# Toronto Fire Station #212

# 12.5 $kW_t$ Solar Water Heating Installation

Final Report – January 2012


Technology

Monitoring

Best Practices

SolarCity Partnership

## PROJECT SNAPSHOT

| | |
|---|---|
| Address: | 8500 Sheppard Avenue East, Toronto, ON |
| Building Type and Use: | Fire and EMS |
| Owner: | City of Toronto |
| Contact: | Joel Arthurs |
| Phone #: | 416-392-5177 |
| Email: | jarthur@toronto.ca |
| System type: | Solar Domestic Hot Water |
| Array Angle: | 45 degrees from horizontal |
| Azimuth: | 25 degrees East |
| System Configuration: | Drain-back with 6 collectors in parallel |
| Collector Manufacturer: | Thermo Dynamics |
| Collector Model: | G32-P |
| Number of Collectors: | 6 |
| Thermal Storage Tank Manufacturer: | Rheem |
| Thermal Storage Tank Model: | ST120 (435 litres) |
| Number of Thermal Storage Tanks: | 2 |
| Collector Fluid: | Water |
| System Size (kW thermal): | 12.5 |
| Total Gross Collector Area (sq. meters): | 17.892 |
| Installation Date: | December 2006 |

### PERFORMANCE

| | |
|---|---|
| 2008/2009 Actual Performance: | 528 $kWh_t/kW$ |
| 2008/2009 RETScreen using actual hot water consumption and local weather: | 432 $kWh_t/kW$ |
| 2008/2009 WATSUN using actual hot water consumption and local weather profiles: | 584 $kWh_t/kW$ |

### FINANCIAL

| | |
|---|---|
| Installed Cost (taxes included): | $29,339 |
| External Funding: | $20,484 from Natural Resources Canada's Renewable Energy Deployment Initiative |
| 2008/2009 Annual Savings: | $313 |
| Simple Payback (excluding external funding): | 93.7 years |
| Cost per $kW_t$ (excluding external funding): | $2,400 |

***Photos provided by Lucio Mesquita***

## MONITORING

| | |
|---|---|
| Monitoring equipment installed: | Yes |
| Overview of the monitoring plan: | Two Kamstrup Multical 601 heat meters. One installed on DHW line between solar tanks and auxiliary heater (Solar Energy Delivered) and the other on the piping connecting solar tanks to the solar heat exchanger (Solar Energy Collected). |
| Cost of M&V (% of total project): | 14% (of total project cost) |
| Who is analyzing the data? | City of Toronto Energy & Waste Management Office |
| Is there a dedicated staff person responsible for system operation management? | No |

## SUMMARY

The City of Toronto's 12.5 $kW_t$ solar thermal system at Fire Hall 212 generated approximately 528 $kWh_t$/kW in 2008/2009, which was 22% higher than RETScreen simulated yield and 9.6% lower than WATSUN simulated yield. Designed to reduce the Fire Hall's use of natural gas for water heating, the system was installed in 2006 for $29,339. Based on 2008/2009 performance, the project will achieve a simple payback in 93.7 years before external grants and 28.2 years after.

Hot water usage was significantly lower than estimated during the design phase of the project, resulting in the system delivering much less usable energy than was initially predicted.  However, when the actual hot water usage is taking into consideration, the results indicate that the system is performing as expected. This reinforces how important the knowledge of the correct load is when designing a solar thermal project.

RETScreen is known to be conservative for solar thermal applications and the use of a more sophisticated software tool, such as WATSUN, is highly recommended.

Further investigation should be undertaken to evaluate the accuracy of heat meters for domestic water heating measurements. Also important for accurate measurement is to ensure that hot water from the system cannot migrate to the cold sensor, which can lead to an underreporting of the amount of heat delivered.

## PERFORMANCE ANALYSIS

This report will evaluate the performance of the solar thermal system from June 2008 to May 2009. 2010 energy production was similar to the 2008/2009 period (see Appendix A).

### Actual Performance vs. Original RETScreen Simulation

The original RESTScreen analysis (Appendix B) predicts an annual energy delivery of 10.19 MWh. Actual energy delivered was 6.6 MWh, significantly below the prediction. However, the original analysis estimated a much larger usage volume than was measured. Measured usage for 2008/2009 was only 59% of the initial estimate.

The initial RETScreen assumed a daily hot water consumption of 1000 litres at 52 °C, which leads to a total annual load prediction of 18.92 MWh. However, only one month reached such high usage, December 2008.

The heat load is defined by the volume and the temperature difference between the inlet and outlet temperatures of the heating system, and in the case of Fire Hall 212, the auxiliary heater operates with a set point of 60 °C (140 °F) for a total calculated load of close to 14 MWh. Unfortunately, even when the set point temperature is taking into consideration, the heat load is significantly lower during the summer months than initially predicted, which lowers the system energy production.

Thus, the system did not reach the expected production because it operated under a much smaller heat load than it was designed for. With a smaller load, the average water temperature in the system rises, and the solar collector efficiency is reduced.

**Actual Performance vs. RETScreen and WATSUN Simulations**

The initial RETScreen inputs were modified to account for measured ambient temperatures, solar radiation, and hot water consumption. Sources of inputs and modifications made can be found in Appendix C.

With the modified inputs, the estimated energy delivered was reduced to 5.4 MWh/year, while the actual delivered was 6.6 MWh. Therefore, the system would have delivered 22% above the estimated RETScreen simulations using the measured heat load.

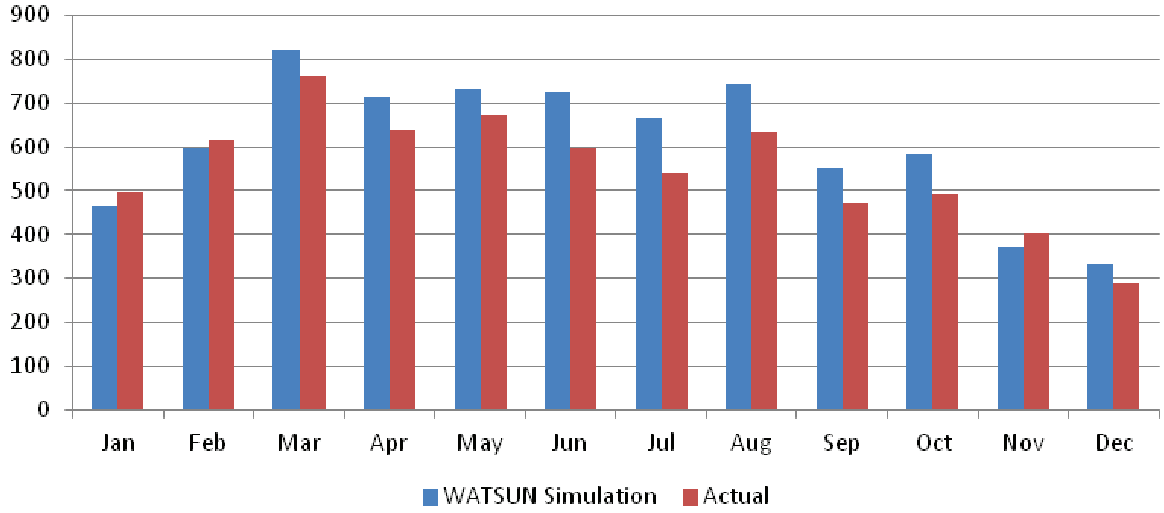
RETScreen is known to give a conservative estimation of energy delivered by solar heating systems (see Appendix D for more discussion), which is why a more accurate software tool, WATSUN, was used to evaluate the performance of the system.

WATSUN algorithms were developed at the University of Waterloo and it performs a full yearly analysis using hourly data. It has been shown to provide accurate results and it allows the modification of weather data inputs, which is very valuable for performance verification, as in this case. As with RETScreen, WATSUN is available free of charge by Natural Resources Canada.

Since not all hourly data was available as an input for WATSUN, a fixed daily hot water usage profile was used, based on the average profile of January, February and March of 2009 (Appendix E). The average monthly hot water draw was also adjusted and factors were applied to WATSUNs solar radiation and ambient temperature data to be similar to the measured values from a University of Toronto meteorological station.

Considering that the simulations used a fixed draw profile and the weather data was not measured on-site, the results agree well and indicate the system is performing as it should. Figure 1 and Appendix F compares the WATSUN simulation to the actual performance.

**Figure 1:** 2008/2009 Energy Delivered to Solar Tanks - WATSUN Simulation vs. Actual Performance




### Measurement Issues

One observation should be made regarding the measurement of the hot water delivered by the solar system. Most heat meters are designed for fairly steady operation, mostly for heat distribution networks. They do not fare as well under dynamic loads, such as domestic hot water applications, especially under short draws, which can lead to an under reporting of energy delivered (see Appendix G for further discussion).

Another issue that also contributes to under-metering is the fact that under low-load conditions, the cold temperature sensor located close to the inlet of the solar storage tanks sometimes gets heated by thermosyphoning flow from the water tank. Then when there is a draw, the warm water in the supply piping causes the meter to register a smaller heat delivered. This can be made worse by un-insulated or poorly insulated sensor fittings and poor location of the sensors. Adaptors that are used to fit sensors made with European standard thread sizes to North American sizes also cause the sensor to sit farther away from the water stream, as it can be seen in Appendix G.

Another measurement issue appears to be the migration of some hot water to the cold water sensor, which is worse in the summer when the temperatures inside the solar tanks are much higher. See Appendix H for further discussion).

## BUSINESS CASE

Table 1 presents the business case for the Fire Hall 212 Solar Thermal Project.  This analysis uses he 2008/2009 delivered energy of 6600 $kWh_t$/yr, which would save approximately $313 per year, assuming a natural gas price of 35¢/$m^3$. The simple payback for this scenario would be 93.7 years before grants and 28.2 years after.

**Table 1:** Fire Hall 212 Solar Thermal Project: Business Case for 2008/2009

| | Total Cost Installed | Grants | Array Output ($kWh_t$/yr) | Dollars Saved* | Simple Payback (years) | Payback after grants (years) |
|---|---|---|---|---|---|---|
| **Adjusted Feasibility Study** | $29,338.80 | $20,484 | 6,600 | $313 | 93.7 | 28.2 |

*Assumes a 70% burner efficiency and a burner-tip natural gas price of $0.35 per $m^3$.

## Installed System Costs

The breakdown of installed system costs are shown in Table 2. The total cost of the system was $29,338.80, or $2,400 per kW installed. Materials accounted for approximately 66% of the total cost. Natural Resources Canada's Renewable Energy Deployment Initiative provided a grant of $20,484 for the project, bringing the final project cost down to $8,854.80, or $708 per kW installed.

**Table 2:** As-Built Cost Breakdown

| FH#212 | Material | Installation | Total |
|---|---|---|---|
| Solar collectors | $5,400.00 | $900.00 | $6,300.00 |
| Collector rack/support, fasteners | $2,054.00 | $1,600.00 | $3,654.00 |
| Piping from collector array to solar storage tank and to conventional hot water tank | $1,540.00 | $800.00 | $2,340.00 |
| Pipe and solar storage tank insulation | $670.00 | $400.00 | $1,070.00 |
| Solar heat exchanger | $700.00 | $300.00 | $1,000.00 |
| Solar heat storage tank(s) | $3,050.00 | $450.00 | $3,500.00 |
| Pump(s) (collector-side) | $920.00 | $450.00 | $1,370.00 |
| Solar system controller | $600.00 | $750.00 | $1,350.00 |
| Design and supervision | $0.00 | $1,800.00 | $1,800.00 |
| Shipping | $1,450.00 | $0.00 | $1,450.00 |
| Metering | $2,660.93 | $1,375.00 | $4,035.93 |
| Commissioning | $0.00 | $0.00 | $0.00 |
| Other Additional Structural Work | $268.87 | $1,200.00 | $1,468.87 |
| **Total (tax included)** | **$19,313.80** | **$10,025.00** | **$29,338.80** |
| External funding | | | $20,484 |
| **FINAL TOTAL** | | | **$8,854.80** |

## APPENDIX A: 2008/2009 VS. 2010

**Figure A1:** Comparison between 2008/2009 and 2010 Average Hot Water Consumption

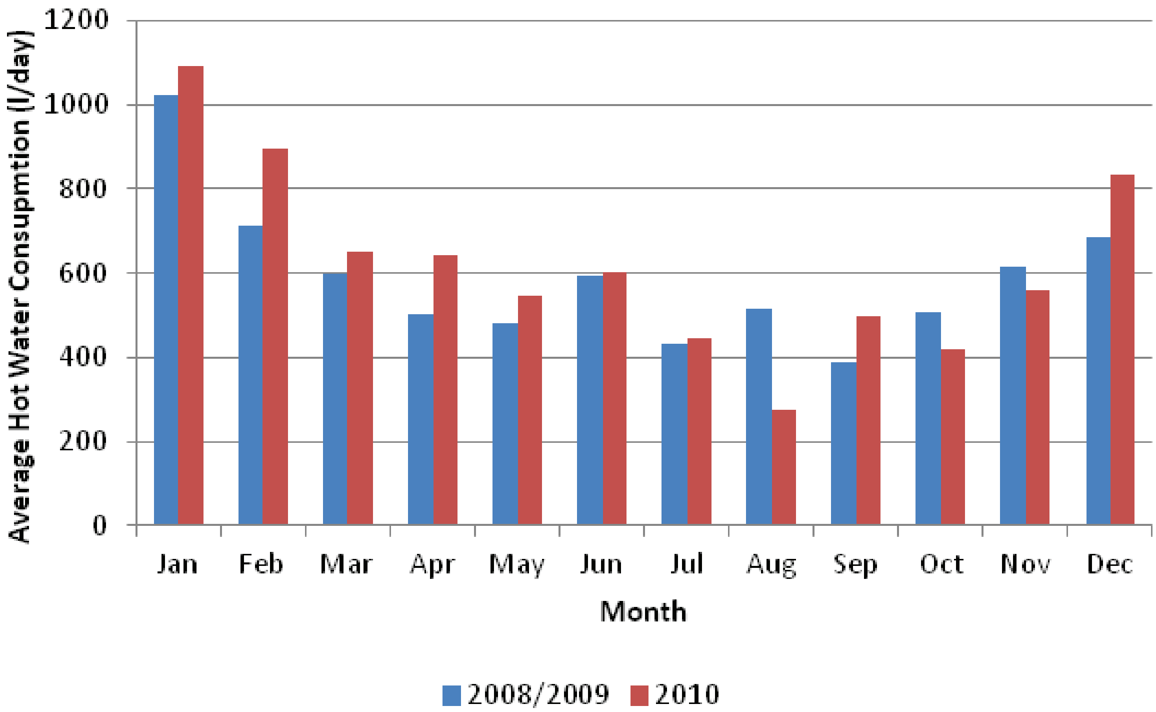
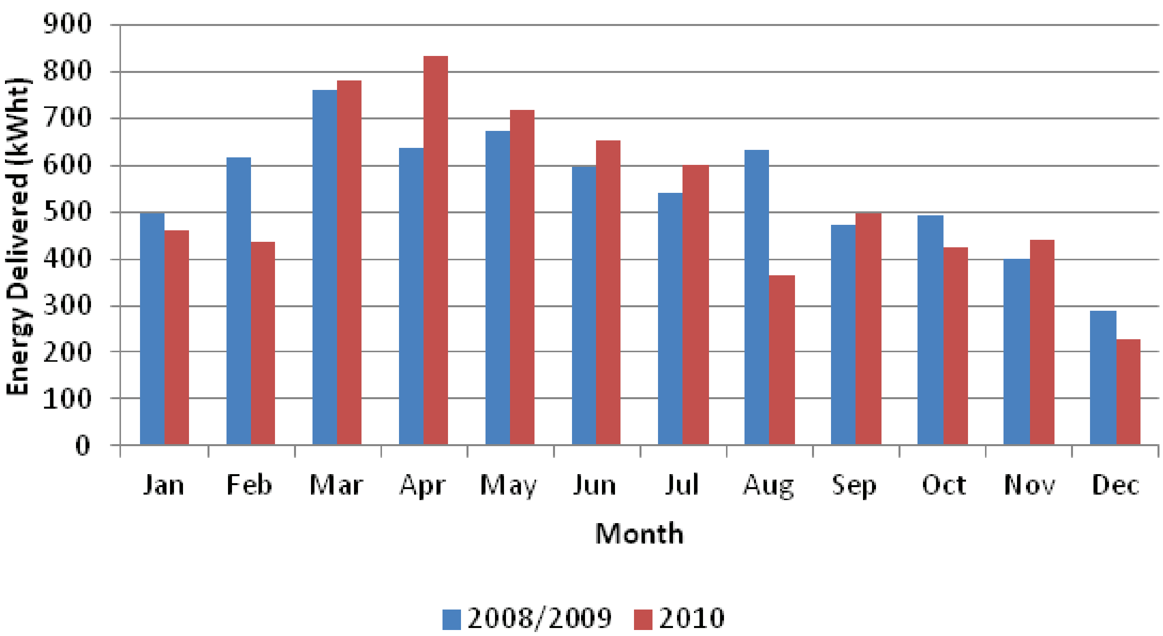



**Figure A2:** Comparison between 2008/2009 and 2010 Actual Energy Delivered




The 2010 consumption and energy delivered are similar to the numbers measured between 2008 and 2009. Most of the performance difference in terms of energy delivered comes from the drop in production in August, most likely due to very low hot water consumption registered for August 2010.

# APPENDIX B: ORIGINAL RETSCREEN ANALYSIS

**RETScreen® Solar Resource and Heating Load Calculation - Solar Water Heating Project**

| Site Latitude and Collector Orientation | | Estimate | Notes/Range |
|---|---|---|---|
| Nearest location for weather data | | Toronto Int'l. A, ON | See Weather Database |
| Latitude of project location | °N | 43.7 | -90.0 to 90.0 |
| Slope of solar collector | ° | 45.0 | 0.0 to 90.0 |
| Azimuth of solar collector | ° | 10.0 | 0.0 to 180.0 |

**Monthly Inputs**

(Note: 1. Cells in grey are not used for energy calculations; 2. Revisit this table to check that all required inputs are filled if you change system type or solar collector type or pool type, or method for calculating cold water temperature).

| Month | Fraction of month used (0 - 1) | Monthly average daily radiation on horizontal surface (kWh/m²/d) | Monthly average temperature (°C) | Monthly average relative humidity (%) | Monthly average wind speed (m/s) | Monthly average daily radiation in plane of solar collector (kWh/m²/d) |
|---|---|---|---|---|---|---|
| January | 1.00 | 1.64 | -5.9 | | 4.9 | 3.19 |
| February | 1.00 | 2.57 | -5.2 | | 4.5 | 4.23 |
| March | 1.00 | 3.67 | -0.5 | | 4.7 | 4.58 |
| April | 1.00 | 4.74 | 6.5 | | 4.8 | 4.84 |
| May | 1.00 | 5.76 | 13.1 | | 3.9 | 5.17 |
| June | 1.00 | 6.31 | 17.7 | | 3.7 | 5.34 |
| July | 1.00 | 6.24 | 21.0 | | 3.3 | 5.42 |
| August | 1.00 | 5.22 | 19.8 | | 3.0 | 5.04 |
| September | 1.00 | 3.92 | 15.1 | | 3.3 | 4.46 |
| October | 1.00 | 2.64 | 8.5 | | 3.7 | 3.74 |
| November | 1.00 | 1.51 | 3.3 | | 4.3 | 2.46 |
| December | 1.00 | 1.25 | -2.9 | | 4.4 | 2.37 |

| | | Annual | Season of Use |
|---|---|---|---|
| Solar radiation (horizontal) | MWh/m² | 1.39 | 1.39 |
| Solar radiation (tilted surface) | MWh/m² | 1.55 | 1.55 |
| Average temperature | °C | 7.5 | 7.5 |
| Average wind speed | m/s | 4.0 | 4.0 |

| Water Heating Load Calculation | | Estimate | Notes/Range |
|---|---|---|---|
| Application type | - | Service hot water | |
| System configuration | - | With storage | |
| Building or load type | - | Industrial | |
| Number of units | - | - | |
| Rate of occupancy | % | - | 50% to 100% |
| Estimated hot water use (at ~60 °C) | L/d | N/A | |
| Hot water use | L/d | 1,000 | |
| Desired water temperature | °C | 52 | |
| Days per week system is used | d | 7 | 1 to 7 |
| Cold water temperature | - | Auto | |
| Minimum | °C | 2.8 | 1.0 to 10.0 |
| Maximum | °C | 12.3 | 5.0 to 15.0 |
| Months SWH system in use | month | 12.00 | |
| Energy demand for months analysed | MWh | 18.92 | |
| | GJ | 68.11 | |

Return to Energy Model sheet

## RETScreen® Energy Model - Solar Water Heating Project

Training & Support

| Site Conditions | | Estimate | Notes/Range |
|---|---|---|---|
| Project name | | Fire Hall #212 | See Online Manual |
| Project location | | 8500 Sheppard Ave., Toronto | |
| Nearest location for weather data | | Toronto Int'l. A, ON | Complete SR&HL sheet |
| Annual solar radiation (tilted surface) | MWh/m² | 1.55 | |
| Annual average temperature | °C | 7.5 | -20.0 to 30.0 |
| Annual average wind speed | m/s | 4.0 | |
| Desired load temperature | °C | 52 | |
| Hot water use | L/d | 1,000 | |
| Number of months analysed | month | 12.00 | |
| Energy demand for months analysed | MWh | 18.92 | |

| System Characteristics | | Estimate | Notes/Range |
|---|---|---|---|
| Application type | | Service hot water (with storage) | |
| **Base Case Water Heating System** | | | |
| Heating fuel type | - | **Natural gas - m³** | |
| Heating system seasonal efficiency | % | 60% | 55% to 350% |
| **Solar Collector** | | | |
| Collector type | - | Glazed | See Technical Note 1 |
| Solar water heating collector manufacturer | | Thermo Dynamics | See Product Database |
| Solar water heating collector model | | G32-P | |
| Area per collector | m² | 3.00 | 1.00 to 5.00 |
| Fr (tau alpha) coefficient | - | 0.74 | 0.50 to 0.90 |
| Fr UL coefficient | (W/m²)/°C | 5.25 | 3.50 to 6.00 |
| Suggested number of collectors | | 5 | |
| Number of collectors | | 6 | |
| Total collector area | m² | 18.0 | |
| **Storage** | | | |
| Ratio of storage capacity to coll. area | L/m² | 50.0 | 37.5 to 100.0 |
| Storage capacity | L | 900 | |
| **Balance of System** | | | |
| Heat exchanger/antifreeze protection | yes/no | Yes | |
| Heat exchanger effectiveness | % | 90% | 50% to 85% |
| Suggested pipe diameter | mm | 13 | 8 to 25 or PVC 35 to 50 |
| Pipe diameter | mm | 19 | 8 to 25 or PVC 35 to 50 |
| Pumping power per collector area | W/m² | 11 | 3 to 22, or 0 |
| Piping and solar tank losses | % | 3% | 1% to 10% |
| Losses due to snow and/or dirt | % | 3% | 2% to 10% |
| Horz. dist. from mech. room to collector | m | 5 | 5 to 20 |
| # of floors from mech. room to collector | - | 2 | 0 to 20 |

| Annual Energy Production (12.00 months analysed) | | Estimate | Notes/Range |
|---|---|---|---|
| Pumping energy (electricity) | MWh | **0.36** | |
| Specific yield | kWh/m² | 566 | |
| System efficiency | % | 37% | |
| Solar fraction | % | 54% | |
| Renewable energy delivered | MWh | **10.19** | |
| | GJ | 36.70 | |
| | | | Complete Cost Analysis sheet |

# APPENDIX C: MODIFIED RETSCREEN INPUTS AND SOURCES

Since the initial Retscreen analysis was done with version 3.0 of the software package and the version now available is 4.0, the first step was to redo the simulation in the new version with the same inputs to verify if the simulated values were consistent. Under those conditions, both version 3 and 4 predicted an annual thermal load of 18.1 MWh/year, and 10.1 MWh/year of heat delivered by the solar system.

Then small changes were made to account for more realistic inputs. First the heat exchanger effectiveness was lowered to 70%, which lower the predicted delivered energy to 9.7 MWh, then the azimuth was corrected to 25°. This changed the output to 9.6 MWh/year. The next step was to introduce the measured solar radiation and average ambient temperature. The cold water minimum and maximum temperatures were also adjusted to the values found in Table A. With the new values, the estimated energy delivered rose to 9.9 MWh/year. This number was still much higher than the measured heat delivered. The next step was to modify the hot water demand to reflect the volume and temperature level that the system had experienced.

The weather data used was taken from the University of Toronto Meterological Station at the Mississauga Campus (solar irradiation) and Pearson International Airport (ambient temperature) stations. Hot water consumption was taken from the system measurements, which were recorded by the heat meters and downloaded periodically by City of Toronto staff. Water Main cold water temperatures were adjusted using long-term averages measured by the University of Toronto in downtown Toronto and are shown in Table C.

**Table C1:** Average mains water temperature for downtown Toronto.

| Month | Avg. Mains Water Temp (°C) |
|---|---|
| Jan | 3.5 |
| Feb | 2.95 |
| Mar | 2.97 |
| Apr | 4.53 |
| May | 6.91 |
| Jun | 8.18 |
| Jul | 10.13 |
| Aug | 13.37 |
| Sep | 14 |
| Oct | 9.85 |
| Nov | 6.95 |
| Dec | 5.04 |

**Table C2:** Global horizontal solar irradiation and average temperatures for the period under analysis – June 2008 to May 2009.

| Month | Irradiation | Average Ambient Temperature |
|---|---|---|
| | kWh/m² day | °C |
| Jan | 1.68 | -8.8 |
| Feb | 2.69 | -3.7 |
| Mar | 4.04 | 0.8 |
| Apr | 4.84 | 7.8 |
| May | 6.15 | 13.1 |
| Jun | 5.56 | 19.6 |
| Jul | 5.93 | 21.5 |
| Aug | 5.47 | 19.7 |
| Sep | 4.1 | 16.9 |
| Oct | 2.9 | 9 |
| Nov | 1.58 | 2.9 |
| Dec | 1.22 | -3.1 |

**Table C3:** Weather data for 2008/2009 and 2010

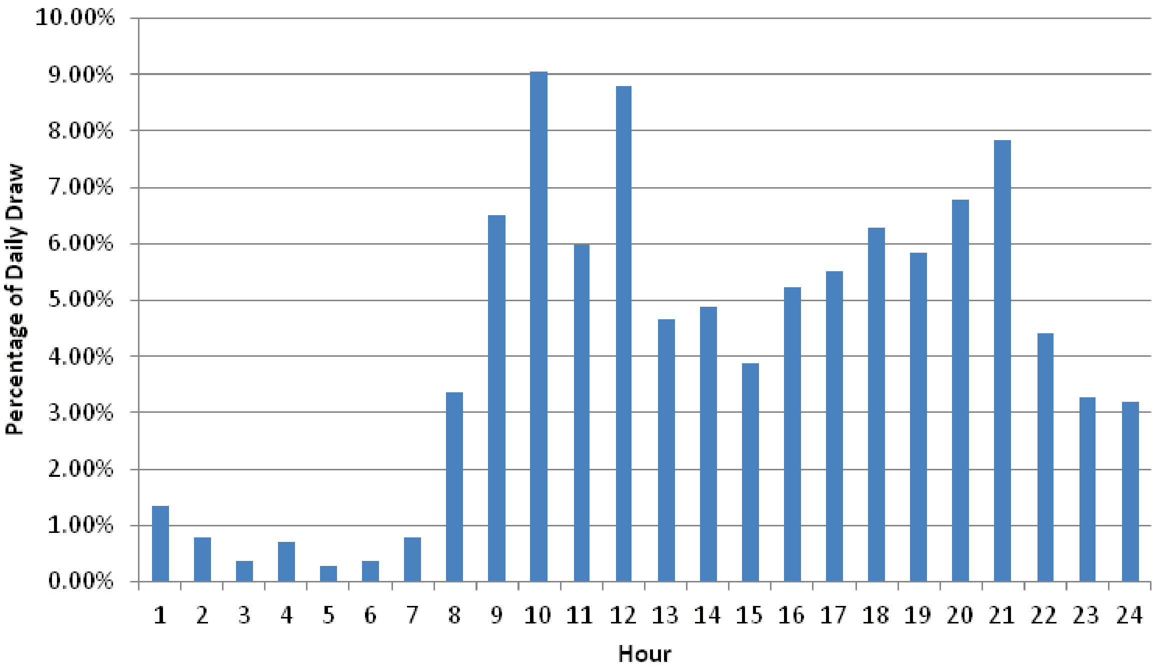
| | 2008-2009 | | 2010 | |
|---|---|---|---|---|
| | Horizontal Global Solar Irradiation | Average Ambient Temperature | Horizontal Global Solar Irradiation | Average Ambient Temperature |
| | kWh/m² day | °C | kWh/m² day | °C |
| Jan | 1.68 | -8.80 | 1.51 | -5.20 |
| Feb | 2.69 | -3.70 | 2.08 | -3.40 |
| Mar | 4.04 | 0.80 | 3.73 | 4.40 |
| Apr | 4.84 | 7.80 | 5.48 | 10.50 |
| May | 6.15 | 13.10 | 5.93 | 16.00 |
| Jun | 5.56 | 19.60 | 5.84 | 19.20 |
| Jul | 5.93 | 21.50 | 6.08 | 23.30 |
| Aug | 5.47 | 19.70 | 5.04 | 22.40 |
| Sep | 4.10 | 16.90 | 3.68 | 16.40 |
| Oct | 2.90 | 9.00 | 2.66 | 10.20 |
| Nov | 1.58 | 2.90 | 1.83 | 4.50 |
| Dec | 1.22 | -3.10 | 1.20 | -3.80 |
| **TOTAL** | **1406.81** | **Avg=7.98** | **1373.79** | **Avg=9.54** |

## APPENDIX D: RETSCREEN DISCUSSION

RETScreen is based on the f-chart method. The f-chart method was developed by researchers at the University of Wisconsin in the 1970s[1]. F-chart is based on hundreds of simulations using a more sophisticated tool, TRNSYS. From the results of the simulations, simple parametric equations were created which allowed the performance evaluation of solar heating systems even by hand calculations, which was the goal when the method was created. F-chart is known to give conservative estimations of energy delivered by solar water heating systems, which seem to be the case in the present analysis.

## APPENDIX E: HOT WATER CONSUMPTION PROFILE

**Table E1:** Fixed daily hot water usage profile used for WATSUN simulation




1 Beckman et al, "Solar Heating Design, by the F-chart Method", Wiley-Interscience, 1977.

## APPENDIX F: WATSUN ACCURACY

**Table F1:** WATSUN predictions vs. Actual Performance

| | WATSUN Estimated | | | Actual | |
|---|---|---|---|---|---|
| Month | Heat collected | Heat losses | Heat delivered | Heat delivered | Difference Between WATSUN predicted and Actual delivered |
| | kWh | kWh | kWh | kWh | (Watsun-Actual)/Actual |
| Jan | 462.4 | -3.5 | 465.9 | 497.0 | -6.26% |
| Feb | 635.0 | 36.8 | 598.3 | 616.0 | -2.87% |
| Mar | 907.4 | 85.6 | 821.8 | 762.0 | 7.85% |
| Apr | 816.8 | 101.3 | 715.5 | 638.0 | 12.15% |
| May | 864.8 | 133.5 | 731.3 | 674.0 | 8.50% |
| Jun | 826.8 | 101.3 | 725.5 | 596.0 | 21.73% |
| Jul | 817.1 | 152.1 | 665.0 | 542.0 | 22.69% |
| Aug | 895.6 | 151.7 | 743.9 | 634.0 | 17.33% |
| Sep | 692.5 | 141.3 | 551.1 | 471.0 | 17.01% |
| Oct | 674.5 | 91.1 | 583.4 | 492.0 | 18.57% |
| Nov | 395.2 | 23.5 | 371.7 | 401.0 | -7.31% |
| Dec | 332.5 | -0.3 | 332.8 | 288.0 | 15.55% |
| Total | 8320.5 | 1014.3 | 7306.1 | 6611.0 | 10.51% |

## APPENDIX G: HEAT MEASUREMENT ACCURACY

One of the reasons for the reduced accuracy is the fact that, to preserve battery charge, the meter calculator only checks the flow rate at discrete intervals. A recent study[2] tested heat meters under short dynamic loads, with 30 seconds of flow at 0.2 l/s and 300 seconds with no flow. The cycles are repeated until a total measured load equals 20 kWh. The tests were conducted with well known heat meter models and the results are presented in Table G.

**Table G1:** Measurement Device Accuracy

| Manufacturer | Model | Flow Meter Type | Error in Test (%) |
|---|---|---|---|
| Kamstrup | Multical Compact | Ultrasonic | -13.8 |
| Kamstrup | Multical 66C92F0312 | Ultrasonic | -10.8 |
| Enermet | 10EVL | Inductive | -3.8 |
| ABB | F3 | Ultrasonic | -2.59 |
| Siemens | 2WR5 | Ultrasonic | -35.35 |
| Actaris | CF Echo | Ultrasonic | -8.06 |

2 Jomni, Y.,"Improving Heat Measurement Accuracy in District Heating Substations", , 2006, Doctoral Thesis, Lulea University of Technology, Sweden.

From those tests it is apparent that all models measured energy below what was really delivered. Of course, domestic hot water loads are not composed only by short bursts, but some of the energy would not be measured under those conditions.

**Figure G1:** Detail of sensor installation at Fire Hall 231

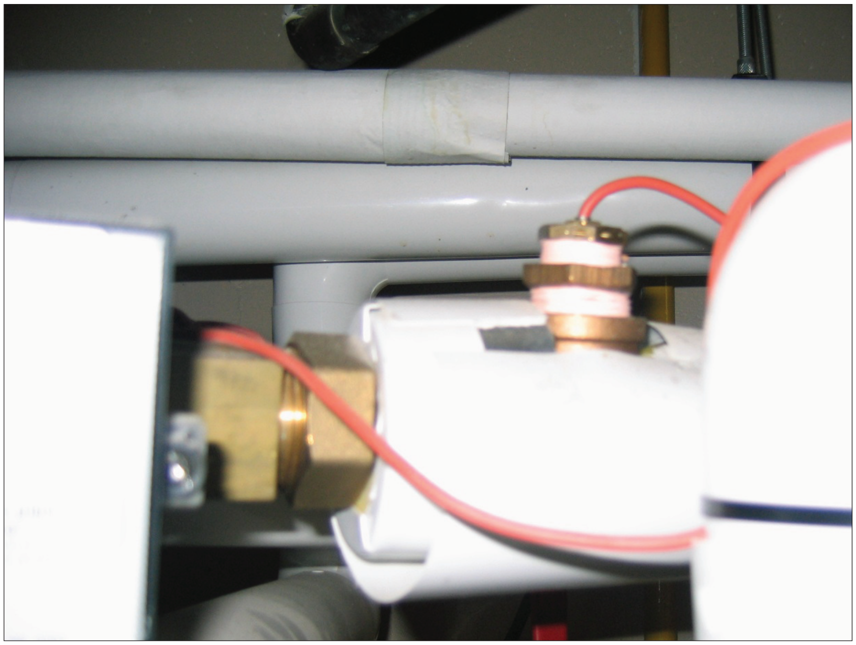
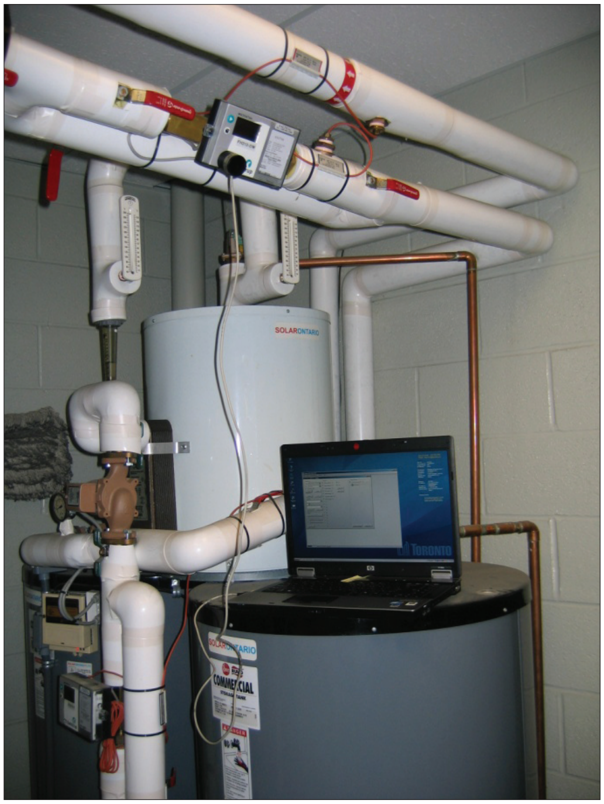


**Figure G2:** Heat meters installed at Fire Hall 212



## APPENDIX H: MIGRATION OF HOT WATER TO COLD SENSOR

Figures H1 and H2 below show the hourly average values for water draw, inlet temperature and outlet temperature to the solar storage tanks and to the heat meter. Figure H1 is for the period between the 21st to the 23rd of March of 2011, a time of the year when average mains water temperature is around 3 °C. Figure H2 shows data for the period between the 1st and the 3rd of August of 2011, when average mains water temperature is around 14 °C. As it can be seen, in both cases the hourly average inlet temperature is much higher than the expected mains water temperature.

**Figure H1:** March 21 to 23, 2011

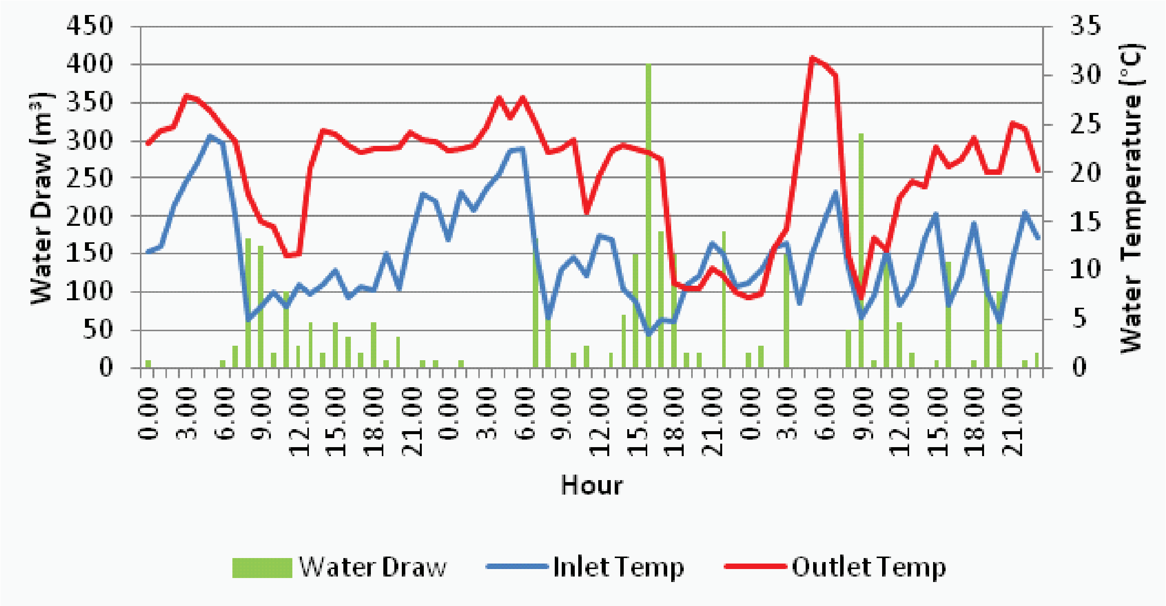
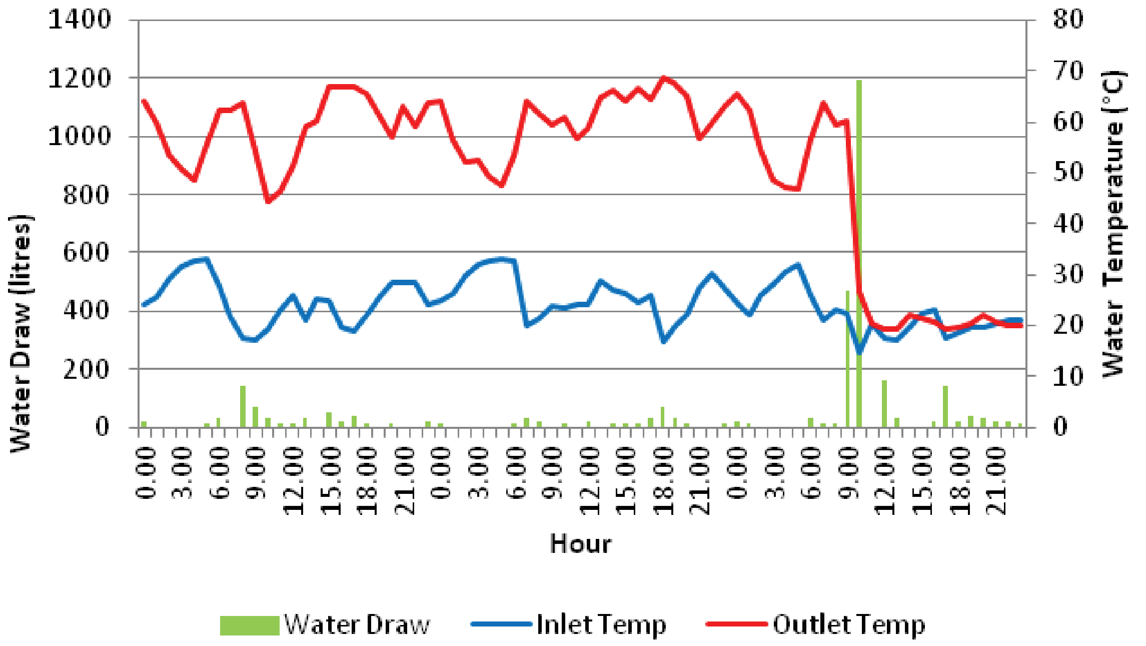
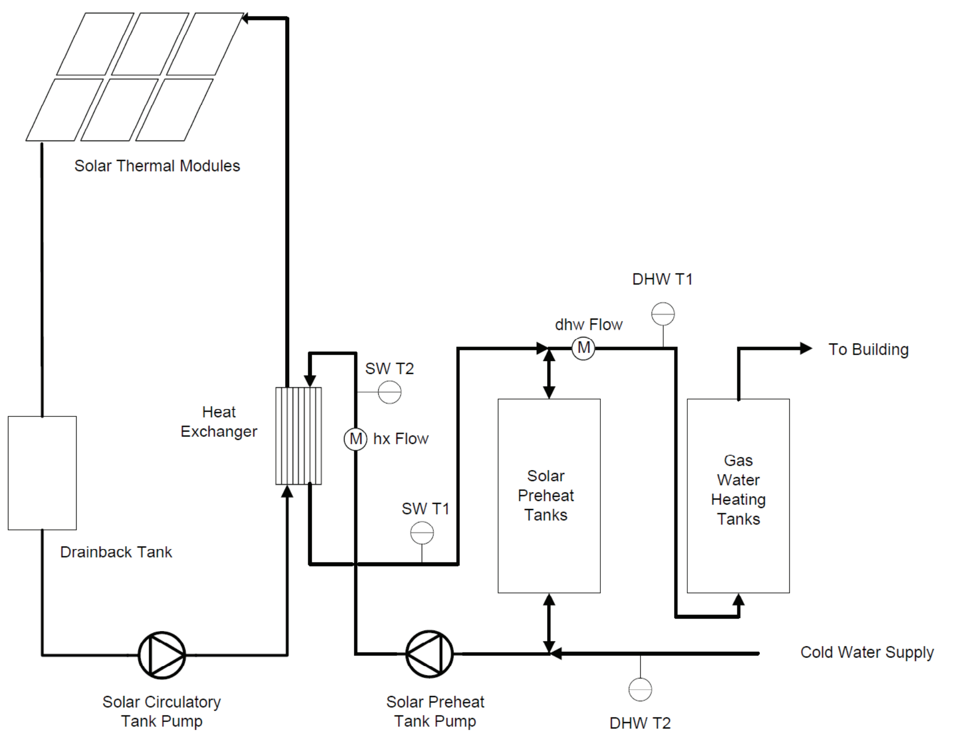



**Figure H2:** August 1 to 3, 2011

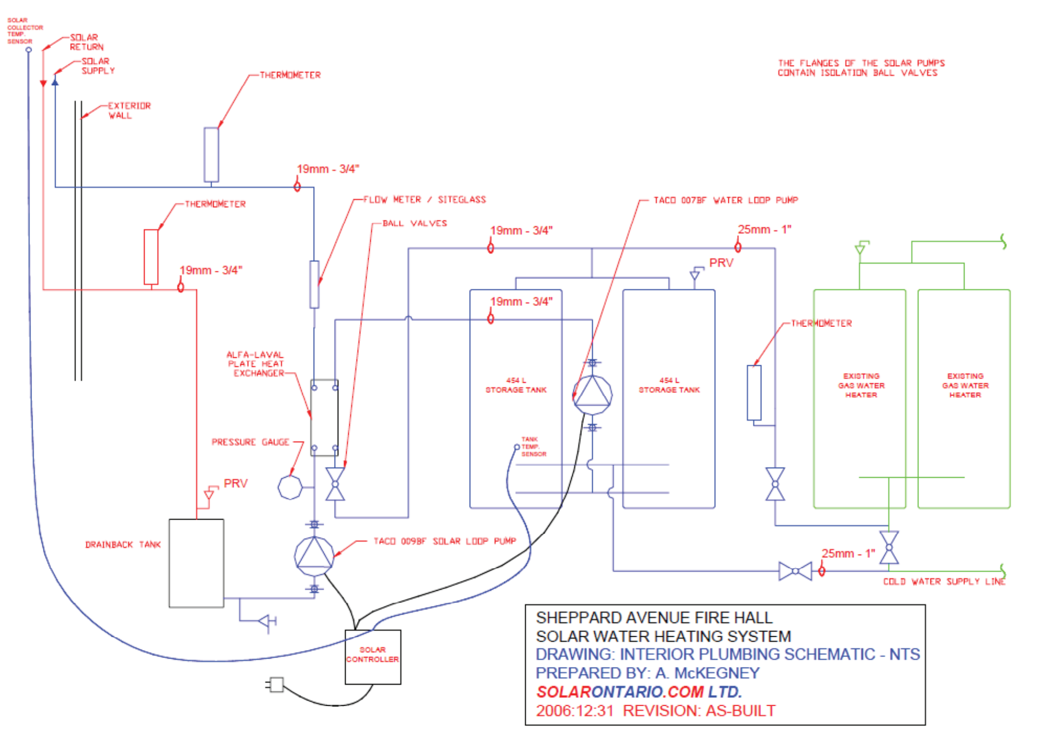


# APPENDIX I: SYSTEM SCHEMATICS

**Figure I1:** Solar Domestic Water Heating Schematic




The array is actually 1 x 6, not 2 x 3.



## About the SolarCity Partnership

The SolarCity Partnership is a joint initiative of the Toronto Atmospheric Fund, Toronto and Region Conservation Authority and the City of Toronto designed to promote best practices and careful monitoring of large solar installations. SolarCity Partnership is an information-sharing hub for both public and private organizations involved in deploying solar power. Our **SolarCityPartnership.ca** website provides case studies, research, and solar weather data to help with the effective use of zero emissions energy from the sun.

### We want to hear from you!

If you have further best practices recommendations, insights into system design, deployment or maintenance or a project to profile, please get involved with the SolarCity Partnership! Contact us at:

info@solarcitypartnership.ca
416-661-6600 ext. 5337
www.solarcitypartnership.ca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