Report for
Energy Efficiency and Conservation Authority

Operation of Swimming Pool Solar Heating at Blackmount School.

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1 EXECUTIVE SUMMARY

The key data for the Blackmount Swimming Pool and the solar Panels are as follows:

Pool Dimensions: 23m * 9m.
Pool Volume: approximately 265m³.
Pool Depth: average depth, 1.3m.
Pool Type: Indoor swimming pool with cover applied overnight.
Design Temperature: 27°C
Pool Open Season: Labour day to the end of March.

Solar Panel Dimensions: 1.5m * 2.9m.
Number of Panels: 20, all panels in parallel and in 4 groups (7,6,4 and 3).
Manufacturer: Solar 60 NZ Ltd.
Panel Type: Solar60 H300 panel
Orientation: 11 degrees West of Solar Noon.
Solar Heating System Cost: $42,275 ($38,000 plus $4,275 procurement fee).

Estimated Swimming Season Energy Requirements of Pool: 60,400kWh (24/10/02 – 31/3/03)

Estimated Swimming Season Energy Contribution from Solar Panels: 35,410kWh (24/10/02 – 31/3/03)

Estimated Swimming Season Cost Saving due to Solar Panels: $2,648 (24/10/02 – 31/3/03)

Estimated Simple Payback Period: 15.9 years.

Contents

2 INTRODUCTION

2.1 MAIN OBJECTIVES OF PROJECT

The main objectives of this project were:

- To determine the efficacy of the solar panel heating system installed for the swimming pool at Blackmount School, to estimate annual savings in diesel fuel and to work out a simple payback period.

- To present the information as a report, in a format that would be useful to engineers as a basis for evaluating proposals for future solar heating installations, with reasonable certainty.

2.2 SITE DESCRIPTION

Blackmount is situated in western Southland about 50km south of Te Anau and 40km north of Tuatapere, in close proximity to the Takitimu Mountains. The swimming pool is situated within an enclosure, located adjacent to the Blackmount Primary School. The pool is two years old, construction of the pool was a community project and it is used by the school and the local community.

The swimming pool is 23m long by 9m wide with a volume of approximately 265m^3, and an average depth of 1.3m. The pool is heated to 27°C and a pool cover is used overnight. The swimming season commences on Labour day and it is intended that the pool will remain open until April, each year.

A 45kW diesel fired Ferroli BF 200 boiler provided heating for the inaugural season. The solar panels were installed in September 2002 to reduce the on going diesel costs and to extend the swimming season for the pool. Commissioning of the solar panels was completed at the start of October 2002.

Figures 1 and 2 show the inside and outside views of the swimming pool enclosure.

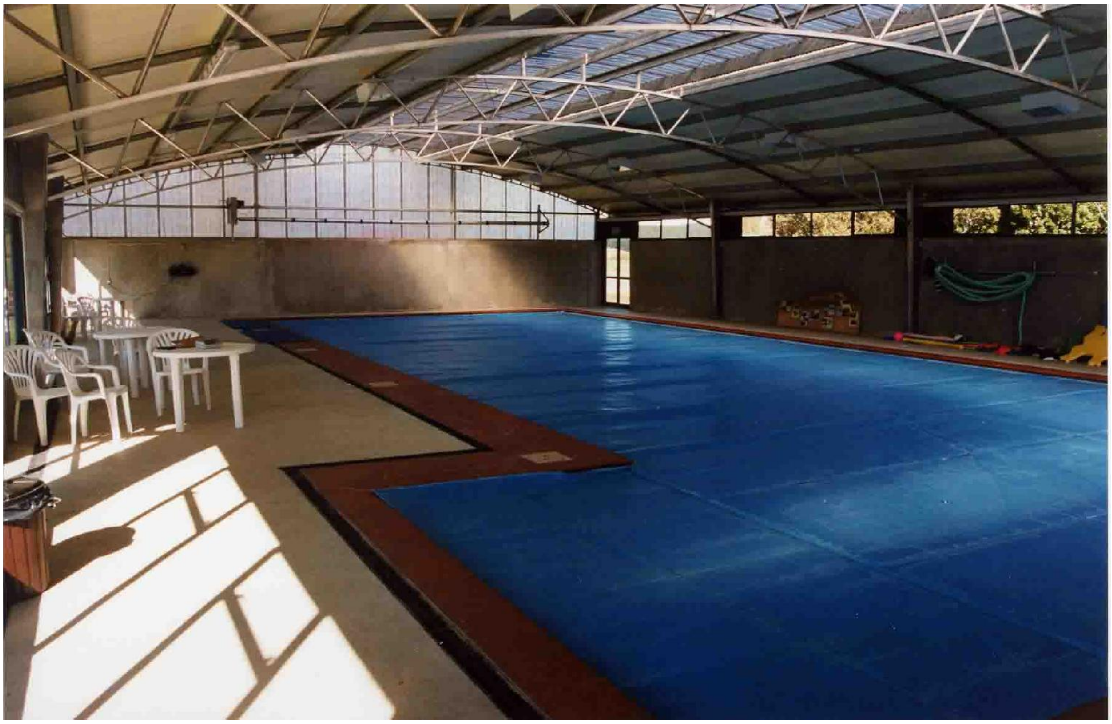


Figure 1, Swimming pool enclosure with cover in place.

Figure 2, Swimming pool with solar panels installed.

The northern face of the swimming pool enclosure and the solar panels are oriented about 11degrees west of solar noon and at a tilt angle of 35 degrees to the horizontal, which is a suitable orientation for passive solar collection.

2.3 THE POOL HEATING SYSTEM

The swimming pool filtration pump is used to circulate pool water through the secondary side of the solar heat exchanger. A separate pump is used on the solar panel side. A clock timer controls the filtration pump. A solar controller controls the solar panel pump. This pump is enabled when the solar panels reach a pre-set temperature (50ºC) and when the swimming pool temperature is below set point.

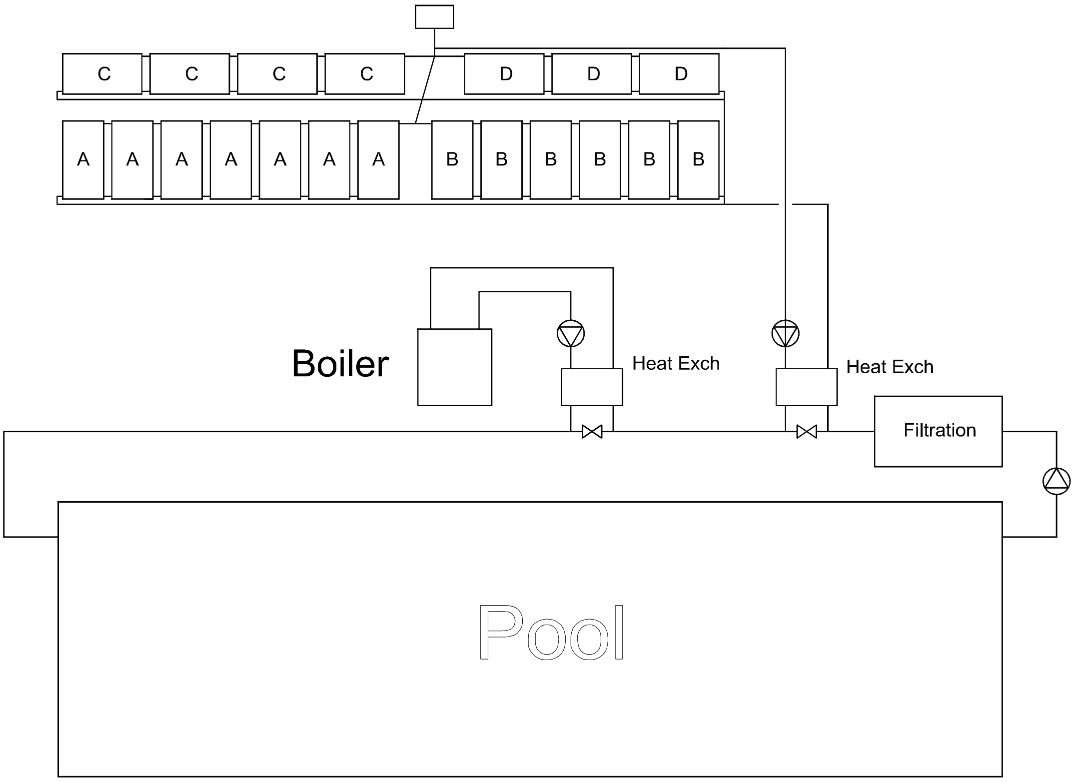


Figure 3, Solar Heating Schematic.

Note: The diesel fired boiler also heats a 200L domestic hot water cylinder, which is not included in the above schematic.

2.4 DATA COLLECTION

2.4.1 Period of monitoring

The operation of the pool and solar collectors were initially monitored between the 15th October and the 14th November. Since the number of sunny days within this initial period were limited and the pool and its surroundings had not reached equilibrium conditions, the period of monitoring was subsequently extended until the 14th December 2002.

2.4.2 Sensors

Sensors were installed to measure the following:

1. Solar heat exchanger primary, temperature of flow from panels.
2. Solar heat exchanger primary, temperature of return to panels.
3. Solar heat exchanger secondary, temperature of flow from pool.
4. Solar heat exchanger secondary, temperature of return to pool.
5. Outdoor temperature.
6. Boiler flow temperature.
7. Global solar energy (insolation), W/m^2.
8. Solar panel flow temperature, group A.
9. Solar panel flow temperature, group B.
10. Solar panel flow temperature, group C.
11. Solar panel flow temperature, group D.
12. Pump for solar panels, On/Off status.

The heat exchanger and solar panel flow temperatures were measured using precision thermistors while the outdoor temperature and boiler flow temperature were measured used integrated circuit temperature detectors.

The status of the solar heating pump was monitored by using a clean contact on a slave relay operated by the pump controller.

The water flow rate through the solar panels was measured by installing a new 40mm flow measurement valve in the solar primary circuit. The heat output from the panels was calculated by using the equation $Q=m*C*\Delta T$.

Global solar energy (insolation) was measured using a solar cell as described in 2.4.3.

Data was collected through an Opto 22 Optomux data acquisition system and a personal computer running proprietary software. Data was downloaded weekly on to a floppy disk and emailed to Dunedin by Mr.Neil Robertson, the chairman of the school Board of Trustees, whose assistance throughout this project is gratefully acknowledged.

2.4.3 Solar Radiation Sensor

Solar radiation at the pool site was measured using a commercially available photovoltaic cell. The sensor was calibrated by comparing it's output with hourly MJ/m^2 data obtained from the National Institute of Water and Atmospheric Research Ltd[1] (NIWA) from their Musselburgh station in Dunedin.

3 HISTORICAL DIESEL CONSUMPTION - 2001 / 2002

Diesel consumption figures for the 2001/2002 season were obtained from the site log book.

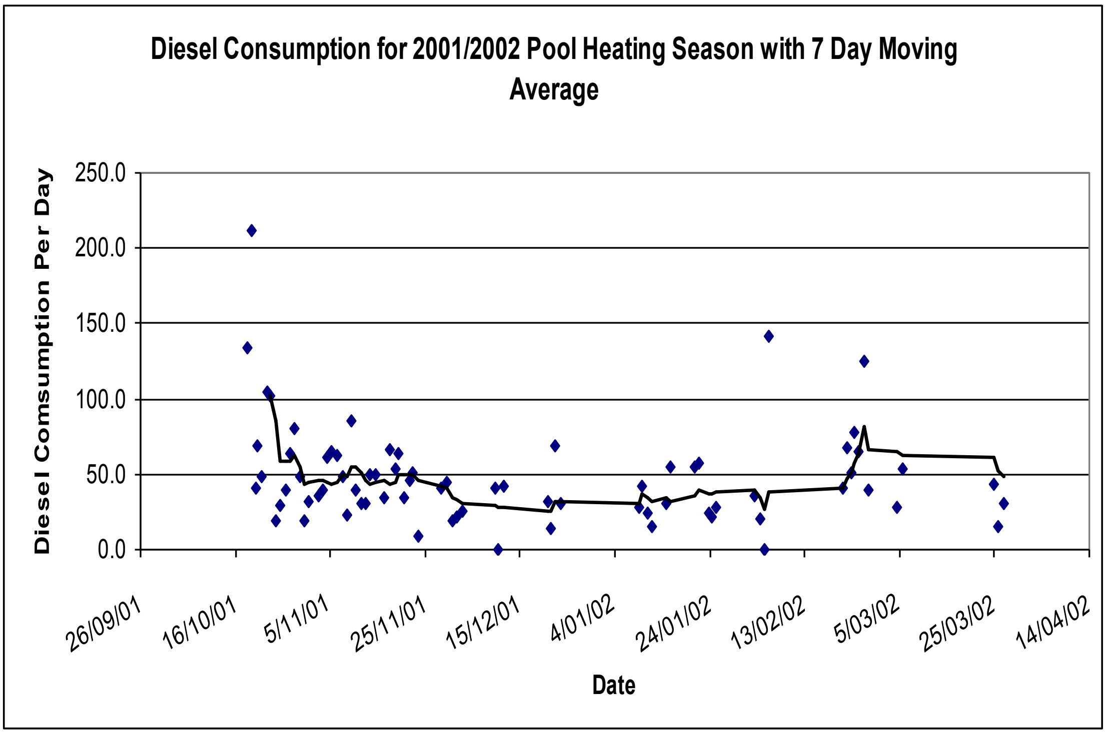
Month	Litres/Day of Diesel	kWh/Day of Diesel	Energy Consumption of Boiler (kWh)	Energy Output to Pool (kWh)
October (Start 17th)	75.0	800	11698	9826
November	43.3	462	13861	11643
December	32.7	349	10821	9090
January	35.6	380	11774	9890
February	46.9	500	13993	11754
March (Finish 26th)	40.1	427	11079	9306
		Total	73225	61509

Boiler Efficiency =	84%
Diesel MJ/L =	38.4

Table 1, 2001/2002 Season Diesel and Energy Consumption

Note: The energy output to the pool includes the hot water for the showers.

[1] Musselburgh solar data was provided by NIWA.



Graph 1, 2001/2002 Season Diesel Consumption

4 SOLAR DATA

4.1 QUEENSTOWN SOLAR DATA

Both historical and hourly solar data for Queenstown was obtained from NIWA for use in the analysis of the Blackmount solar heating panels. The historical data covered the years 1991 to 2002 and included the monthly average of MJ/m²/day along with the maximum and minimum average values of. MJ/m²/day.

Queenstown													
1991-2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Max	25.9	23.4	16.9	11.0	7.1	5.0	6.2	9.3	14.3	20.1	25.4	27.2	15.1
Average	23.7	20.8	15.7	10.2	6.2	4.6	5.8	8.5	13.1	18.1	21.7	24.1	14.3
Min	21.5	19.3	14.2	8.8	5.6	4.3	5.1	7.7	10.8	16.2	17.9	20.7	13.8

Table 2, Historical Solar Data for Queenstown[2]

[2] Historical monthly solar data was provided by NIWA.

4.2 CALCULATION OF SOLAR INTENSITY FOR NEW ZEALAND

To estimate the monthly energy output of the solar panels, the computer model given by the American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) was used.

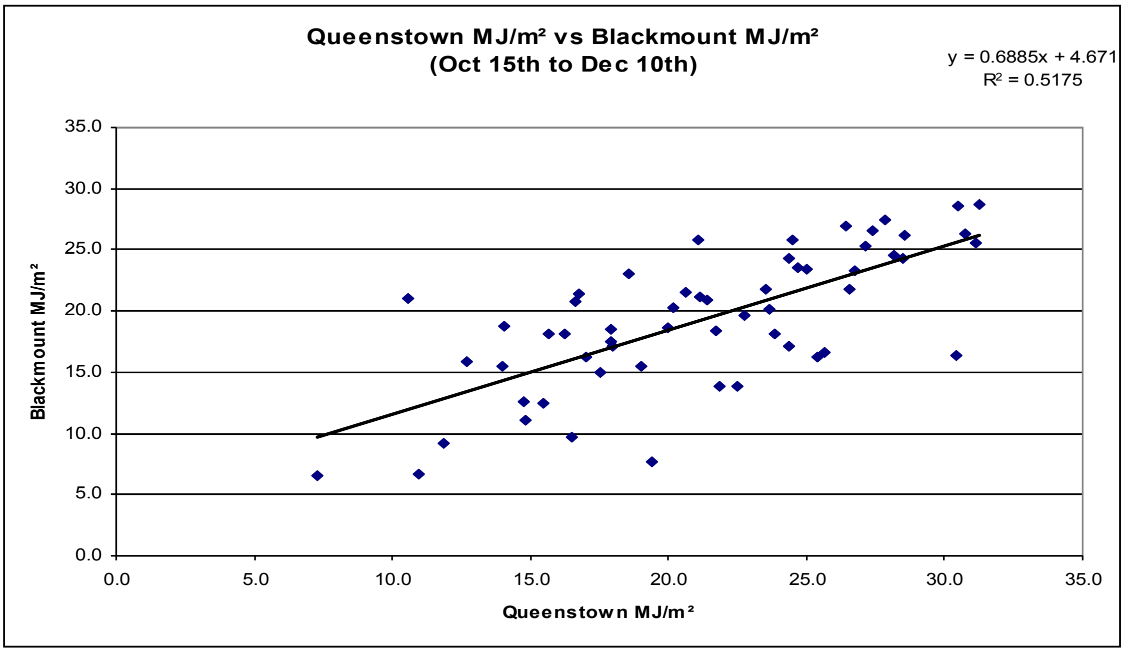
Where estimates of the maximum clear sky monthly MJ/m² were required, these values were calculated using the ASHRAE clear sky radiation model. The ASHRAE equation was used together with the New Zealand constants provided in the Building Research Association of New Zealand (BRANZ) reprint No. 101 (1990) "The Estimation of Solar Radiation in New Zealand".

This is further explained in Appendix 1.

5 COMPARISON OF SITE SOLAR DATA AND NIWA DATA FOR QUEENSTOWN

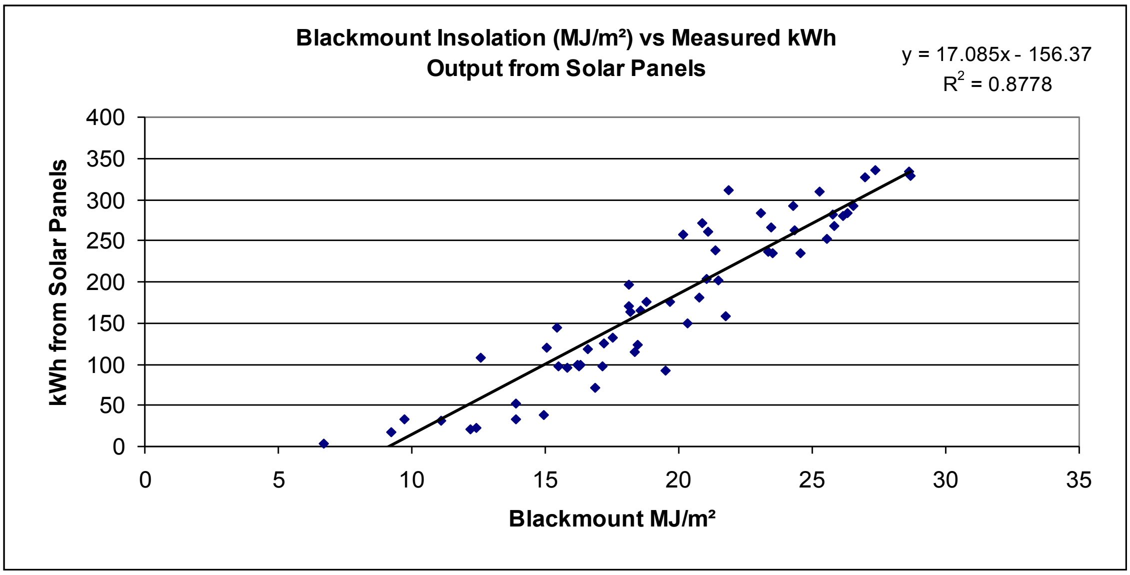
5.1 SITE SOLAR DATA COMPARISON WITH QUEENSTOWN DATA

The comparison of the Blackmount site solar data and the Queenstown data shows significant daily differences. This highlights possible difficulties in predicting heat output from solar systems when historical data is not available for a particular location.



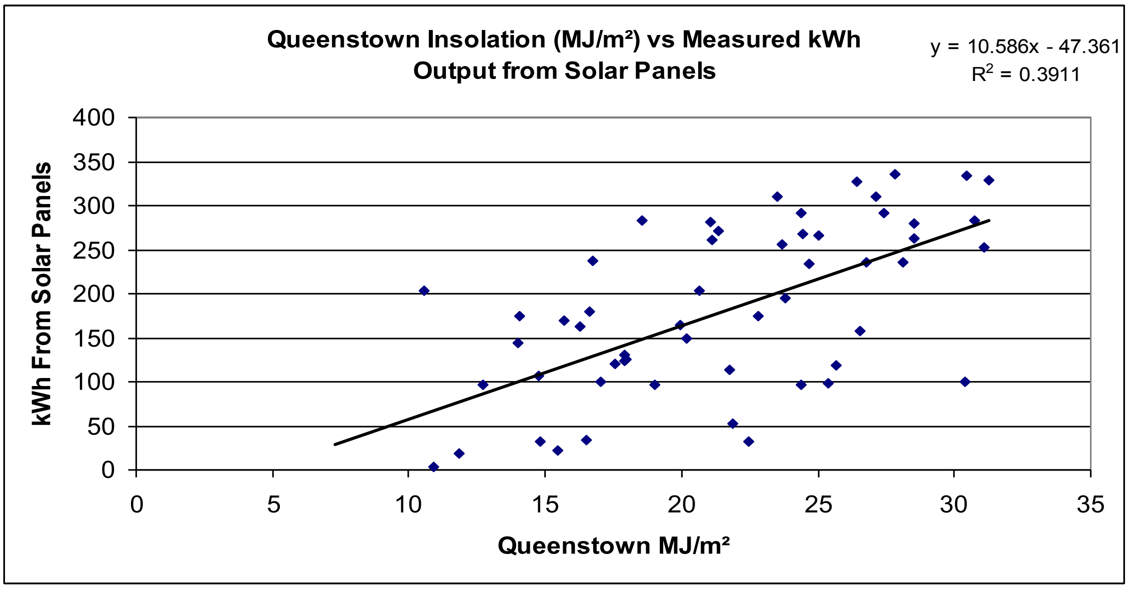
Graph 2, Comparison of Queenstown[3] and Blackmount Solar Data

Graphs 3 and 4 compare the measured heat output of the solar panels against the Blackmount and Queenstown solar data respectively. As can be seen from the graphs the heat output from the solar panels correlates well with the Blackmount data but poorly with the Queenstown data.



Graph 3, Blackmount Solar Data compared with Solar Panel Output

[3] Hourly and daily solar data for Queenstown was provided by NIWA.



Graph 4, Queenstown[4] Solar Data compared with Solar Panel Output

5.2 FORTNIGHTLY COMPARISON OF BLACKMOUNT AND QUEENSTOWN SOLAR

During the two-month period of monitoring, Blackmount averaged 10% less solar radiation than Queenstown as shown in the table below.

	15th to 28th Oct	29th Oct - 11th Nov	12th to 25th Nov	26th Nov to 9th Dec		Average
Blackmount Average MJ/m²	16.5	17.9	21.0	21.6		19.3
Queenstown Average MJ/m²	17.9	19.2	24.6	24.2		21.5
Percentage	92%	93%	85%	89%		90%

Table 3, Solar Radiation Comparison Between Blackmount and Queenstown[5]

Despite this measured difference in total solar radiation between Blackmount and Queenstown, the calculations of the seasonal contribution to the pools

[4] Hourly and daily solar data for Queenstown was provided by NIWA.
[5] Hourly and daily solar data for Queenstown was provided by NIWA.

heating have to be based on the available historical data, which is for Queenstown.

6 ANALYSIS OF BLACKMOUNT SOLAR PANELS

6.1 SOLAR PANEL EFFICIENCY

Based on the monitoring that was carried out, the efficiency of the solar panels at Blackmount are as follows:

	Total Panel Insolation (kWh)	kWh Output	Efficiency
15th Oct to 14th Nov	14529	5014	35%
15th Nov to 14th Dec	14057	5351	38%

Table 4, Solar Panel Efficiency over Monitoring Period

This compares quite favourably with the calculated efficiencies (36 % and 38%) for the same periods, using the ASHRAE equations.

By using the ASHRAE equations, the efficiency of the panels for the heating season was calculated and the results are as follows:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Panel Efficiency	42%	43%	40%	35%	25%	17%	20%	25%	32%	35%	37%	39%

Table 5, Estimates of Monthly Panel Efficiency

Note: Panel efficiencies were calculated for total solar when incident angles are less than 90 degrees. As daytime temperatures were not available for Blackmount, average daytime temperatures for each month were calculated using hourly Dunedin air temperatures for 1999 and adjusted using historical monthly average temperatures for both Dunedin and Queenstown.

6.2 PREDICTION OF SOLAR PANEL ENERGY OUTPUT

The estimated daily energy output of the solar panels in Table 6 below are based on the solar panel efficiencies calculated in section 6.1 above and average monthly solar MJ/m² for Queenstown between 1991 and 2002 (solar data provided by NIWA[6]).

These average daily outputs were estimated using Queenstown solar as monthly MJ/m² data is not available for Blackmount.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Insolation (MJ/m²)	23.7	20.8	15.7	10.2	6.2	4.6	5.8	8.5	13.1	18.1	21.7	24.1
Solar Panel Output (kWh)	241	251	214	149	80	44	61	93	146	182	197	219

Table 6, Average Daily Solar Panel Output

6.3 DIESEL SAVINGS FROM SOLAR PANELS AND PAYBACK

Diesel savings have been based using the 2001/2002 diesel consumption figures extracted from the site log book (see section 3). The energy input to the pool during the 2001/2002 season was calculated using the calorific value and thermal efficiency figures given in section 3. It was assumed that over the same heating period this season, the pool would use the same amount of energy- consisting of solar energy and energy from the diesel fired boiler.

The total diesel consumption for the 2001/2002 season between 17th October and 26th March was 8,115 litres. There was some usage of the pool up to the 14th April, however the diesel records after the 26th March are not clear, therefore have not been included.

During the first nine days of monitoring the diesel boiler was switched off in order to see if the solar panels would raise the pool to operating temperature (27°C). By the 24th of October the pool had levelled off at about 22°C. At this stage the diesel fired boiler was turned on to raise the pool to set point by opening day.

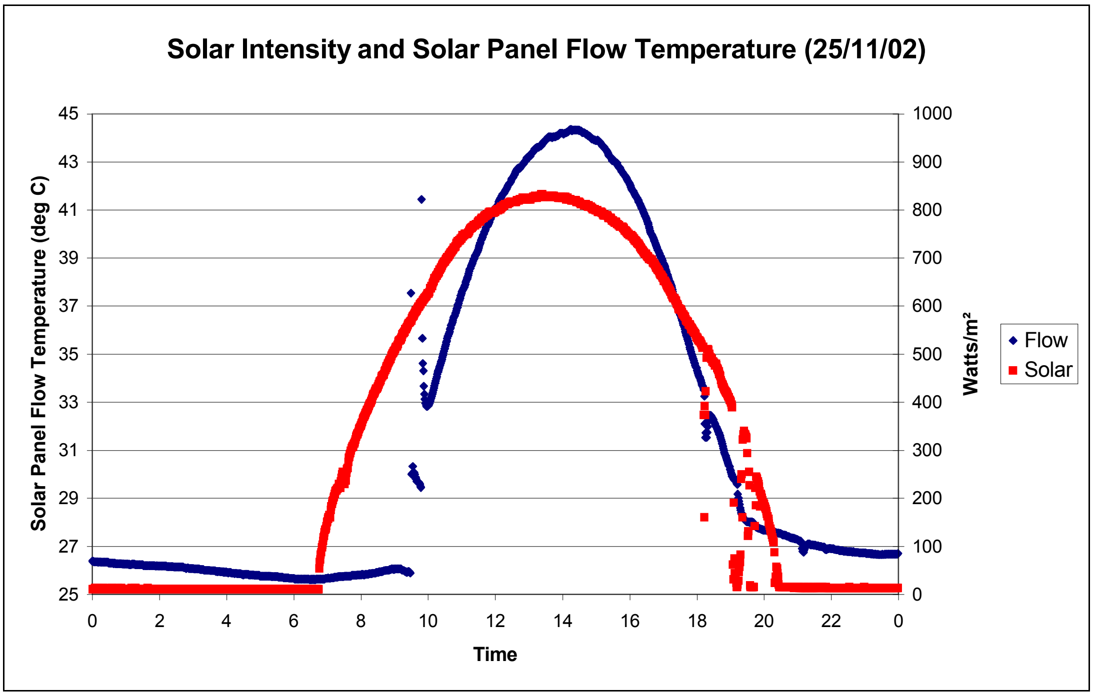
The comparison of energy input to the pool over the monitoring period and an equivalent period over the previous season, showed close similarities. This provided assurance that the diesel consumption figures from the log book were reliable.

[6] Monthly average MJ/m² were provided by NIWA

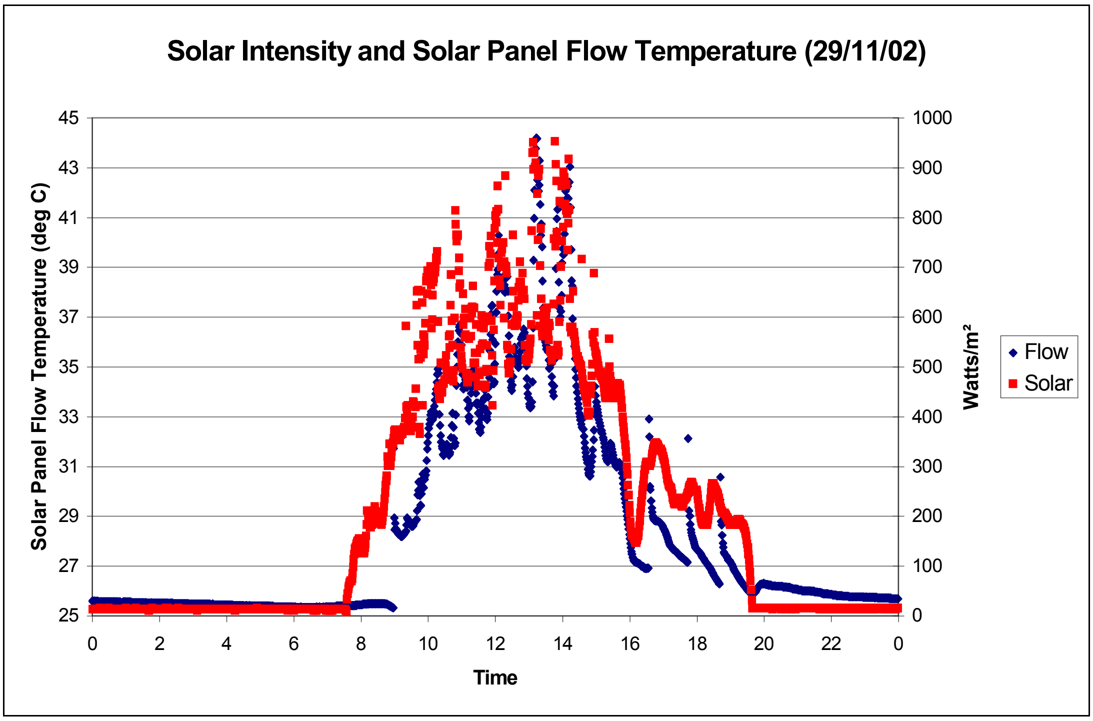
The calculated saving over the swimming season ending March 31st 2003, is expected to be 3952 Litres of diesel (35,410 kWh) at a cost saving of $2,648 (at $0.67/Litre).

Given the cost of the solar heating system at $42,275 ($38,000 plus $4,275 procurement fee) the simple payback period is 15.9 years.

6.4 TYPICAL SOLAR PANEL FLOW TEMPERATURES



Graph 5, Panel Flow Temperature and Solar Intensity for 25/11/2002



Graph 6, Panel Flow Temperature and Solar Intensity for 29/11/2002

Appendix 1

Calculations of the efficiency of the solar panels during the monitoring period and projections of the likely annual heat output were made using the following data and methods.

- Measurements of solar radiation and heat output at the pool site.
- Calculated energy admitted to the panels based on the solar data and incident angle. The admittance was based on single glazed collectors with flat black paint plates as given in ASHRAE Handbook Applications but modified using available transmittance and absorptance values for the Solar60 panels.
- The upward heat loss from the panels was estimated using the difference between the calculate energy admitted to the panels and the measured energy output. A collector heat loss factor was selected from ASHRAE Applications and collector plate temperatures were calculated in order to produce an equation relating the energy admitted to the collector and a collector plate temperature.
- Maximum monthly direct normal solar intensities and MJ/m² were calculated using the ASHRAE clear sky radiation model. The ASHRAE equation was used together with the New Zealand constants provided in the Building Research Association of New Zealand (BRANZ) reprint No. 101 (1990) "The Estimation of Solar Radiation in New Zealand".
- Monthly heat output was calculated by modifying the calculated direct normal solar intensities by the ratio of the calculated maximum MJ/m² and Queenstown averages obtained from NIWA.