

# CASE STUDY 7

## SOLAR DOMESTIC HOT WATER SYSTEM

ATLANTIC ECOWORKS, NOVEMBER 2010

### SUMMARY

Using a solar domestic hot water (SDHW) system to capture the sun's energy and produce hot water is a practical way for homeowners to lessen their environmental impact.

The Thermo Dynamics two collector SDHW system featured in this case study (see Photo 1) saved 484 litres of heating oil in its first year of operation. At an estimated cost of \$0.80 per litre for heating oil, this translates into annual savings of \$387. The estimated annual system economics of the SDHW system are summarized in Table 1, to the right.

The annual avoided emissions of 1,307 kilograms of carbon dioxide (due to not consuming 484 litres of heating oil) are equivalent to taking a 2010 Pontiac Vibe off the road for four months.



Photo 1: SDHW Collectors

Table 1: Estimated Annual System Economics

Description	
Cost of System after Incentives	\$3,825
Estimated Annual Fuel Savings	\$387
Simple Payback ( $\$3,825/(\$387/\text{year})$ )	9.9 yrs
Return on Investment ( $\$387/\$3,825 \times 100$ )	10.1 %

### DETAILS

- 1. System:** Thermo Dynamics glazed flat plate solar domestic hot water system (SB64-9PV)
- 2. Date of Installation:** August 9, 2009
- 3. Cost before/after Incentives:** \$7,250/\$3,825
- 4. Collectors:** Two glazed flat plate collectors each measuring 1.20 m x 2.47 m (nominally 4 ft x 8 ft) with a cumulative gross area of 5.92 m<sup>2</sup> (64 ft<sup>2</sup>)
- 5. Collector Orientation:** South 20° West
- 6. Collector Tilt:** 40° (rack mounted on roof with 4 in 12 pitch - 18.4°)
- 7. Solar Storage Tank:** 246-litre Bradford White upright electric water heater (Model M2-HE-65R6DS, see Photo 2, to the right)
- 8. Heat Exchanger Type:** Shell and coil
- 9. Boiler:** Fleetline
- 10. Household Occupancy:** 2 adults, 2 children



Photo 2: Solar Storage Tank and Heat Exchanger

**11. System Operation:** When the sun shines, a photovoltaic-powered circulating pump moves a heat transfer fluid (consisting of a non-freezing distilled water/propylene glycol mixture) through the roof mounted collectors causing the fluid temperature to rise. The hot fluid then passes through a heat exchanger where a portion of its heat is transferred to the domestic hot water. The fluid, which has now become cooler, is returned to the collectors to regain heat and repeat the cycle.

The domestic hot water is stored in the Bradford White upright electric water heater. With the upper and lower heating elements disconnected, the water heater serves the same purpose as a specialized (and more expensive) solar storage tank.

When a hot water faucet is opened in the house, the preheated water from the solar storage tank passes through the boiler's tankless coil (heat exchanger) before being delivered to the faucet. The burner will fire if necessary to maintain the desired water temperature.

**12. Method :** Oil delivery records (dates and volumes) beginning two years prior to the installation of the SDHW system and continuing for one year after the installation were examined to determine annual oil consumption rates.

Variance in winter temperatures was considered by adjusting the annual heating oil consumption rates using heating degree day data from Environment Canada. The heating oil consumption rates were increased or decreased to reflect how much oil would have been consumed if the winter was as cold as the average winter over the last nine years.

All data, calculations, and explanations have been provided in Appendix A.

**13. Results:** The SDHW system saved 484 litres of heating oil in its first year of operation. At an estimated cost of \$0.80 per litre for heating oil, this translates into annual savings of \$387.

In 2009, several provincial and federal incentives were available to reduce the initial cost of the system from \$7,250 to \$3,825 (taxes included). The SDHW system's estimated annual economics as derived from its cost and fuel savings are presented in Table 2, below.

Description	
Cost of System after Incentives	\$3,825
Estimated Annual Fuel Savings	\$387
Simple Payback ( $\$3,825/(\$387/\text{year})$ )	9.9 yrs
Return on Investment ( $\$387/\$3,825 \times 100$ )	10.1 %

Notwithstanding any maintenance costs, the system will pay for itself in 9.9 years, which is equivalent to receiving a 10.1 percent return on investment (tax free). As the price of heating oil rises, so too will the avoided fuel costs, thereby reducing the length of the time to simple payback and increasing the return on investment.

The average avoided oil consumption of 484 litres per year reduces the household's total carbon dioxide emissions by 1,307 kilograms. This is equivalent to taking a 2010 Pontiac Vibe (with a 2.4 litre engine and manual transmission) off the road for four months.

**14. Considerations:** Improvements in system performance may be realized by installing a boiler by-pass so that the boiler can be turned off during non-space heating months (i.e., late spring, summer, and early fall) and by connecting the upper element in the solar storage tank to the home's main electrical panel to ensure adequate domestic hot water is available on cloudy days.

Also, ensuring that the high temperature limit of the differential temperature control is set to 180 °F (80 °C) versus the factory preset of 158 °F (70 °C) will allow the heat transfer fluid to provide more energy to the domestic hot water in the solar storage tank (albeit with some increase in the chance that the pressure relief valve on the solar storage tank may activate).

## Appendix A: Data and Calculations

This appendix provides the data and calculations necessary to provide an estimate of the avoided oil consumption for the SDHW system's first year of operation (August 9, 2009 to August 8, 2010) compared to the two years prior to its installation (August 9, 2007 to August 8, 2009).

### Heating Oil Consumed

Table 2, below, provides the heating oil delivery dates and volumes for this three year period. (Note: Oil volumes occurring in heating oil delivery periods coinciding with the beginning and end of any of the years have been prorated into the appropriate year.)

Heating Oil Delivery Periods	Litres	Days in Period	Litres/Day	Aug. 9/07 – Aug. 8/08 Days/Total Litres	Aug. 9/08 – Aug. 8/09 Days/Total Litres	Aug. 9/09 – Aug. 8/10 Days/Total Litres
May 4/07 – Sept. 20/07	646	228	2.83	43/122		
Sept. 21/07 - Dec. 14/07	839	85	9.87	85/839		
Dec. 15/07 – Jan. 17/08	520	34	15.29	34/520		
Jan. 18/08 – Feb. 21/08	630	35	18.00	35/630		
Feb. 22/08 – Mar. 27/08	592	35	16.91	35/592		
Mar. 28/08 – May 14/08	540	48	11.25	48/540		
May 15/08 – Oct. 9/08	707	148	4.78	86/411	62/296	
Oct. 10/08 – Dec. 5/08	550	57	9.65		57/550	
Dec. 6/08 – Jan. 8/09	586	34	17.24		34/586	
Jan. 9/09 – Feb. 5/09	542	28	19.36		28/542	
Feb. 6/09 – Mar. 13/09	550	36	15.28		36/550	
Mar. 14/09 – Apr. 23/09	513	41	12.51		41/513	
Apr. 24/09 – Aug. 10/09	505	109	4.63		107/496	2/9
Aug. 11/09 – Nov. 12/09	568	94	6.04			94/568
Nov. 13/09 – Dec. 19/09	449	37	12.14			37/449
Dec. 20/09 – Jan. 28/10	559	40	13.98			40/559
Jan. 29/10 – Mar. 4/10	471	35	13.46			35/471
Mar. 5/10 – Apr. 21/10	467	48	9.73			48/467
Apr. 22/10 – Aug. 31/10	488	132	3.70			109/403
<b>Total Litres Consumed</b>				<b>366/3,654</b>	<b>365/3,533</b>	<b>365/2,926</b>

### Adjustment for Differences in Number of Heating Degree Days

In considering the reduction in oil consumption that can be attributed to the SDHW system, it is necessary to recognize that the boiler consumes oil not only for the purpose of providing domestic hot water but also for the purpose of providing space heating. When comparing consumption rates over several space-heating seasons, it is necessary to account for the variation in outside temperature which, in turn, affects heating load and therefore oil consumption. An adjustment can be made to oil consumption by considering the number of heating degree days occurring within each time period.

Heating degree days are calculated by subtracting the average daily outside temperature from 18 degrees Celsius. For example, an average daily outside temperature of 3 degrees would result in 15 heating degree days.

Table 3, to the right, summarizes heating degree day data from Environment Canada for the last three space-heating seasons based on temperature readings from the Charlottetown Airport. Data for the months of July and August have been omitted from the table as there is little need for space heating during these months.

Table 4, below, summarizes the adjustments that must be made to annual oil consumption to account for the differences in the number of heating degree days that occur during each space-heating season. A heating degree baseline was established using the average number of heating degree days occurring at the Charlottetown Airport over the last nine years. By considering how much warmer or colder a particular year is relative to the nine-year average, it is possible to adjust oil consumption (by adding litres of oil for a warmer than average winter and subtracting litres of oil for a colder than average winter) to reflect what it would be for a winter with an average number of heating degree days.

Month	2007/08	2008/09	2009/10
Sep	120.3	121.3	134.8
Oct	247.7	300.6	345.1
Nov	446.6	421.2	392.1
Dec	730.7	619.6	642.9
Jan	728.0	865.6	686.4
Feb	686.1	663.9	607.9
Mar	694.0	674.6	543.3
Apr	418.4	419.5	366.5
May	285.7	245.0	262.3
Jun	95.1	101.8	113.5
<b>Total</b>	<b>4,452.6</b>	<b>4,433.1</b>	<b>4,094.8</b>

	2007/08	2008/09	2009/10
Heating Degree Days (°C)	4,452.6	4,433.1	4,094.8
9 Year HDD Average (°C)	4,369.6	4,369.6	4,369.6
Difference Relative to Average (%)	1.90	1.45	-6.29
Adjusted Difference (%)	1.43	1.09	-4.72
Unadjusted Oil Consumption (L)	3,654	3,533	2,926
Consumption Adjustment (L)	-52	-39	+138
Adjusted Oil Consumption (L)	3,602	3,494	3,064
Average Adjusted Oil Consumption for Previous Two Years (L)	3,548		--
<b>Adjusted Oil Savings Compared to Previous Two Years (L)</b>			<b>484</b>

Here are the calculations from Table 4 for the 2008/09 heating season.

$$\text{Heating Degree Days (}^{\circ}\text{C)} = 4,433.1$$

$$\text{9 Year HDD Average (}^{\circ}\text{C)} = 4,369.6$$

$$\text{Difference Relative to Average (\%)} = (4,433.1 - 4,369.6) / (4,369.6) \times 100 = 1.45$$

$$\text{Adjusted Difference (\%)} = 1.45 \times 0.75 = 1.09$$

Note: The factor of 0.75 is used to recognize that approximately 75% of the oil consumed in the household is used for the purpose of space heating and is therefore influenced by differences in the number of heating degree days. This helps ensure that only the portion of oil consumed for space heating will be adjusted for temperature variations during the heating season (i.e., heating degree days).

$$\text{Unadjusted Oil Consumption (L)} = 3,533$$

$$\text{Consumption Adjustment (L)} = 3,533 \times (1.09/100) = -39.$$

Note: Since the 2008/09 heating season was colder than the 9-year average, the consumption adjustment is negative. This means that consumption will be reduced by 39 litres.

$$\text{Adjusted Oil Consumption (L)} = 3,533 - 39 = 3,494$$

**Average Annual Savings of Heating Oil**

From Table 4, the annual savings of heating oil for the first year since the installation of the SDHW system is estimated to be 484 litres.

**Average Annual Avoided Carbon Dioxide Emissions**

Savings of 484 litres of heating oil per year corresponds to avoided emissions of 1,307 kilograms per year (484 litres of heating oil x 2.7 kg of CO<sub>2</sub> per litre of heating oil = 1,307 kg.). This is equivalent to taking a 2010 Pontiac Vibe (with a 2.4 litre engine and manual transmission) off the road for four months.