7711	5800 / 1630	1.4 / 2.5	9.4037
XAA094 -	Pressure Relief Valve, set to 50 psi Watts P/N 1/2 53 Z13 050	1	0.3500	0.1588	120	2.5000	0.0476
CAA282-R1 -	Filter 100 Micron	1	0.0067	0.0030	440	2.5000	0.0033
CAA283-R0 -	Compression Spring	1	0.0050	0.0023	120	2.5000	0.0007
HAA191 -	1/8" NPT Hex Nipple x 1", Brass	2	0.0200	0.0181	30	2.5000	0.0014
HAA179 -	Quick Connect Nipple 1/8", Brass, With EPDM Seal	2	0.0550	0.0499	120	2.5000	0.0150
HAA204 -	Oring Metric, 16.1mm ID x 1.6mm Width, EPDM	2	0.0020	0.0018	7428	3.4300	0.0462
XAA083 -	Oring Port Plug m18 x 1.5, Fugas P/N 10.0290	2	0.0417	0.0378	7428	3.4300	0.9631
CAA128-R2 -	Adapter Coupling, MG Series pump to Oriental Motor	1	0.4000	0.1814	90	2.5000	0.0408
XAA042 -	Induction Motor With Capacitor (Oriential Motors P/N 21K6A - AWU)	1	1.6500	0.7484	8900 / 3400	1.4 / 2.5	15.6872
XAA076 -	Magnetic Coupling, 6mm Shaft	1	0.1833	0.0832	5800 / 1700	1.4 / 2.5	1.0287
HAA116 -	#8 Nylock Nut	4	0.0045	0.0082	20	2.5000	0.0004
XAA075 -	Pump-MG209 Gear Manifold Mount	1	0.8500	0.3856	5800 / 1700	1.4 / 2.5	4.7693
HAA218 -	Screw , 4/40 x 1/4" hex socket cap screw , Zinc-Bright, Steel	6	0.0015	0.0041	20	2.5000	0.0002
CAA312-R0 -	Upper Manifold	1	1.8500	0.8392	5800 / 1630	1.4 / 2.5	10.2335
BAA144-R1 -	Expansion Tank Elbow Assembly	1	0.5000	0.2268	220	2.5000	0.1247
CAA341-R0 -	Adaptor 1" Female NPT to 1/2" Copper	1	0.1600	0.0726	30	2.5000	0.0054
XAA082 -	Expansion Tank - 1 Litre, 1" NPT SS Connection Flexcon Model PW2	1	2.1000	0.9526	600	2.5000	1.4288
CAA242-R2 -	Valve Body	1	0.0060	0.0027	780	2.5000	0.0053
HAA178 -	Dow el Pin - DP100 2.5mm x 20mm	1	0.0030	0.0014	780	2.5000	0.0027
HAA050 -	Ball-Plastic SG=1.4 7/16 Diameter, White Plastic, Derlin	1	0.0040	0.0018	780	2.5000	0.0035
CAA290-R2 -	Electrical Bracket - 18 Guage	1	0.7500	0.3402	90	2.5000	0.0765
XAA080 -	Step Dow n Transformer 120VAC - 24VAC	1	0.7000	0.3175	160	2.5000	0.1270
CAA313-R2 -	Controller Mount	1	0.8000	0.3629	90	2.5000	0.0816
XAA067 -	Customized D-155 Controller Pkg	1	0.3333	0.1512	3200	3.4300	1.6594
HAA251 -	#8 x 3/8" Phillips Drive Pan Head-Thread Cutting Screw , Type F	1	0.0035	0.0016	20	2.5000	0.0001
HAA257 -	3/8" Flare Fitting Cap	1	0.0350	0.0159	20	2.5000	0.0008
HAA269 -	1/4" Female x 1/8" Male Reducing Elbow - Brass for Upper Manifold of Energy Pack Versa Fittings # 115-BA	1	0.0667	0.0302	20	2.5000	0.0015
				Total Energy Embodied due to Transportation			65.1315

Table D: HeatSafe Collector Information Supplied by EnerWorks

ITEM #	DESCRIPTION	QTY.	Values per total Items MASS (lbs)	Volume (in3)	DENSITY (lb/in3)	Energy Embodied (MJ/kg)	Total Energy Embodied (MJ)	Ref. used	Mass of components (Kg)	Mass Of Individual Component (kg)	mWh	Tonnes CO_2 British Columbia	Tonnes CO_2 Ontario	Tonnes CO_2 Alberta
XAA 027	Glass, tempered 96x46x1/8"	1	49.8456	552.0000	0.0903	26.2	592.38	4	22.60958384	22.60958384	0.1646	0.00444286	0.038833925	0.15056374
CAA 245	Grommet 5/16 ID (EPDM rubber)	2	0.0312	0.7260	0.0430	110.0	1.56	4	0.014152082	0.007076041	0.0004	1.1676E-05	0.000102054	0.00039568
CAA 244 R1	Plug, thermister port (Plastic)	2	0.0006	0.1360	0.0044	110.0	0.03	4	0.000272155	0.000136078	0.0000	2.2453E-07	1.96258E-06	7.6092E-06
CAA 351 R1 .375	Residential insulation 3/8 thk, blank pipe filler (Poly-Iso-Cyanurate Foam)	4	0.0173	13.3640	0.0013	1.75	0.01	2	0.007825889	0.001956472	0.0000	1.0272E-07	8.9782E-07	3.481E-06
CAA 346 R1	Insulation 1" res-collector blank for top/ bottom pieces (Poly-Iso-Cyanurate Foam)	2	0.1500	116.1876	0.0013	1.75	0.12	2	0.068038856	0.034019428	0.0000	8.9303E-07	7.80571E-06	3.0264E-05
CAA 345 R1	Insulation 1" res-collector blank stock for side pieces (Poly-Iso-Cyanurate Foam)	2	0.3400	264.0000	0.0013	1.75	0.27	2	0.154221406	0.077110703	0.0001	2.0242E-06	1.76929E-05	6.8598E-05
BAA 139	**Residential back insulation**	**1**	**16.7938**	**5014.3200**					7.617539543	7.617539543	0.0000	0	0	0
"	Aluminium	1	8.4162	86.3200	0.0975	24.1	91.95	4	3.817524104	3.817524104	0.0255	0.00068963	0.00602787	0.02337077
"	Mineral wool	1	8.3776	8.3776	0.0017	15.6	59.28	2	3.800015439	3.800015439	0.0165	0.00044461	0.00388622	0.01506734
CAA 236 R1	Hat channel residential - Steel	1	2.4000	5.3670	0.4472	17.5	19.05	3	1.088621688	1.088621688	0.0053	0.00014288	0.001248914	0.00484219
RAA 027 R0	Silicone bead (Silicone adhesive)	1	4.5000	58.1395	0.0774	110.0	224.53	4	2.041165665	2.041165665	0.0624	0.00168399	0.014719341	0.05706863
CAA 237 R3	Intake grill (Steel)	1	1.5000	6.6400	0.2259	17.5	11.91	3	0.680388555	0.680388555	0.0033	8.9303E-05	0.000780571	0.00302637
CAA 249 R1	Glazing stand off (EPDM rubber)	3	0.0090	0.3120	0.0288	110.0	0.45	4	0.004082331	0.001360777	0.0001	3.368E-06	2.94387E-05	0.00011414
HAA 093	Short flare nut - 3/8 tube forged (Brass)	2	0.0800	0.4080	0.1961	62.0	2.25	4	0.03628739	0.018143695	0.0006	1.6874E-05	0.000147491	0.00057184
BAA 119-R3	**Absorber serpentine residential**	**1**	**13.3567**	**99.6900**					6.058480806	6.058480806	0.0000	0	0	0
"	Aluminium sheet	1	8.1522	83.6118	0.0975	33.2	122.84	4	3.697753266	3.697753266	0.0341	0.00092131	0.00805295	0.03122224
"	Paint	1	0.1199	2.3100	0.0519	98.1	5.33	4	0.054380736	0.054380736	0.0015	4.0011E-05	0.000349729	0.00135594
"	Copper serpentine	1	5.2045	16.0782	0.3237	70.6	166.67	4	2.360727541	2.360727541	0.0463	0.00125003	0.010926171	0.04236206
CAA 272	Thread plug 5/16 nutsert (EPDM)	4	0.0040	2.5080	0.0016	110.0	0.20	4	0.001814369	0.000453592	0.0001	1.4969E-06	1.30839E-05	5.0728E-05
HAA 228	#8x1-1/2" self drilling screw, Philips drive pan head	8	0.0673	0.3360	0.2004	34.8	1.06	4	0.03054237	0.003817796	0.0003	7.9717E-06	6.96786E-05	0.00027015
HAA 250	#8x1" Philips drive pan head- thread cutting screw, type F	4	0.0280	0.1397	0.2004	34.8	0.44	4	0.012700586	0.003175147	0.0001	3.3149E-06	2.89748E-05	0.00011234
HAA 251	#8 x 3/8 Philips drive pan head-thread cutting screw, type F	4	0.0120	0.0599	0.2004	34.8	0.19	4	0.005443108	0.001360777	0.0001	1.4207E-06	1.24178E-05	4.8145E-05
HAA 229	#8 X 1/2" Philips Drive Pan Head, self drilling screw, Teks	2	0.0072	0.0360	0.2004	34.8	0.11	4	0.003272397	0.001636198	0.0000	8.5411E-07	7.46556E-06	2.8945E-05
HAA 194	3/8" - 18 flared fitting plug (Plastic)	2	0.0080	0.2356	0.0340	103.0	0.37	4	0.003628739	0.001814369	0.0001	2.8033E-06	2.45025E-05	9.4999E-05
CAA 248	Damper Hinge (Stainless Steel)	2	0.0440	1.0920	0.0403	148.0	2.95	4	0.019958064	0.009979032	0.0008	2.2154E-05	0.000193641	0.00075077
CAA 212 - R8	Frame one piece, assembled residential, prepainted galvalume (Steel)	1	18.1320	63.9350	0.2836	17.5	143.93	3	8.224521431	8.224521431	0.0400	0.00107949	0.009435526	0.03658265
CAA 250Z -R0-1	Glazing spacer (1ft) - EPDM rubber	24	2.1000	994.2480	0.0021	110.0	104.78	4	0.952543977	0.039689332	0.0291	0.00078586	0.006869026	0.02663203
CAA 240 R1	Valve sealing Channel (Stainless Steel)	1	1.1500	4.1750	0.2754	17.5	9.13	3	0.521631226	0.521631226	0.0025	6.8465E-05	0.000598438	0.00232021
HAA 224	Rivet closed 3/16x3/8 head x1/8-1/4 grip	2	0.0120	0.0312	0.3846	14.8	0.08	4	0.005443108	0.002721554	0.0000	6.042E-07	5.28112E-06	2.0476E-05
BAA 147	Valve Actuator link riveted to valve damper (Stainless Steel)	1	1.5000	6.0100	0.2496	68.3	46.47	4	0.680388555	0.680388555	0.0129	0.00034854	0.003046458	0.01181148
CAA 322-R1	Damper cover EDPM.....	1	0.7000	14.0100	0.0500	110.0	34.93	4	0.317514659	0.317514659	0.0097	0.00026195	0.002289675	0.00887734
CAA 243	Guide Nylon 6 HS, natural	1	0.0034	0.0210	0.1619	148.0	0.23	4	0.001542214	0.001542214	0.0001	1.7119E-06	1.49632E-05	5.8014E-05
CAA 239	Push Rod, 16 gauge, 304 ss	1	0.0400	0.1720	0.2326	68.3	1.24	4	0.018143695	0.018143695	0.0003	9.2943E-06	8.12389E-05	0.00031497
CAA 241 - R1	Spring seat, Nylon 6HS natural	1	0.0020	0.0460	0.0435	148.0	0.13	4	0.000907185	0.000907185	0.0000	1.007E-06	8.80187E-06	3.4126E-05
CAA 153 - R2	Spring - bias, wire dia 0.024", 302 ss	1	0.0035	0.0400	0.0875	68.3	0.11	4	0.001587573	0.001587573	0.0000	8.1325E-07	7.1084E-06	2.756E-05
CAA 296 - R1	Spring SMA (compression), wire dia 0.063" NiTi Alloy H	1	0.0050	0.0230	0.2174		0.00		0.002267962	0.002267962	0.0000	0	0	0
CAA 255	Spring Mount (Stainless steel)	1	0.0800	0.3400	0.2353	68.3	2.48	4	0.03628739	0.03628739	0.0007	1.8589E-05	0.000162478	0.00062995
CAA 259 - R1	Stepped Rivet, soft brass	1	0.0070	0.0220	0.3182	62.0	0.20	4	0.003175147	0.003175147	0.0001	1.4765E-06	1.29054E-05	5.0036E-05
HAA 093	Short flare nut - 3/8 tube forged (Brass)	2	0.0800	0.4080	0.1961	62.0	2.25	4	0.03628739	0.018143695	0.0006	1.6874E-05	0.000147491	0.00057184
				Total Energy Embodied (MJ)			**1649.92**							

Table E: Information Regarding Mounting Kits for Two Collectors (Residential), supplied by EnerWorks

Item	Description	Qty.	Total Mass (lb)	Coef. Of Energy Embodied	Energy Embodied per Components	Ref. Used	Mass of components (Kg)	Mass Of Individual Component (kg)	mWh	Tonnes CO_2 British Columbia	Tonnes CO_2 Ontario	Tonnes CO_2 Alberta
CAA245L-R1	Mount with hook, left, powder coat black paint	2	0.6000	34.8	9.4711	4	0.272155422	4.735552935	0.0026	7.10339E-05	0.000620889	0.0024
CAA245R-R1	Mount with hook, right, powder coat black paint	2	0.6000	34.8	9.4711	4	0.272155422	4.735552935	0.0026	7.10339E-05	0.000620889	0.0024
CAA253-R1	Lower collector mount bracket, powder coat black paint	4	1.0000	34.8	15.7852	4	0.45359237	3.946294112	0.0044	0.00011839	0.001034814	0.0040
HAA234-R1	Screw 5/16-1" Hex Cap steel, powder coat black	8	0.2000	34.8	3.1570	4	0.090718474	0.394629411	0.0009	2.3678E-05	0.000206963	0.0008
HAA231-R1	screw 3/8-16 x 3/4" Hex Cap, powder coat black	8	0.2400	34.8	3.7884	4	0.108862169	0.473555293	0.0011	2.84135E-05	0.000248355	0.0010
HAA192	B-line Twril nut 3/8" PLTD	8	0.8000	34.8	12.6281	4	0.362873896	1.578517645	0.0035	9.47118E-05	0.000827851	0.0032
HAA162-R1	3/8 Hardened washer, powder coat black	8	0.0500	34.8	0.7893	4	0.022679619	0.098657353	0.0002	5.91949E-06	5.17407E-05	0.0002
HAA163-R1	5/16 Hardened washer, powder coat black	8	0.0900	34.8	1.4207	4	0.040823313	0.177583235	0.0004	1.06551E-05	9.31333E-05	0.0004
XAA093-R0-102	1 5/8" x 1 5/8" Unistrut, slotted, galvanized and cut to 102"	2	28.5600	34.8	450.8246	4	12.95459809	225.4123197	0.1252	0.003381212	0.029554296	0.1146
CAA229	Mount - Spacer	8	0.4800	103	22.4258	4	0.217724338	2.803229611	0.0062	0.000168195	0.00147015	0.0057
HAA156	Screw 3/8 x 5" Lag - hot galvanized finish	8	1.2000	34.8	18.9422	4	0.544310844	2.367776467	0.0053	0.000142068	0.001241777	0.0048
HAA162	3/8" hardened washer galvanized	8	0.2400	34.8	3.7884	4	0.108862169	0.473555293	0.0011	2.84135E-05	0.000248355	0.0010
XAA060	2' Flashing Plumbing	1	0.3500	110	17.4635	4	0.15875733	17.46348544	0.0049	0.000130977	0.001144838	0.0044
HAA237	Woodbinder screw, Hex washer head - painted	4	0.0500	34.8	0.7893	4	0.022679619	0.197314706	0.0002	5.91949E-06	5.17407E-05	0.0002
	3/8" Flare 90º Elbow	2		62	0.0000	4	0	0	0.0000	0	0	0.0000
	Insulation for 3/8" copper pipe				0.0000		0		0.0000	0	0	0.0000
	Copper line set 50 feet			70.6	0.0000	4	0		0.0000	0	0	0.0000
RAA023	Polyurethane Roof Sealant	1	1.0000	74	33.5662	4	0.45359237	33.56617981	0.0093	0.000251748	0.002200467	0.0085
Total Amount of Energy Embodied due to Installation (considering a two collector system)					**604.31**							

Tank Composition:
- Steel 275 lbs
- Polyurethane foam 19 lbs
- Glass 10 lbs
- Magnesium 4 lbs
- Plastic and rubber 1.5 lbs
- Brass 0.8 lbs

Table F: Conversion Factors Based on Provice

Conversions	
Alberta	0.915
Onatrio	0.236
B.C.	0.027

Table G: Masses, Coefficients of Energy, and Tonnes of CO2 for Materials Comprising EnerWorks Spectrum Preheat Appliance, supplied by EnerWorks

Item	Mass (lb)	Mass (kg)	Coef. Of Energy	Energy Embodied per	Ref. Used	mWh	Tonnes CO_2 British Columbia	Tonnes CO_2	Tonnes CO_2 Alberta
Steel	275	124.7379	68.3	8519.60		2.3666	0.06390	0.5585	2.1654
Polyurethane Foam	19	8.618255	80.1	690.32	EW	0.1918	0.00518	0.0453	0.1755
Glass	10	4.5359237	18.5	83.91	ICE	0.0233	0.00063	0.0055	0.0213
Mg	4	1.8143695			ICE	0.0000	0.00000	0.0000	0.0000
Rubber	1.5	0.6803886	91.0	61.92		0.0172	0.00046	0.0041	0.0157
Brass	0.8	0.3628739	62.0	22.50	ICE	0.0062	0.00017	0.0015	0.0057
Total		137.89208		9378.25	EW	2.6051	0.07034	0.6148	2.3837

The total embodied energy for the water tank is 4126.9MJ. This includes both the embodied energy for feedstock as well as fuel. This is for an 86.2 kg water tank

9.6 *Appendix 6: Benefit Cost Analysis Template and Data*

This appendix contains all of the tables that were present on the MS Excel spreadsheets used to complete the BCA for the four different scenarios. The information that is represented in this appendix contains tables H to AA, and they are organized on separate pages as the individual scenarios.

Tables H-L: Scenario One information representing the net present value of installing the EnerWorks Spectrum Preheat Appliance at real electricity and natural gas inflation rates of 0%, across the three remaining Solar Colwood incentive profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate

Table H

Discount Rate (%)		1.00%
Cost of elec . / kWh		$0.0627
Cost of gas / kWh		$0.0515
Annual energy off set of EnerWorks Sprectrum Preheat Appliance (kWh/yr)		2235
Energy Inflation Rate (%)	elec.	0
	gas.	0
Incentive Package Amount		$3,500.00
Cost of EnerWorks System, with installation		$8,900.00

Table I: Energy saving for duration of the project considering annual energy inflation

	Elec.	Gas
1	$ 140.13	$ 115.10
2	$ 140.13	$ 115.10
3	$ 140.13	$ 115.10
4	$ 140.13	$ 115.10
5	$ 140.13	$ 115.10
6	$ 140.13	$ 115.10
7	$ 140.13	$ 115.10
8	$ 140.13	$ 115.10
9	$ 140.13	$ 115.10
10	$ 140.13	$ 115.10
11	$ 140.13	$ 115.10
12	$ 140.13	$ 115.10
13	$ 140.13	$ 115.10
14	$ 140.13	$ 115.10
15	$ 140.13	$ 115.10
16	$ 140.13	$ 115.10
17	$ 140.13	$ 115.10
18	$ 140.13	$ 115.10
19	$ 140.13	$ 115.10
20	$ 140.13	$ 115.10
21	$ 140.13	$ 115.10
22	$ 140.13	$ 115.10
23	$ 140.13	$ 115.10
24	$ 140.13	$ 115.10
25	$ 140.13	$ 115.10
26	$ 140.13	$ 115.10
27	$ 140.13	$ 115.10
28	$ 140.13	$ 115.10
29	$ 140.13	$ 115.10
30	$ 140.13	$ 115.10
Total	$ 4,204.04	$ 3,453.08
NPV	$3,616.55	$2,970.53

Table K: Net Benefits of Electricity and Gas

Net Benefit (electricity)	-$1,838.45
Net Benefit (gas)	-$2,484.47

Table L: Incentive Profile

	$3,500.00	$3,000.00	$2,250.00
Net Benefit (electricity)	-$1,838.45	-$2,338.45	-$3,088.45
Net Benefit (gas)	-$2,484.47	-$2,984.47	-$3,734.47

Table J: Homeowner Costs and Benefits

Homeowner costs			Homeowner Benefits	
Cost of EnerWorks Sprectrum Preheat Appliance including installation less total rebates	$ 5,400.00		PVB of energy savings over length of the project (elec.)	$3,616.55
Cost of Home Inspection	$ 55.00		PVB of energy savings over length of the project (gas.)	$2,970.53
Total PVC	$ 5,455.00			
PVC - Present Value Costs			PVB - Present Value Benefits	

Tables M-Q: Scenario Two information representing the net present value of installing the EnerWorks Spectrum Preheat Appliance at real electricity and natural gas inflations rate of 3% and 2% respectively across the three remaining Solar Colwood incentive profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate

Table M		
Discount Rate (%)		1.00%
Cost of elec . / kWh		$0.0627
Cost of gas / kWh		$0.0515
Annual energy off set of EnerWorks Sprectrum Preheat Appliance (kWh/yr)		2235
Energy Inflation Rate (%)	elec.	3
	gas.	2
Incentive Package Amount		$2,250.00
Cost of EnerWorks System, with installation		$8,900.00

Table N: Energy saving for duration of the project consideing annual energy inflation		
	Elec.	Gas
1	$ 140.13	$ 115.10
2	$ 144.34	$ 117.40
3	$ 148.67	$ 119.75
4	$ 153.13	$ 122.15
5	$ 157.72	$ 124.59
6	$ 162.45	$ 127.08
7	$ 167.33	$ 129.62
8	$ 172.35	$ 132.22
9	$ 177.52	$ 134.86
10	$ 182.84	$ 137.56
11	$ 188.33	$ 140.31
12	$ 193.98	$ 143.12
13	$ 199.80	$ 145.98
14	$ 205.79	$ 148.90
15	$ 211.97	$ 151.88
16	$ 218.32	$ 154.91
17	$ 224.87	$ 158.01
18	$ 231.62	$ 161.17
19	$ 238.57	$ 164.39
20	$ 245.73	$ 167.68
21	$ 253.10	$ 171.04
22	$ 260.69	$ 174.46
23	$ 268.51	$ 177.95
24	$ 276.57	$ 181.51
25	$ 284.86	$ 185.14
26	$ 293.41	$ 188.84
27	$ 302.21	$ 192.61
28	$ 311.28	$ 196.47
29	$ 320.62	$ 200.40
30	$ 330.24	$ 204.40
Total	$ 6,666.96	$ 4,669.49
NPV	$5,611.28	$3,958.27

Table P: Net Benefits of Electricity and Gas	
Net Benefit (electricity)	-$1,093.72
Net Benefit (gas)	-$2,746.73

	Table Q: Incentive Profile		
	$3,500.00	$3,000.00	$2,250.00
Net Benefit (electricity)	$ 156.28	-$ 343.72	-$1,093.72
Net Benefit (gas)	-$1,496.73	-$1,996.73	-$2,746.73

Table O: Homeowner Costs and Benefits			
Homeowner costs		Homeowner Benefits	
Cost of EnerWorks Sprectrum Preheat Appliance including installation less total rebates	$ 6,650.00	PVB of energy savings over length of the project (elec.)	$5,611.28
Cost of Home Inspection	$ 55.00	PVB of energy savings over length of the project (gas.)	$3,958.27
Total PVC	$ 6,705.00		

Tables R-V: Scenario Three information representing the net present value of installing the EnerWorks Spectrum Preheat Appliance at real electricity and natural gas inflations rate of 5% and 4% respectively, across the three remaining Solar Colwood incentives profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate

Table R		
Discount Rate (%)		1.00%
Cost of elec . / kWh		$0.0627
Cost of gas / kWh		$0.0515
Annual energy off set of EnerWorks Sprectrum Preheat Appliance (kWh/yr)		2235
Energy Inflation Rate (%)	elec.	5
	gas.	4
Incentive Package Amount		$2,250.00
Cost of EnerWorks System, with installation		$8,900.00

Table S: Energy saving for duration of the project consideing annual energy inflation		
	Elec.	Gas
1	$ 140.13	$ 115.10
2	$ 147.14	$ 119.71
3	$ 154.50	$ 124.49
4	$ 162.22	$ 129.47
5	$ 170.33	$ 134.65
6	$ 178.85	$ 140.04
7	$ 187.79	$ 145.64
8	$ 197.18	$ 151.47
9	$ 207.04	$ 157.53
10	$ 217.39	$ 163.83
11	$ 228.26	$ 170.38
12	$ 239.68	$ 177.20
13	$ 251.66	$ 184.28
14	$ 264.24	$ 191.65
15	$ 277.46	$ 199.32
16	$ 291.33	$ 207.29
17	$ 305.90	$ 215.58
18	$ 321.19	$ 224.21
19	$ 337.25	$ 233.18
20	$ 354.11	$ 242.50
21	$ 371.82	$ 252.20
22	$ 390.41	$ 262.29
23	$ 409.93	$ 272.78
24	$ 430.43	$ 283.69
25	$ 451.95	$ 295.04
26	$ 474.55	$ 306.84
27	$ 498.27	$ 319.12
28	$ 523.19	$ 331.88
29	$ 549.35	$ 345.16
30	$ 576.81	$ 358.96
Total	$ 9,310.37	$ 6,455.52
NPV	$7,730.34	$5,395.82

Table U: Net Benefits of Electricity and Gas	
Net Benefit (electricity)	$1,025.34
Net Benefit (gas)	-$1,309.18

	Table V: Incentive Profile		
	$3,500.00	$3,000.00	$2,250.00
Net Benefit (electricity)	$2,275.34	$1,775.34	$1,025.34
Net Benefit (gas)	-$ 59.18	-$ 559.18	$2,250.00

Table T: Homeowner Costs and Benefits				
Homeowner costs			**Homeowner Benefits**	
Cost of EnerWorks Sprectrum Preheat Appliance including installation less total rebates	$ 6,650.00		PVB of energy savings over length of the project (elec.)	$7,730.34
Cost of Home Inspection	$ 55.00		PVB of energy savings over length of the project (gas.)	$5,395.82
Total PVC	$ 6,705.00			

Tables W-AA: Scenario Four information representing the net present value of installing the EnerWorks Spectrum Preheat Appliance at real annual electricity and natural gas inflations rate of 3% and 2% respectively, across the three remaining Solar Colwood incentives profiles. This is calculated assuming all costs of installation in the present, and 30 years of benefits starting one year after installation as an estimate based upon a discount rate of 0% (considers present and future generations are equivalent)

Table W		
Discount Rate (%)		0.00%
Cost of elec. / kWh		$0.0627
Cost of gas / kWh		$0.0515
Annual energy off set of EnerWorks Sprectrum Preheat Appliance (kWh/yr)		2235
Energy Inflation Rate (%)	elec.	3
	gas.	2
Incentive Package Amount		$2,250.00
Cost of EnerWorks System, with installation		$8,900.00

Table X: Energy saving for duration of the project consideing annual energy inflation	Elec.	Gas
1	$ 140.13	$ 115.10
2	$ 144.34	$ 117.40
3	$ 148.67	$ 119.75
4	$ 153.13	$ 122.15
5	$ 157.72	$ 124.59
6	$ 162.45	$ 127.08
7	$ 167.33	$ 129.62
8	$ 172.35	$ 132.22
9	$ 177.52	$ 134.86
10	$ 182.84	$ 137.56
11	$ 188.33	$ 140.31
12	$ 193.98	$ 143.12
13	$ 199.80	$ 145.98
14	$ 205.79	$ 148.90
15	$ 211.97	$ 151.88
16	$ 218.32	$ 154.91
17	$ 224.87	$ 158.01
18	$ 231.62	$ 161.17
19	$ 238.57	$ 164.39
20	$ 245.73	$ 167.68
21	$ 253.10	$ 171.04
22	$ 260.69	$ 174.46
23	$ 268.51	$ 177.95
24	$ 276.57	$ 181.51
25	$ 284.86	$ 185.14
26	$ 293.41	$ 188.84
27	$ 302.21	$ 192.61
28	$ 311.28	$ 196.47
29	$ 320.62	$ 200.40
30	$ 330.24	$ 204.40
Total	$ 6,666.96	$ 4,669.49
NPV	$6,666.96	$4,669.49

Table Z: Net Benefits of Electricity and Gas	
Net Benefit (electricity)	-$38.04
Net Benefit (gas)	-$2,035.51

	Table AA: Incentive Profile		
	$3,500.00	$3,000.00	$2,250.00
Net Benefit (electricity)	$1,211.96	$ 711.96	-$ 38.04
Net Benefit (gas)	-$ 785.51	-$1,285.51	-$2,035.51

Table Y: Homeowner Costs and Benefits				
Homeowner costs			**Homeowner Benefits**	
Cost of EnerWorks Sprectrum Preheat Appliance including installation less total rebates	$ 6,650.00		PVB of energy savings over length of the project (elec.)	$6,666.96
Cost of Home Inspection	$ 55.00		PVB of energy savings over length of the project (gas.)	$4,669.49
Total PVC	$ 6,705.00			