FACTSHEET

Assessing the Feasibility of Using Solar-Thermal Systems for Your Agricultural or Agri-Food Operation

Solar-thermal systems collect the sun's energy and convert it into heat. This energy can be used to heat water or air. It can also be used to cool water or air. This fact sheet briefly describes suitable solar-thermal systems (namely hot water, chilled water and heated air) for agricultural and agri-food operations and each system's desirable operating characteristics. It offers guidance on how to assess whether your agricultural or agri-food operation might benefit from these solar-thermal systems.

This fact sheet is based on results from a detailed study *Benchmarking of Solar-Thermal Technologies in B.C.'s Agricultural and Agri-Food Operations*. Funding for this project was provided by *Growing Forward*, a federal-provincial-territorial initiative.

When considering if a solar-thermal system is suitable for your agricultural or agri-food operation there are four key factors to keep in mind:

1. Current fuel and alternative fuel costs;
2. Nature of heating/cooling demand (annual, seasonal, intermittent load duration);
3. Required useable (load) temperatures or temperature demand; and
4. Orientation and location of solar-thermal collectors.

Solar-Thermal Options

Solar Hot Water systems are used to preheat either potable or process water using the sun's energy. This type of system is useful for agricultural or agri-food operations that have a daily use for hot water such as dairy farms. These systems can also be used in operations that use radiant water space heating 10 months of the year such as poultry barns. Figure 1 is a simple flow diagram of how a solar hot water system works and Figure 2 is a drawing of a solar hot water system.

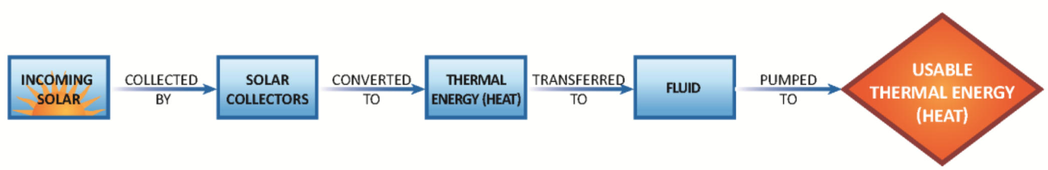

Figure 1. Flow Diagram of How a Solar Hot Water System Works

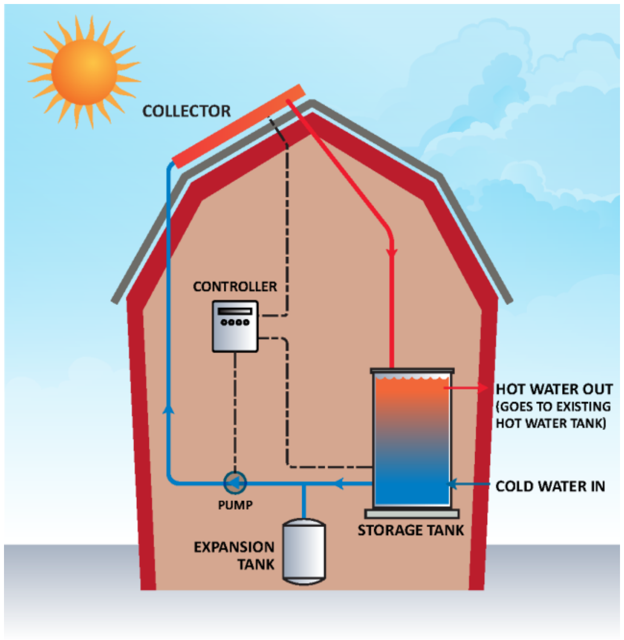

Figure 2. Drawing of a Solar Hot Water System

Solar Chilled Water systems are used to cool either air (also known as solar assisted air-conditioning) or cool process water using the sun's energy. In B.C. this type of system is limited to operation in the summer because the available solar radiation in fall, winter and spring is not enough to efficiently drive the system. This type of system is useful for agricultural or agri-food operations that need cool fluid or air in the summer. Figure 3 is a simple flow diagram of how a solar chilled water system works and Figure 4 is a drawing of a solar chilled water system.

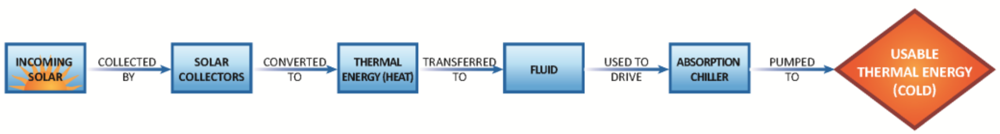

Figure 3. Flow Diagram of How a Solar Chilled Water System Works

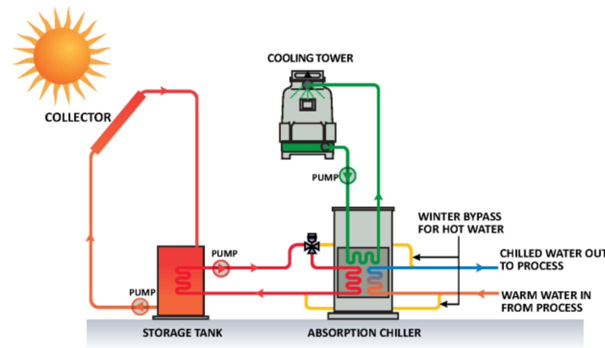

Figure 4. Drawing of a Solar Chilled Water System

Solar Heated Air (also known as transpired solar) systems are used to preheat ventilation air using the sun's energy. In the Northern Hemisphere the collector is located on the roof or south-facing exterior of a building to maximize exposure to the sun. This type of system is useful for agricultural or agri-food operations that need warm indoor air and continual ventilation such as a poultry barn. Other agricultural sectors that might benefit from solar heated air are crop-drying facilities. Figure 5 is a simple flow diagram of how a solar heated air system works and Figure 6 is a drawing of a solar air heated system.

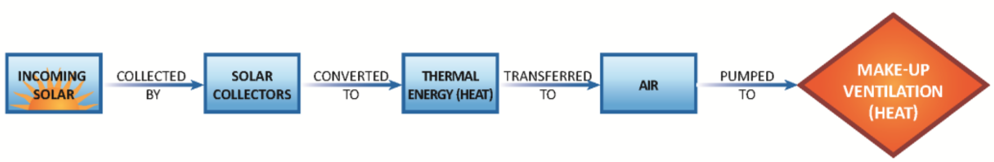

Figure 5. Flow Diagram of How a Solar Heated Air System Works

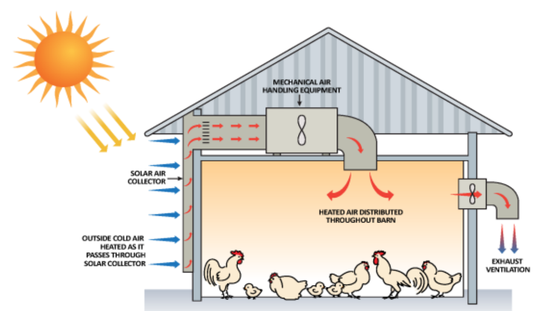

Figure 6. Drawing of a Solar Heated Air System

Characteristics of Financially Viable Solar-Thermal Systems

Fuel Costs

Solar-thermal systems save agricultural or agri-food operators money by switching a portion of the annual heating/cooling costs from typical fuel sources such as electricity, natural gas and propane to the renewable and free heat source of the sun. Though the cost of the energy from the sun is free to the operator, the installed costs of solar-thermal systems are generally high relative to the energy savings produced.

The current cost to supply and install a **solar hot water** system is about $1,800 per square metre of flat plate collector. Table 1 compares the cost of usable solar energy to the price of typical fuels for several locations in B.C. The simplified solar energy cost is based on a 25 year life span and can be calculated as follows: 1,800 $/m^2 divided by annual usable solar energy divided by 25 years.

Table 1. Solar Hot Water Energy Cost versus Fuel Costs

Location	Annual Usable Solar Energy	Solar System Installed Cost	Simplified Solar Energy Cost	Local Electrical Cost	Local Natural Gas Cost	Local Propane Cost
	(kWh/m^2)	($/m^2)	($/kWh)	($/kWh)	($/kWh)	($/kWh)
Abbotsford	618	$ 1,800	$ 0.117	$ 0.090	$ 0.036	$ 0.080
Kelowna	714	$ 1,800	$ 0.101	$ 0.084	$ 0.032	$ 0.080
Salt Spring Island	576	$ 1,800	$ 0.125	$ 0.088	$ 0.061	$ 0.080
Vernon	627	$ 1,800	$ 0.115	$ 0.084	$ 0.032	$ 0.084

The minimum cost to supply and install a **solar chilled water** system is about $2,350 per square metre of flat plate collector. This minimum cost is dependent on the site conditions and the system it will be tying into. Table 2 compares the cost of usable solar energy to the electrical cost in Kelowna (which would be fairly indicative throughout B.C.). The solar energy cost is only compared to the electrical cost because chilled water systems are only electrically driven. The simplified solar energy cost is based on a 70 kW sized chiller operating over an 8 week process period in the summer over a 25 year life span and is calculated as follows: 2,350 $/m^2 divided by annual usable solar energy divided by 25 years.

Table 2. Solar Chilled Water Energy Cost versus Electrical Energy Cost

Location	Annual Usable Solar Energy	Solar System Installed Cost	Simplified Solar Energy Cost	Local Electrical Cost
	(kWh/m^2)	($/m^2)	($/kWh)	($/kWh)
Kelowna	160	$ 2,350	$ 0.588	$ 0.084

The current cost to supply and install a **solar heated air** system is about $300 per square metre of collector. Table 3 compares the cost of usable solar energy to the price of typical fuels for several locations in B.C. The simplified solar energy cost is based on a 25 year life span and can be calculated as follows: 300 $\$/m^2$ divided by annual usable solar energy divided by 25 years.

Table 3. Solar Heated Air Energy Cost versus Fuel Costs

Location	Annual Usable Solar Energy	Solar System Installed Cost	Simplified Solar Energy Cost	Local Electrical Cost	Local Natural Gas Cost	Local Propane Cost
	(kWh/m^2)	($\$/m^2$)	($/kWh)	($/kWh)	($/kWh)	($/kWh)
Abbotsford	431	$ 300	$ 0.028	$ 0.090	$ 0.036	$ 0.080
Kelowna	498	$ 300	$ 0.024	$ 0.084	$ 0.032	$ 0.080
Salt Spring Island	402	$ 300	$ 0.030	$ 0.088	$ 0.061	$ 0.080
Vernon	437	$ 300	$ 0.027	$ 0.084	$ 0.032	$ 0.084

Annual Load Duration

A common feature of agricultural and agri-food operations with financially viable solar-thermal systems are moderate thermal load temperatures (60 ^{o}C hot water; 25-35^{o}C hot air) for long periods of time throughout the year. This is because the capital investment required for solar-thermal systems can only generate a return on investment when the systems are operating. Short duration, high intensity loads (hot water 80^{o}C or higher; and chilled water 7 to 10^{o}C) are the least profitable because the necessary high capacity equipment only operates for a limited number of hours per year, and therefore, cannot produce enough savings to overcome the installation costs.

- Solar hot water systems have the highest performance potential for agricultural and agri-food operations where a demand for hot water exists on a consistent, daily basis all year-round.
- Solar chilled water systems, on the other hand, do not offer the same performance potential because the available solar radiation in B.C. during the fall, winter and spring season is not sufficient to drive the absorption chiller used in these types of systems.
- Solar heated air systems likely have potential for B.C. agricultural operations such as poultry and hog farms, and crop-drying facilities.

Through installation monitoring, simulation and economic analysis, the United Facilities Criteria of the U.S. Army Corps of Engineers has determined that the most efficient use of solar energy is for heating water up to 60^{o}C on a year-round basis such as that needed by service water heating. This application has been found to yield the best use of solar energy per square metre of installed collector area and represents the greatest potential for cost effective solar energy use.

Required Load Temperatures

In order to make a **solar hot water** system technically and financially viable the following operation parameters are required:

- System heats the water to the useable temperature between 50 and 100°C.
- Hot water is required at least 10 months of the year including summer months.

In order to make a **solar chilled water** system technically and financially viable the following operating parameters must be met:

- Minimum cooling requirement is 35 kW (10 ton);
- Chilled water temperature required by process is or above 7°C; and
- Chilled water required during July and August, with a preheat hot water demand for the other 10 months of the year.

In order to make a **solar heated air** system technically and financially viable the following operating parameters are required:

- Heated ventilation air temperature is between 25 and 35°C;
- Heated air is required for at least 6 hours during the daytime;
- Heated air is required at least 10 months of the year (September to July); and
- Ventilation required is between 18 to 180 cubic metres per hour per square metre of floor area.

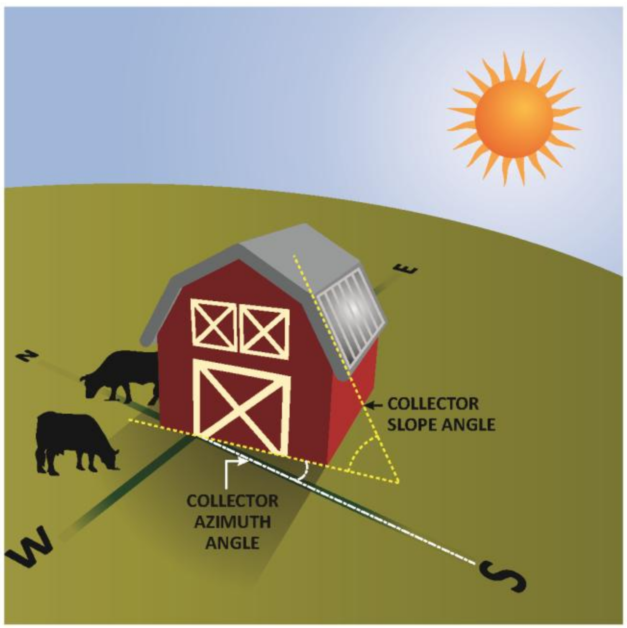

Figure 7. Solar Collector Azimuth and Slope Angle

Solar Collector Orientation

For a solar-thermal system to work the solar collector must have a clear view of the sun as it travels across the southern sky and be free of shading from trees, buildings or mountains. The orientation of the collector is defined by the azimuth and slope angle shown in Figure 7.

Generally in Canada, a solar collector azimuth angle can be between 30 degrees to the east of south and 30 degrees to the west of south. For example, a south pointed collector has an azimuth angle of 0 degrees; and a southeast pointed collector has an azimuth angle of 45 degrees.

The slope angle (or tilt) of the collector can be orientated to maximize solar potential. Because of the change in position of the sun in the sky from winter to summer, a steeper collector tilt will perform better during the winter months, whereas, a less steep collector tilt will perform better in the summer months.

For a solar-thermal system operated year-round, tilt the collector at a slope angle equal to the location's latitude. For example, in Abbotsford, 50 degrees latitude, tilt the collector at 50 degrees. To collect the most sun in summer, tilt the collector at a shallower slope angle equal to location's latitude minus 15 degrees. For example, in Abbotsford tilt the collector at 35 degrees. To collect the most sun in winter, tilt the collector at a steeper slope angle equal to location's latitude plus 15 degrees. For example, in Abbotsford tilt the collector at 65 degrees. For collectors mounted on a wall, as for solar heated air systems, the slope angle is equal to 90 degrees.

Potential Energy Cost Savings of Solar-Thermal Systems

The following provides agricultural and agri-food operators with a rough estimate of the potential energy cost savings that can be expected from installing solar hot water or solar heated air at their operation. While all calculations are based on a number of simplifying assumptions, the following results will provide operators with a good indication as to whether or not a proposed solar-thermal system warrants further evaluation.

Potential Solar Hot Water Savings if currently using natural gas for heating

Current cost of natural gas: $/GJ ________ (A)

1) Input your hot water flow rate: ________ US-gallon/minute (B)
2) Input your temperature rise: ________ Fahrenheit (C) (temperature of your hot water minus incoming supply water temperature)
3) Calculate thermal energy required: Multiply (B) x (C) x 500 = ________ Btu/h (D)
4) Convert Btu/h to kW: Divide (D) by 3,416 = ________ kW (E)
5) Input your estimated annual hours of hot water use: ________ hours (F)
6) Calculate annual hot water energy required: Multiply (E) x (F) = ________ kWh (G)
7) Convert kWh to GJ: Divide (G) by 278 = ________ GJ (H)
8) Assume a load saving of 65% due to solar: Multiply (H) x 0.65 = ________ GJ (J)
9) Calculate potential natural gas savings: Multiply (A) x (J) = $ ________

Potential Solar Hot Water Saving if currently using electricity for heating

Current cost of electricity: $/kWh ________ (A)

1) Input your hot water flow rate: ________ US-gallon/minute (B)
2) Input your temperature rise: ________ Fahrenheit (C) (temperature of your hot water minus incoming supply water temperature)
3) Calculate thermal energy required: Multiply (B) x (C) x 500 = ________ Btu/h (D)
4) Convert Btu/h to kW: Divide (D) by 3,416 = ________ kW (E)
5) Input your estimated annual hours of hot water use: ________ hours (F)
6) Calculate annual hot water energy required: Multiply (E) x (F) = ________ kWh (G)
7) Assume a load saving of 65% due to solar: Multiply (G) x 0.65 = __________ kWh (H)
8) Calculate potential electricity savings: Multiply (A) x (H) = $ ________

Potential Solar Heated Air Savings if currently using natural gas for heating

Current cost of natural gas: $/GJ ________ (A)

1) Input your ventilation air requirement: ________ cubic feet/minute (B)
2) Calculate solar wall area: Divide (B) by 4 = ________ square feet (C)
3) Calculate annual energy savings: Divide (C) by 6.75 = ________ GJ (D)
4) Calculate potential natural gas savings: Multiply (A) x (D) = $ ________

if currently using electricity for heating

Current cost of electricity: $/kWh ________ (A)

1) Input your ventilation air requirement: ________ cubic feet/minute (B)
2) Calculate solar wall area: Divide (B) by 4 = ________ square feet (C)
3) Calculate annual energy savings: Multiply (C) by 41 = ________ kWh (D)
4) Calculate potential electricity savings: Multiply (A) x (D) = $ ________

Self-Assessment Guide—Predicting Site Suitability for Solar-Thermal Systems

Given the many variables that influence the financial viability of solar-thermal systems, it can be a challenge to determine the suitability for a particular agricultural or agri-food operation without a detailed site assessment. However, based on known common characteristics of profitable scenarios, an agricultural or agri-food operator can use the following two diagrams (figures 8 and 9) to judge the likelihood that a solar-thermal system will be suitable for their operation.

The majority of agricultural and agri-food operations will likely have a combination of characteristics from both diagrams. If this refers to your operation, you should carefully weigh the benefits of potential energy cost savings (calculated on the previous page) against the relevant features at your site. Agricultural or agri-food operations with the potential for considerable energy cost savings and at least one of the features listed in the high likelihood circle calls for a discussion with a professional to determine if a detailed evaluation is warranted.

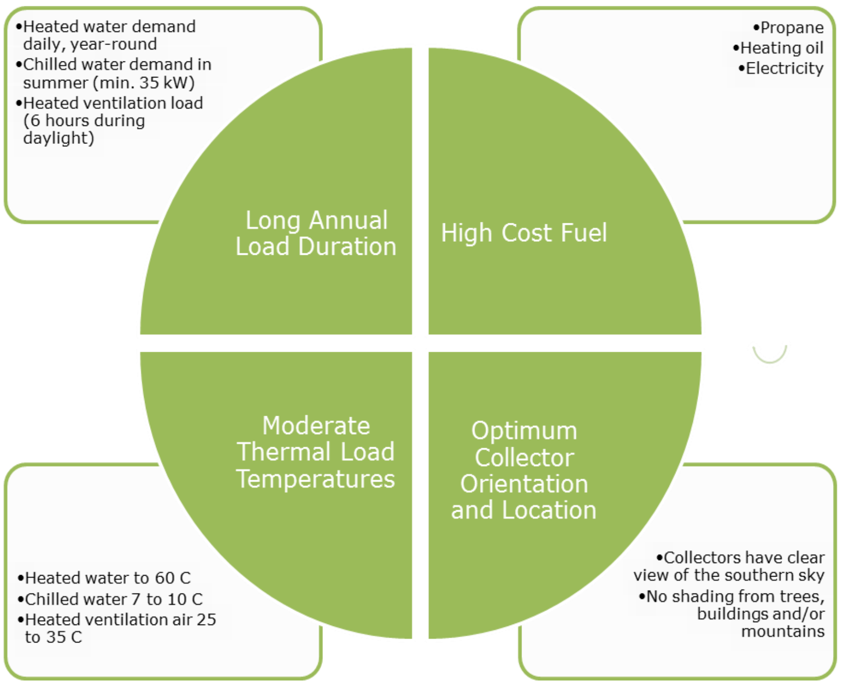

Figure 8. High Likelihood of Solar-Thermal Suitability

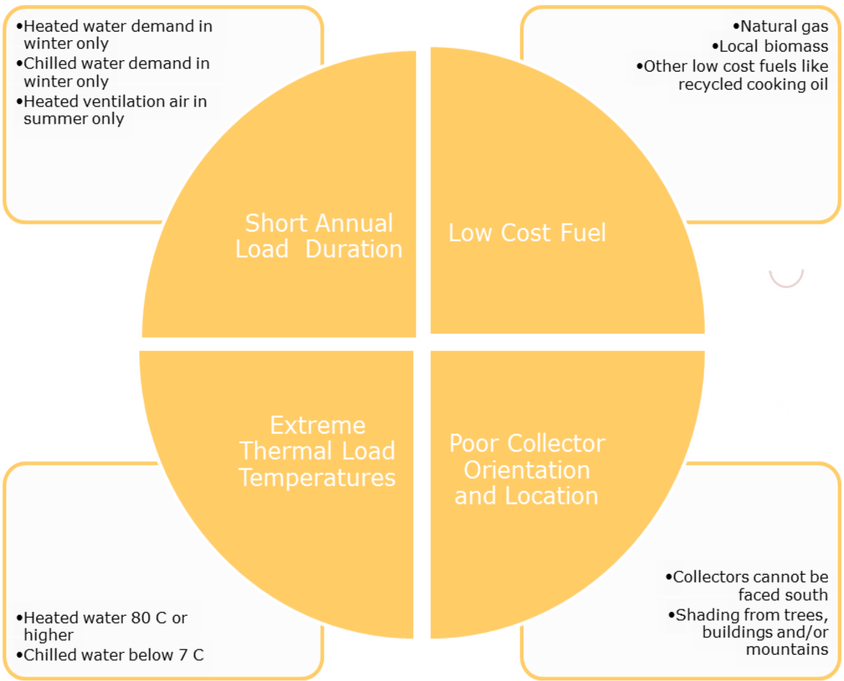

Figure 9. Low Likelihood of Solar-Thermal Suitability