POOLHEAT 6

SWIMMING POOL HEAT LOAD ANALYSIS AND HEATER SIZING

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POOLHEAT LICENSE CONDITIONS

The PoolHeat license covers installation by the licensee at one site only.

By installing this software you acknowledge that Thermal Design assumes no responsibility or liability for the accuracy of the program or for the results which may arise from its use.

SOFTWARE INSTALLATION

Installation is a three step process

1. Run the *setup.exe* program
2. Copy the file *license6.dat* to the **PoolHeat** installation directory. The default location is c:\program files (x86)\poolheat
3. Copy the climate data files **.TMY* to the **PoolHeat** installation directory.

To start PoolHeat

Double click on the PoolHeat windows icon 

or use the Windows explorer to find and run POOLHEAT.NET.EXE in the directory you selected during installation.

NOTE: Depending on your computer security setup it may be necessary to set Poolheat to run as administrator – see separate instructions.

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INTRODUCTION

PoolHeat calculates heat loss from outdoor and indoor swimming pools and models the performance of swimming pool heating systems.

PoolHeat is a thermal analysis package for evaluating temperatures and energy flows in indoor and outdoor swimming pools. Operating characteristics can be determined for pools with the following heating systems

- Unheated outdoor pool.
- Gas heating.
- Heat pump heating.
- Solar collector heating.
- Solar collector heating with gas booster
- Solar collector heating with heat pump booster

The thermal analysis is based on procedures defined in Australian and ISO Standards

- AS 3634 **Solar heating systems for swimming pools**
- AS 5352 **Swimming pool heat pump systems**
- AS 5348 **Pool covers**
- ISO TR12596 **Solar heating - Swimming pool heating systems - Dimensions, design and installation guidelines**

PoolHeat output includes monthly summaries of water temperatures (minimum, average and maximum) and the following energy flows

- Direct solar heating of outdoor pools, with allowance for shading, local wind conditions and pool covers.
- Modes of heat loss, evaporation, convection, radiation, make-up water heating and filter back flushing.
- Solar collector, gas and heat pump heating system input.
- Air heating load for indoor pools.
- Humidity conditions for indoor pool enclosure.

PROGRAM FEATURES

- Heating system analysis for gas, heat pump and solar heat source.
- Climate data for a large number of locations.
- Pool design features.
- Effect of number of users on heat loss due to evaporation.
- Sizing of heating system to meet required temperature specifications.
- Minimum and maximum pool temperatures for a specified heating system capacity.
- Effect of pool covers for both indoor and outdoor pools.
- Ventilation analysis of pool building for indoor pools.
- Solar collector efficiency characteristics for a specific solar collector or use one of 32 collector and roof types defined in the program.
- Evaluation of single speed, dual speed and variable speed heat pumps

Outdoor pools

Pool shading.

Exposure to wind.

Pool cover.

Over temperature control.

Heater capacity required for a specified operating temperature or for a specified heating system capacity.

Indoor pools

Monthly pool heating requirements.

Pool cover.

Ventilation analysis of pool building.

Temperature and humidity levels in the pool building.

Space heating requirements.

Solar collector heating

Collector efficiency data for 32 collector/roof combinations or user defined solar collector efficiency.

Solar collector types include plastic extrusions, flat plate and evacuated tube collectors.

Heat pump heating

Single speed, dual speed and variable speed

CLIMATE DATA LOCATIONS

PoolHeat uses hourly records of solar radiation, ambient temperature, ambient humidity and wind speed. Some of the available locations are shown in the following tables. Climate data files for locations not listed in the following tables can be generated if the required hourly meteorological data is available. Contact Thermal Design at t_design@tpg.com.au for information about additional climate data. Climate data files for other locations are listed on the POOLHEAT website.

Queensland	Amberley
	Brisbane
	Cairns
	Cunnamulla
	Gold Coast
	Hughenden
	Longreach
	Mt Isa
	Noosa
	Oakey Army
	Rockhampton
	Tara
	Townsville
New South Wales	Broken Hill
	Casino
	Cobar
	Coffs Harbour
	Dubbo
	Lightning Ridge
	Moree
	Nowra
	Orange
	Richmond
	Sydney
	Tamworth
	Wagga Wagga
	Williamtown
	Wollongong
Victoria	Ballart
	Echuca
	Melbourne
	Mildura
	Ryll
	Sale
	Shepparton

Tasmania	Hobart
	Launceston
South Australia	Adelaide
	Mt Gambier
	Oodnadatta
	Woomera
Northern Territory	Darwin
	Alice Springs
Western Australia	Albany
	Broome
	Carnarvon
	Corrigin
	Dwellingup
	Forrest
	Geraldton
	Hall's Creek
	Kalgoorlie
	Newdegate
	Perth
	Port Hedland
ACT	Canberra
New Zealand	Auckland
	Christchurch
	Dunedin
	Invercargill
	New Plymouth
	Queenstown
	Wellington

China	Beijing
	Chengdu
	Guangzho
	Kunming
	Nanjing
	Shanghai
	Wuhan
	Xiamen
United Arab Emirates	Abu Dhabi
	Dubai
Cyprus	Nicosia
Taiwan	Taipei

Europe	
Portugal	Lisbon
Spain	Madrid
France	Marseille
France	Paris
Indonesia	Bandung
Thailand	Chiang Mai
	Phuket
USA	
Memphis	Tennessee
Modesto	California
San Jose	California
Santa Rosa	California

PROGRAM OPERATION OVERVIEW

The **program input screens** are selected by clicking on the menu items along the top of the screen. Numerical values can be changed by over-typing default start-up values. Select options from lists by pointing with the mouse and pressing the left mouse button.
To save the input data to a specified file name, select **File - Save** before running a simulation. The results will be saved to a file with the name specified in the save operation, with file type .RES. If the **File - Save** option is not used the input data and results will be saved in file names DEFAULT.DAT and DEFAULT.RES in the PoolHeat installation directory.
The program calculates pool heat loss and heating system inputs using a one minute time step thermal simulation model.

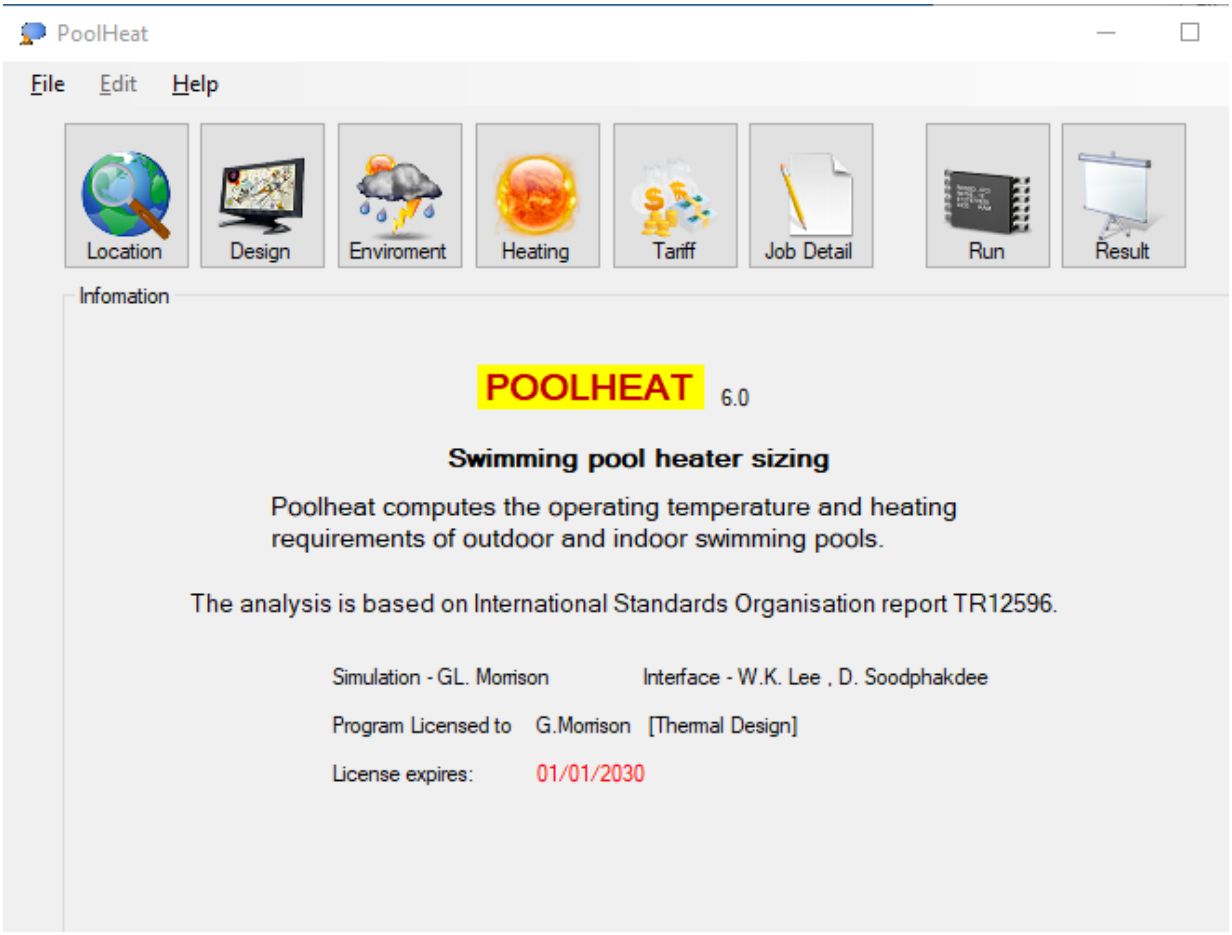
After an annual performance calculation has been completed the results can be viewed by selecting **Result** from the top menu bar. The pool temperature and purchased energy use can be selected from the tabs on the result window. The full results are displayed in a text result file that may be viewed and printed by selecting the "Result Summary" tab in the result window. The result file is in standard text format and may be read into a word processor document (use Courier font so that table items line up) or viewed out of PoolHeat by using a text editor.
A comma separated variable result file is also produced; this data can be loaded into EXCEL templates supplied with PoolHeat (different templates for indoor and outdoor result files). The templates have prepared graphs of pool temperatures, energy flows and indoor space conditions etc throughout the year. PoolHeat can be run in parallel with Excel so that the PoolHeat output is displayed directly in Excel figures or tables.

ANALYSIS

The analysis in **PoolHeat** follows the procedures specified in Australian Standards AS 3634, AS 5348, AS 5352 and International Standards Organisation report TR12596. As a large number of alternative design, operating conditions and usage levels may be specified the applicability of a given result rests with the user. *By installing this software the licensed user acknowledges that Thermal Design assumes no responsibility or liability for the accuracy of the program or for the results which may arise from its use.*

PROGRAM OPERATION

The startup screen is shown below



FILE : The default file name is DEFAULT, results are saved to the file DEFAULT.RES unless the input data has been saved to a new file name before the **Run** command is selected.

DATA ENTRY PROCEDURE

Details of the pool size, environment, heating system and operating conditions are set using the menus at the top of the page

For a new evaluation the sequence of operations is

- select the climate conditions by selecting a location in the **Location** Menu.
- enter pool parameters using the **Design** menu,
- enter the pool environment using the **Environment** menu
- enter details of the heating system using the **Heating** menu. See sub-menus for different heating ystems
- enter the gas and electric supply times and cost tariffs using the **Tariff m**enu
- enter details of the work using the **Job Detail** menu
- save the input data using the **File - Save** pull down menu.
- select **Run**; results will be written to the file name specified in the **File - Save** operation.

The data entry procedure for modifying a previously saved case is

- use the **File - Open** operation to load the previous data file
- edit the parameters using the Location, Design, Environment, Heating and Tariff menus.
- save the new data using the **File - Save** operation and enter a new file name.
- select **Run**. (results will be written to the file name specified in the **File - Save** operation).

FILE NAME

The current file name is displayed at the bottom of the screen

INDOOR/OUTDOOR POOLS

The parameters for indoor or outdoor swimming pools are selected in the Environment window. The Environment window changes for indoor or outdoor.

RUN

Selecting the **Run** button will start the annual performance evaluation. The simulation progress is displayed during the analysis.

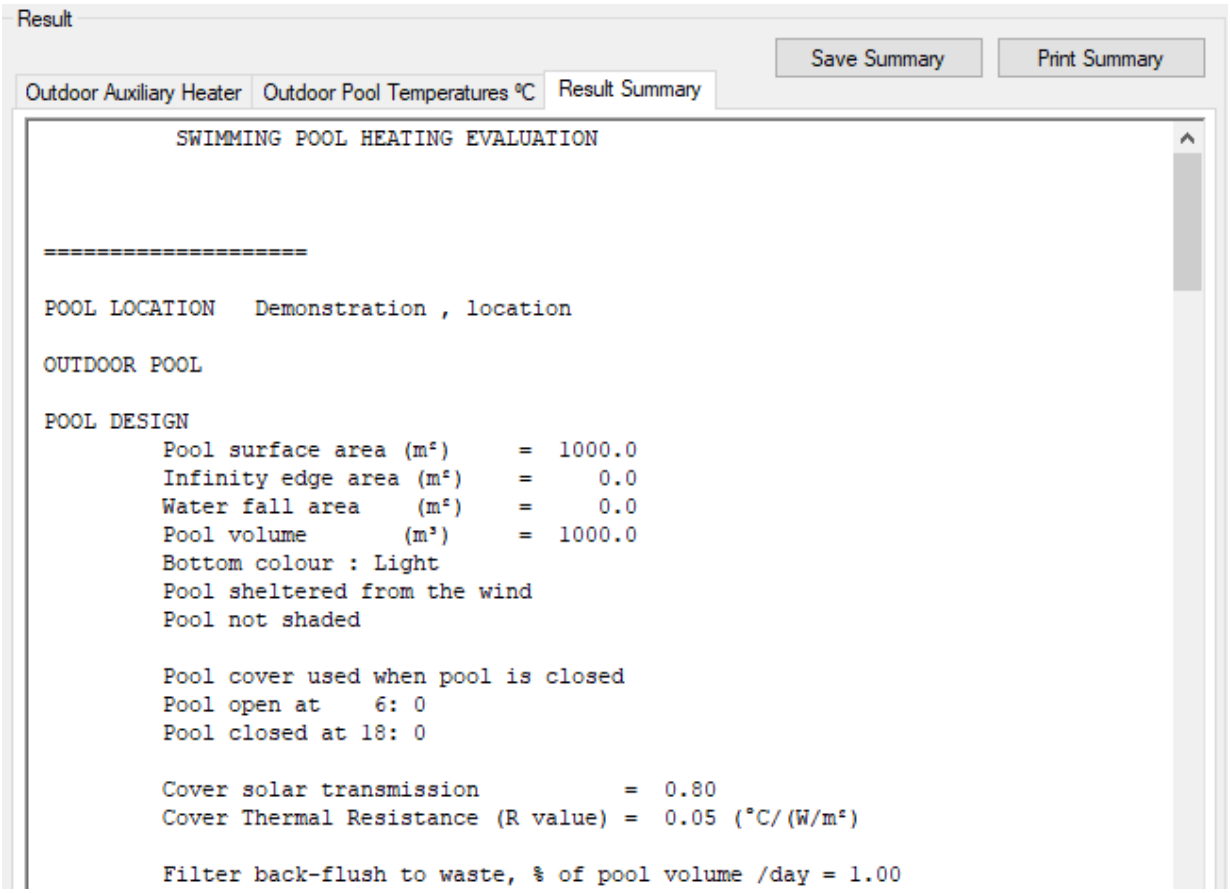
RESULTS

Selecting the **Results** button on the top menu bar will display the results tabs

Outdoor Auxiliary Heater | Outdoor Pool Temperatures °C | Result Summary

	Average Heater Output (MJ/Hr)	Fuel Use (kWhr)	Operating Cost ($)
Jan	0	0	492
Feb	0	0	0
Mar	0	0	0
Apr	19.8	104.2	1689
May	109.6	605.3	0
Jun	170.4	1074.5	0
Jul	167.2	1065.2	45371
Aug	134.3	859.4	0
Sep	62	381.6	0
Oct	28.4	156.5	23188
Nov	5.8	30.4	0
Dec	0	0	0
Annual	0	130999.5	70740

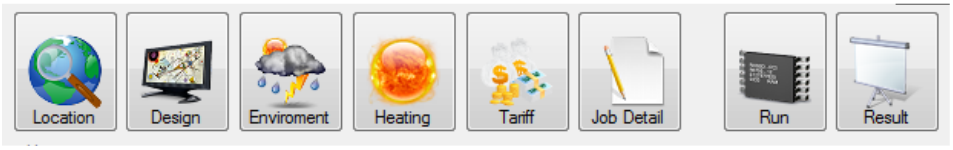
The full results record may be viewed by selecting the **Result Summary** tab.



The results file can be saved or printed using the **Save Summary** and **Print Summary** tabs at the top right of the result screen. The result file may also be read into a word processor document (use Courier font to line up table columns).

SELECTING FORMS

There are eight forms for defining the swimming pool and heating systems configuration.



Location – selection of climate data

Design - swimming pool parameters

Environment - swimming pool operating environment

Heating -(solar, gas or heat pump or combinations

Tariff - electricity and gas supply tariffs and costs

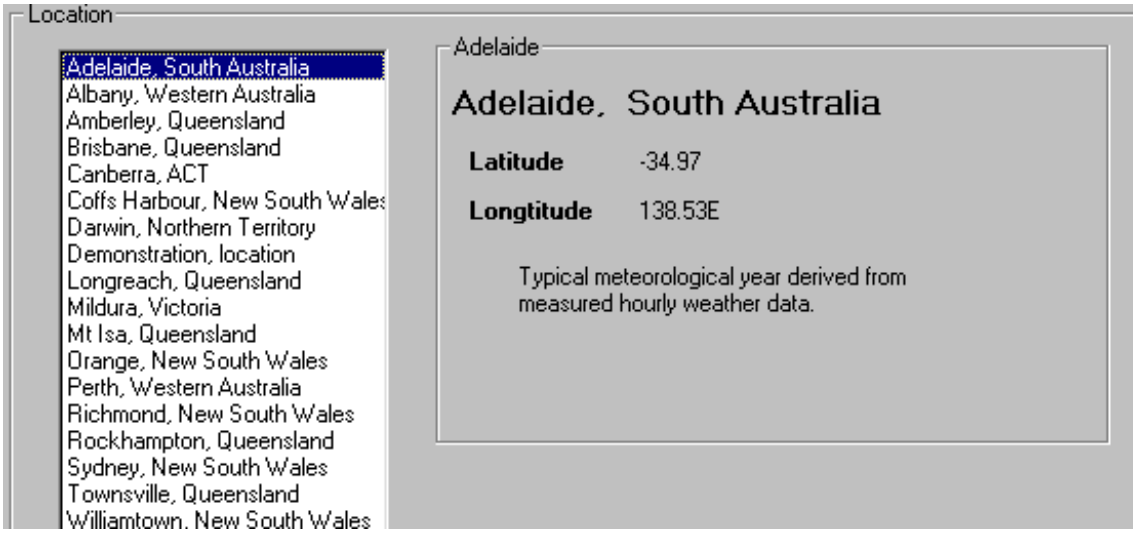
Job Details - record of customer information and job notes

Run – start calculation of annual performance

Result – view the result pages and print the result summary file.

LOCATION

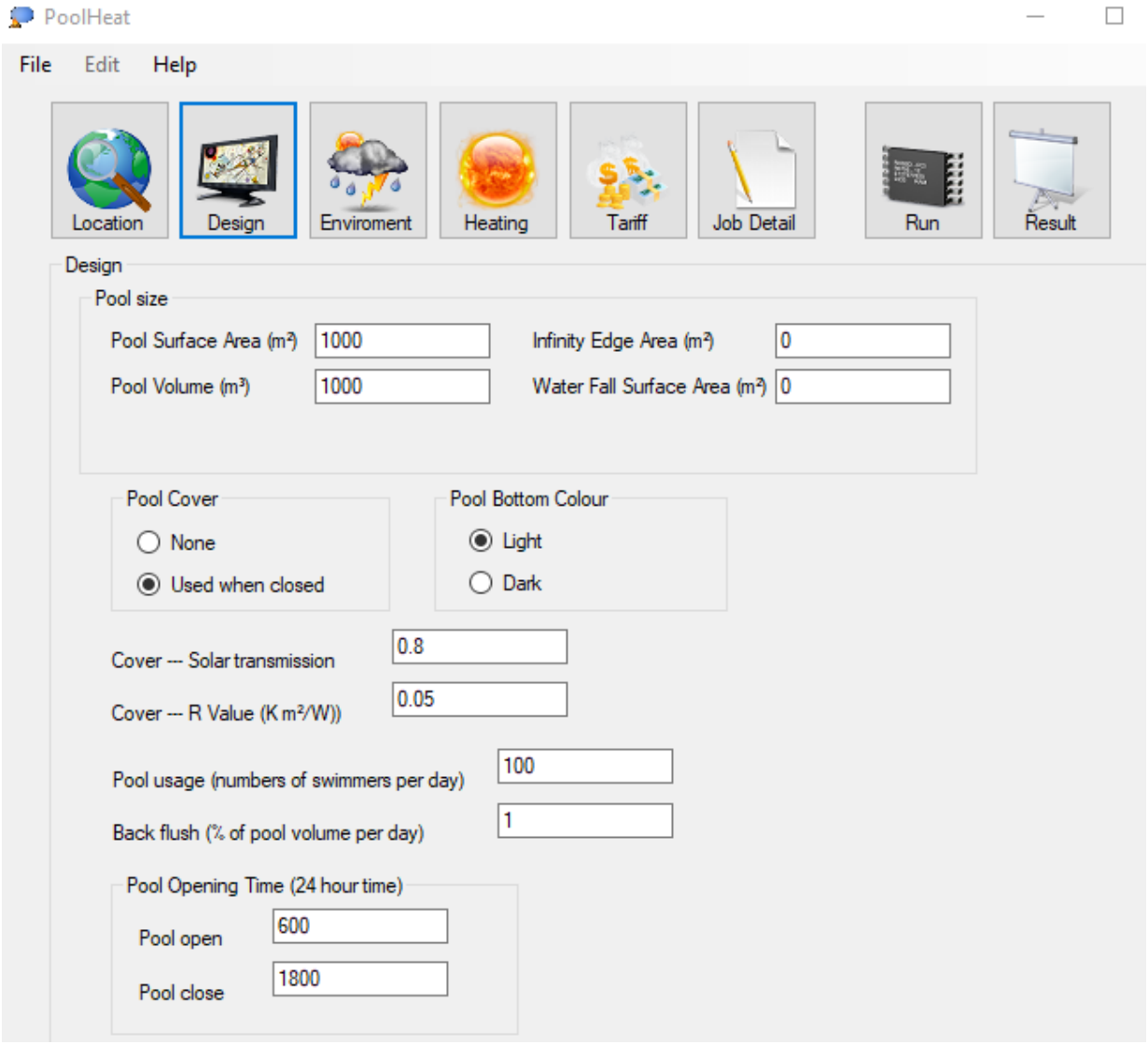
The location screen lists the climate data files in the working directory. Select the location from the list by pointing with the mouse or use the up/down arrow keys.



The particular locations listed will depend on the climate data files that have been included with your version of PoolHeat. Additional climate data files can be obtained from Thermal Design.

DESIGN

The design screen is used for describing the pool size and operating features.



Infinity edge area

The infinity edge area is the surface area of water over a shallow edge of the pool.

Water fall surface area

The water fall surface area refers to a water fall or pool feature over which water is flowing. The area is the water surface area exposed to the atmosphere, for a free-falling water fall the surface area is the sum of the front and back areas. For water flowing down a slide etc the surface area would be the top area only.

Cover

If a cover is specified it is assumed to be fitted when the pool is closed. The solar transmission specifies the fraction of solar radiation that is retained by the cover and the pool when the cover is in place. This includes solar radiation transmitted through the cover and absorbed by the cover. The cover R value is the thermal resistance of the cover for heat conducted through the cover see AS 5348.

Pool Usage

The number of swimmers in the pool each day is used to compute the additional water evaporation as a function of pool use.

NOTE: The level of usage of a pool can have a significant effect on the evaporation heat loss. If the size of a pool is changed the **Pool Usage** input should also be changed.

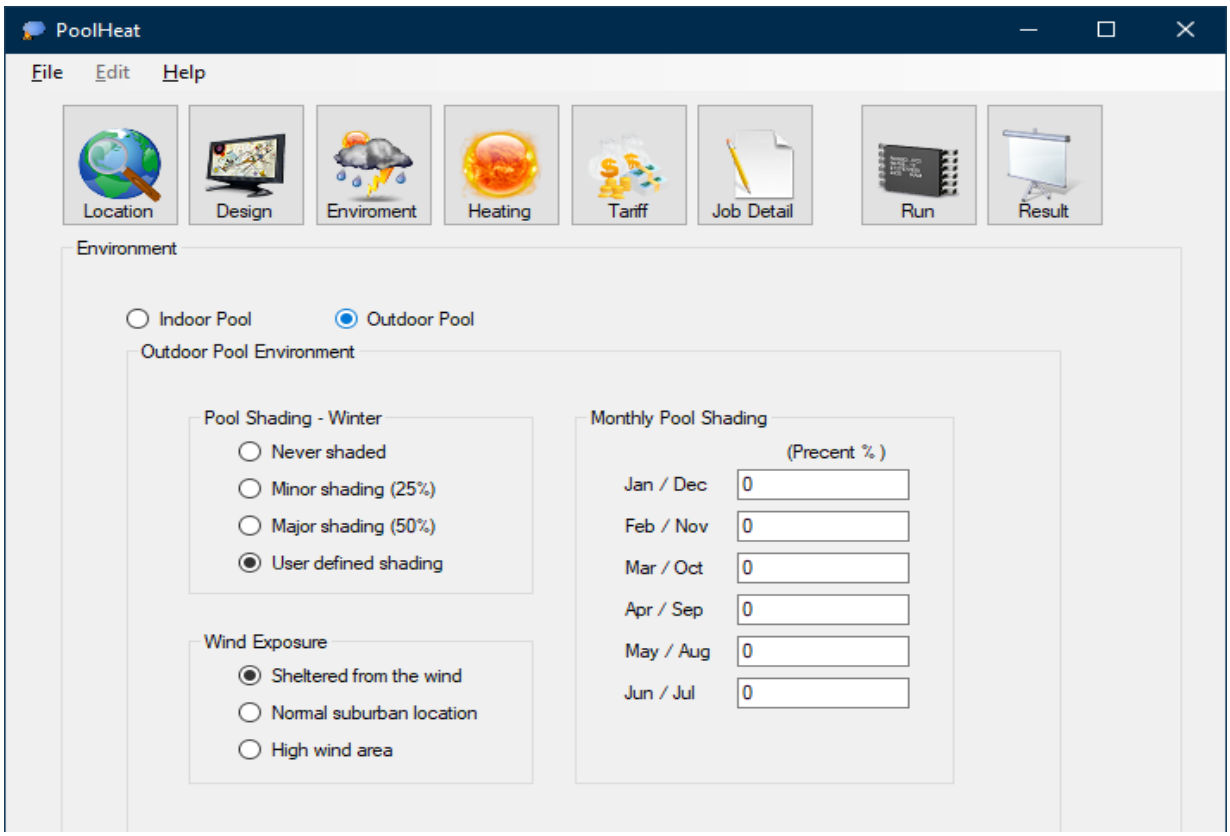
Flushing and evaporation make-up

The pool energy balance includes the effect of the addition of mains water to compensate for evaporation and filter flushing. The temperature of mains water is included in the climate data file where it is known (reference 1). If the mains water temperature is not known for the location selected it is taken as the average air temperature in the previous month.

ENVIRONMENT

The environment screen is used for setting the conditions in which the pool is operating.

Outdoor environment



Shading

Specify typical shading of the pool water surface due to surrounding buildings or trees in winter, or select

User defined shading to specify month by month shading levels

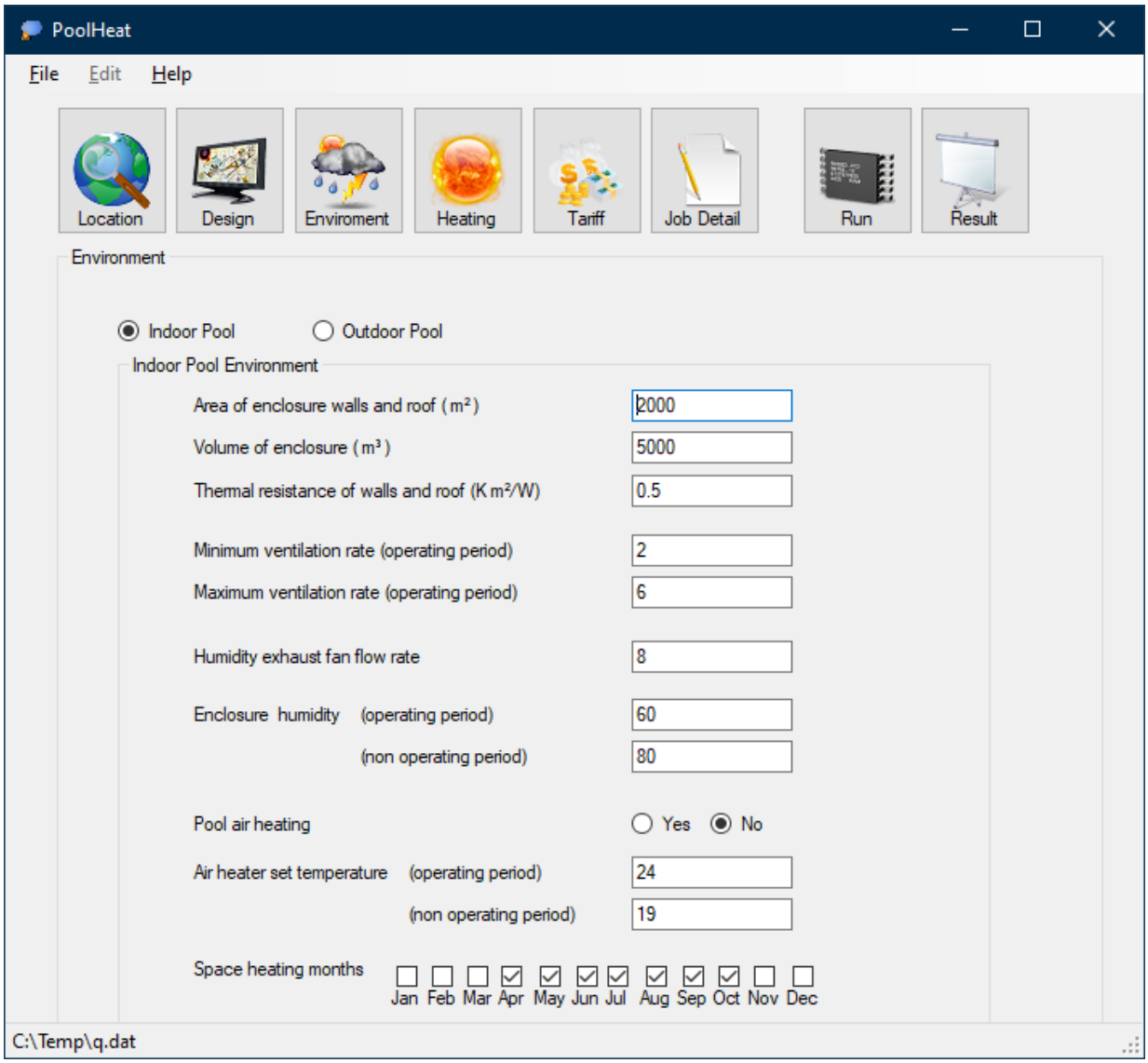
In the monthly shade specification box enter 100 for full shade and 0 for no shade on the pool during the middle 6 hours of the day in winter and middle 8 hours of the day in summer.

Wind exposure

Specify the typical ground level wind condition for an outdoor pool as either

- Sheltered location, ie wind breaks fitted around the pool.
- Open position.
- Exposed windy location.

Indoor environment



Ventilation

Specify the minimum day time ventilation rate of the pool space, in air changes per hour. A minimum of 2 air changes per hour would be required for comfort. Also specify the maximum day time ventilation rate of the pool space in air changes per hour. The ventilation rate is varied during the operating period in order to maintain the specified day time humidity level.

If the indoor humidity level is less than the set point humidity the minimum ventilation rate is used. If the indoor humidity is higher than the set point the ventilation flow rate is increased (up to the specified maximum) until the set point humidity is achieved. If the outside humidity is higher than the indoor humidity set point the maximum air flow rate is used.

Outside of the operating hours the ventilation fans are turned off.

Exhaust fan

Specify the ventilation capacity of the exhaust fan in air changes per hour. The exhaust fan is assumed to operate when the indoor humidity exceeds the humidity set point.

At night the humidity exhaust fans are turned off if the indoor humidity is less that the night time humidity set point. If evaporation from the pool causes the indoor humidity to rise above the night time set point, the humidity exhaust fans are turned on (ventilation fans remain off).

Humidity

Specify the desired humidity of the pool enclosure during pool opening hours. If the outside humidity and restrictions on ventilation rates do not allow this value to be maintained then the program computes the actual inside humidity condition.

Specify the desired humidity of the pool enclosure outside of pool opening hours. This value should be high to minimise night time heat loss from the pool however, condensation on the walls must be considered when a high value is specified.

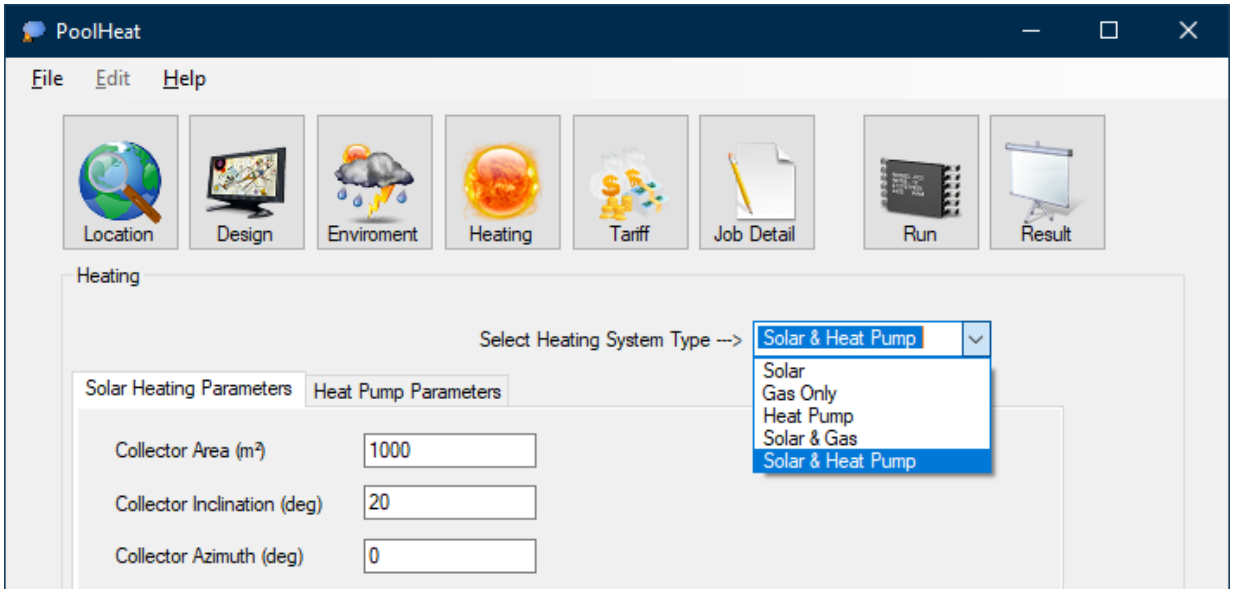
Air Heating

Specify if the fresh air to the pool enclosure is heated. If heating is used specify the set temperature of the air heating system. If night time air heating is not required specify a low night time set temperature.

Air heating is supplied by the same heat source as for pool water heating.

HEATING SYSTEM

The heating system screen contains a series of menus for specifying the heating system parameters. The **Select Heating System Type** tab opens a list of heating systems can be selected. The primary heating screen changes in response to the type of heating system selected.



If multiple heating systems are specified (eg solar and gas) there are two heating system screens, the toggle between the two screens will appear at the top of each of the screens.

The solar collector efficiency can be specified in terms of measured performance (reference 7) or a specific solar collector type and roof system may be selected from a built-in list of 32 types of solar heating systems.

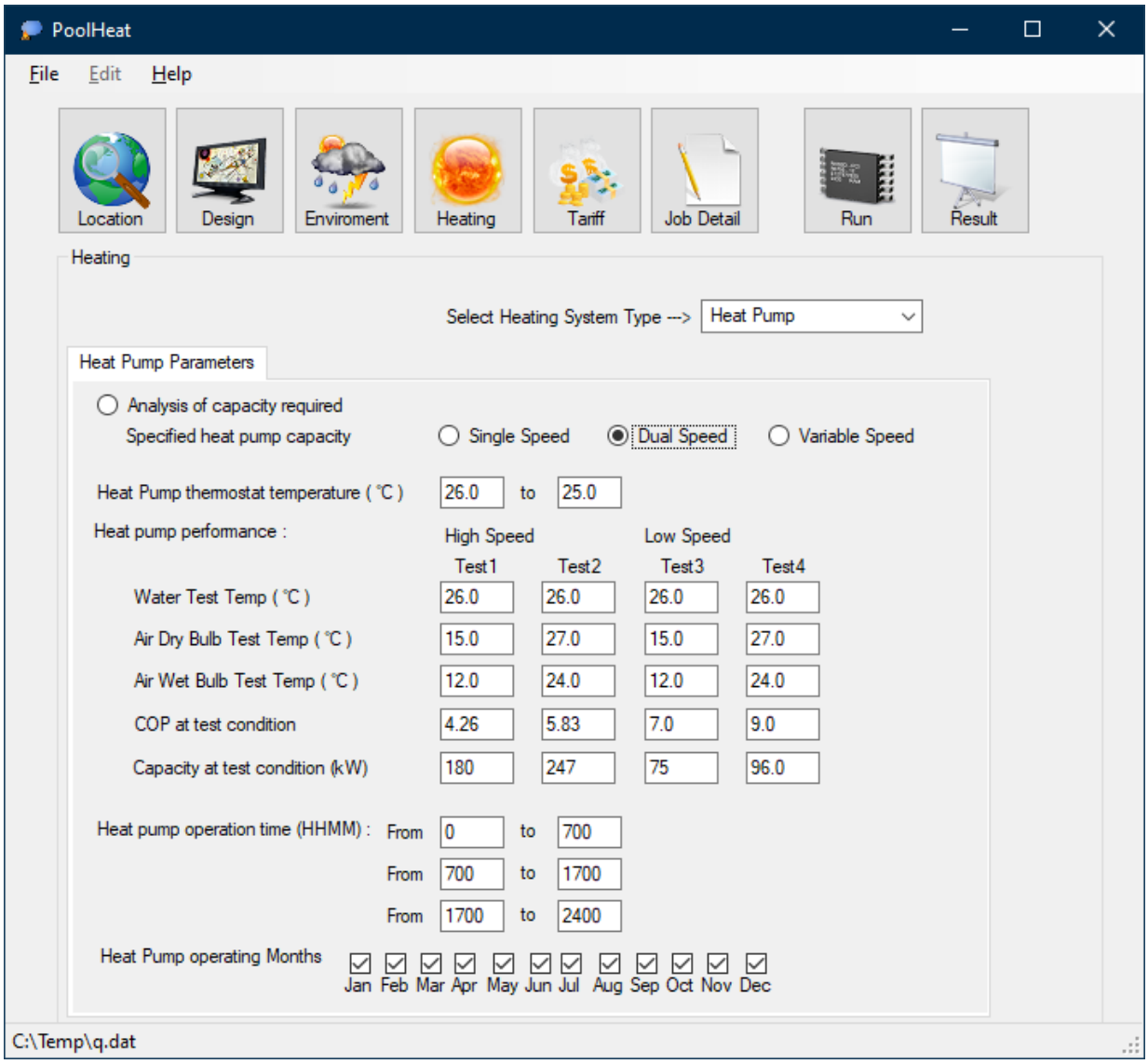
Heating system capacity analysis

The capacity of heat pump or gas heater may be specified or the program used to compute the average capacity required to meet the set point temperature specification. If the "Analysis of heating capacity requirements" option is selected the program will calculate the average heat pump or gas heater capacity required each month, on the basis of 24 hr operating time (or maximum possible operating time if the heater daily start and stop times are specified).

If the minimum pool temperature is critical then the effect of specifying the listed capacity can be checked by entering a specified capacity and running the analysis again to determine the minimum temperature during each month for the selected heater capacity.

Heat pump specification

The **heat pump** specification screen is



Heat pump performance data measured using AS 5352, NF 414 or ANSI/AHRI 1161(SI) can be used as inputs. For single speed heat pumps performance data is required for two operating conditions. For dual speed or variable speed heat pumps performance data is required for maximum capacity and for part load capacity (50% or less of maximum capacity or 75% or less of maximum speed). The standard rating conditions required by AS 5352, NF 414 and ANSI/AHRI 1161 are shown in Table 1.

Table 1

Standard heat pump rating conditions

	Ambient air temperature		Intake water temperature
	Dry-bulb	Wet-bulb	°C
	°C	°C	
High air temperature - high humidity	27	24	26
Standard air temperature - mid humidity	15	12	26
Low air temperature - high humidity	7	6	26

Table 2

Test data

Parameter	Maximum capacity	Part load capacity	Units
Heating capacity			kW
Power input			kW
COP			

Variation of heat pump performance with operating conditions

The variation of heat pump **COP** and electric power input (**Power**) is determined from the performance for the two ambient test conditions using a linear model, see appendix for details of heat pump performance variation with operating temperatures and heat pump speed.

Analysis of heat capacity requirements

If "Analysis of heating capacity requirements" option is selected (see above) then the heat pump output is equal to the pool heat loss rate at the upper set point temperature condition. An indication of the average capacity required each month is computed from the total heat load for the month divided by the number of operating hours for the heat pump.

Dual speed heat pump

The control scheme for a dual speed heat pump is

a) The heat pump initially starts on low-speed mode. If the pool temperature drops below the lower set point temperature, then the heat pump is set to high speed until the pool temperature is raised to the upper set point temperature.
b) If the pool temperature falls below the upper set point, then the heat pump is set on low speed. The low-speed mode is maintained provided the pool temperature remains above the lower set point temperature. The heat pump will turn OFF if the upper set point temperature is reached.
c) If the pool temperature falls below the lower set point temperature while the heat pump is operating in low speed mode then the heat pump is set on high-speed mode until the pool temperature reached the upper set point temperature.

Variable speed heat pump

The control scheme for a variable speed heat pump is

a) The heat pump initially starts on low-speed mode.
b) If the pool temperature falls below the upper set point then the heat pump speed is varied from low speed if the pool temperature is equal to the upper set point temperature to high speed if the pool temperature is equal to the lower set point temperature. The heat pump COP, capacity and electric power input are varied as a function of speed, see appendix.

Only one set of test data

If a heat pump has only been tested at one set of temperature conditions, then the COP for the second column of test results should be set to less than 1. The following default temperature dependence conditions for COP and Power are then applied

COP temperature sensitivity = -0.03 * COP_{test} (-/K)

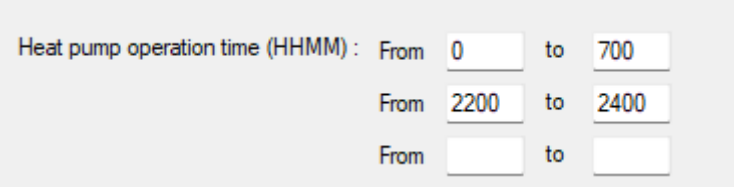
Power temperature sensitivity = 0.003 * $Power_{test}$ (kW/K)

Heat pump operation times

The heat pump operation time during each day can be specified in the Heating menu for up to three time periods.

Specification of a heat pump that is available all day is shown below

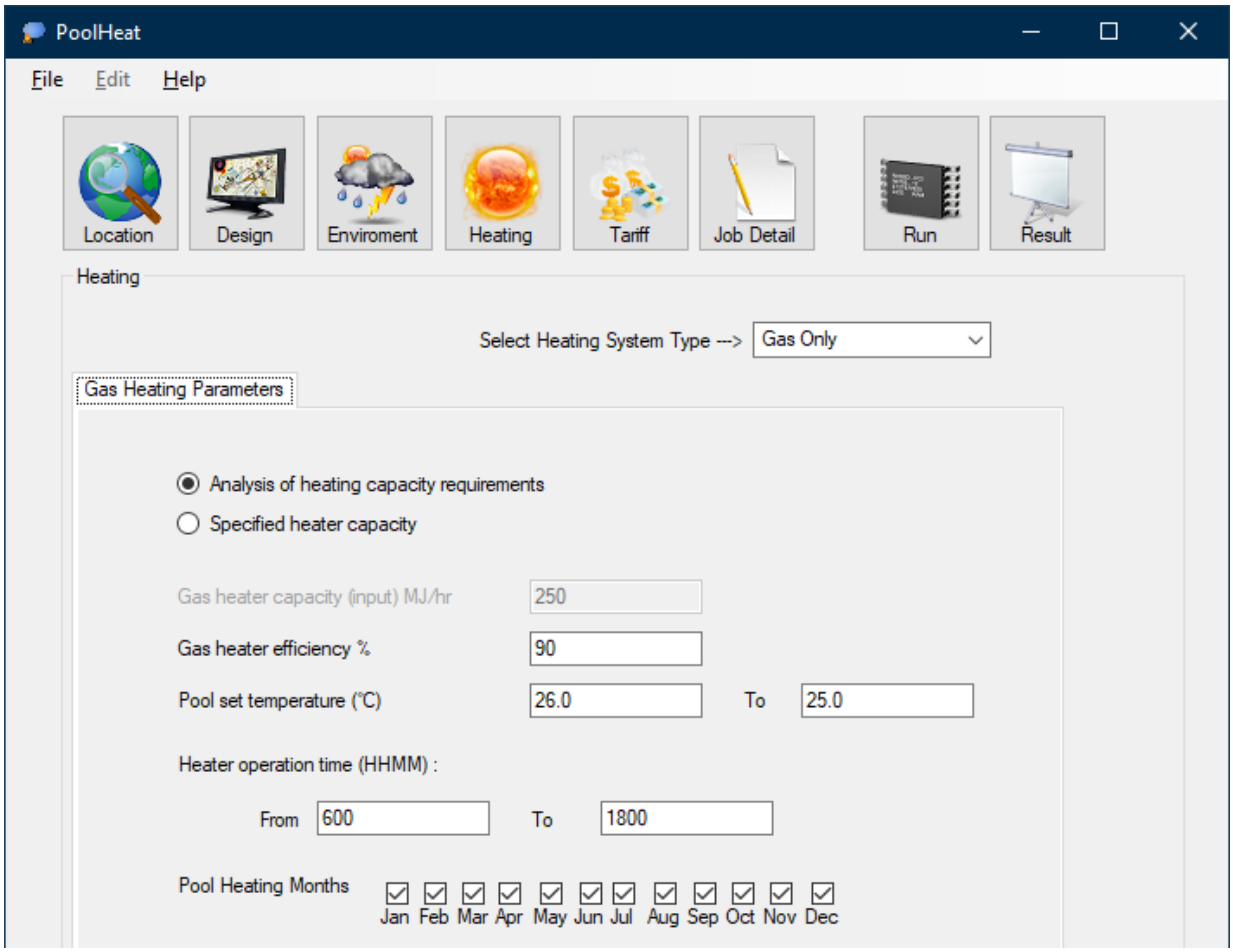
A standard off-peak operation specification is shown below.



Operating periods that are not used may be left blank.

Gas heater specification

The **gas heater** specification screen is



If "Analysis of heating capacity requirements" option is selected (see above) then the heater output is equal to the pool heat loss rate at the upper set point temperature condition. An indication of the average capacity required each month is computed from the total heat load for the month divided by the number of operating hours for the heater.

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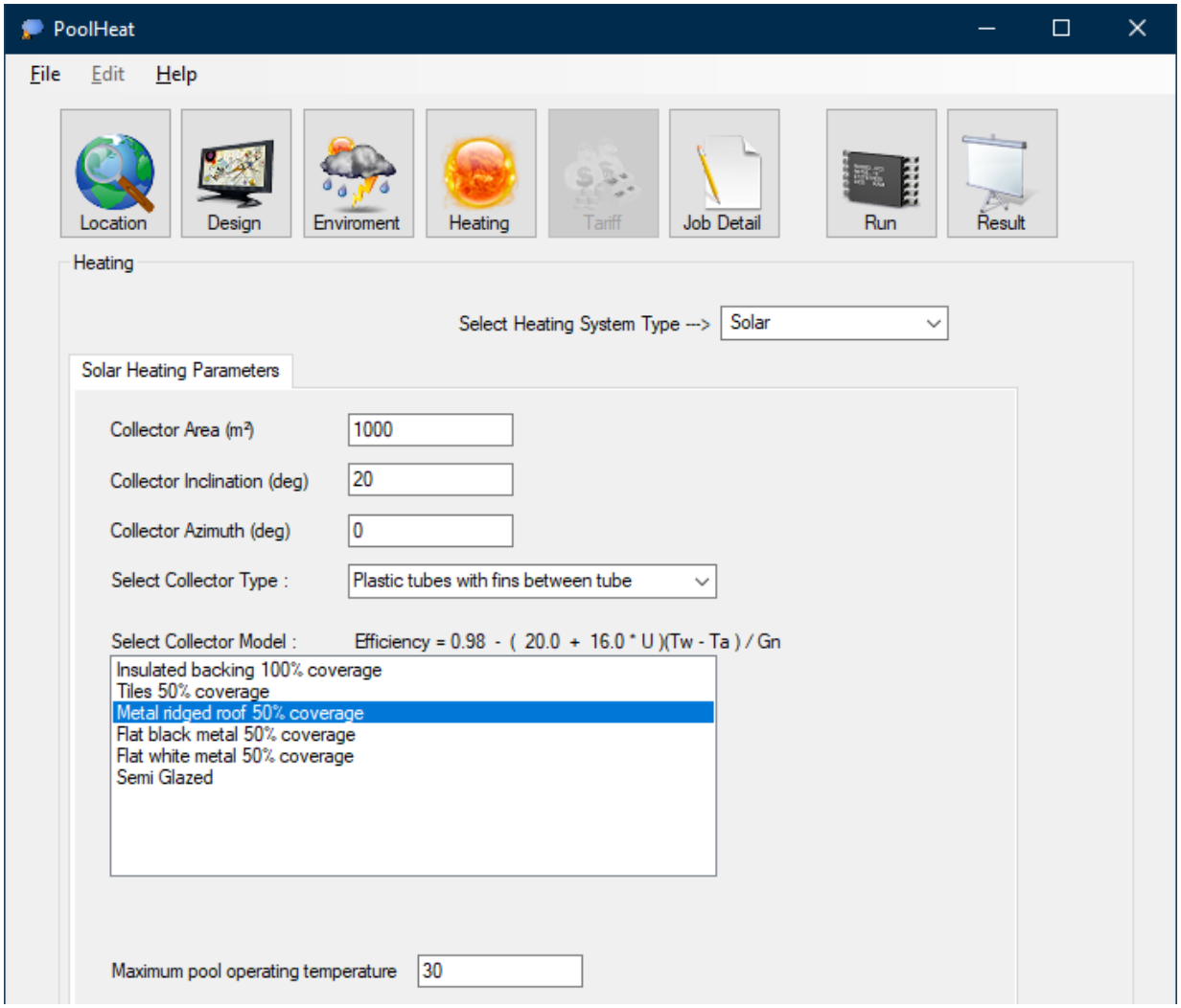
Solar heater specification

The **solar heater** screen is



Solar collector area

For the collector efficiencies in PoolHeat the Collector Area is the aperture area of the collector. For a collector consisting of parallel strips of absorber tubing, mounted on the roof with spacing between the parallel strips, the aperture area is the area of the strips only. For the default evacuated tube solar collector, the aperture area is the cross-sectional area of the tubes (the outer glass envelope).

If user tested collector efficiency coefficients are entered into PoolHeat then the collector area is the area used by the test laboratory to calculate collector efficiency; the solar collector efficiency coefficients depend on whether gross area, aperture area of absorber area was used by the test laboratory in determining the efficiency coefficients.

Azimuth angle (180° to -180°) is the horizontal angle from the north/south line to the direction the solar collector is facing. The azimuth is zero for a collector facing the equator and is positive for a collector facing towards east.

The % coverage specification for some of the Collector Models refers to the % of the section of roof covered by the absorber. An unglazed collector absorber receives direct solar input and heat input from adjacent sections of the base roofing material.

Solar collector efficiency

A solar collector may be selected from the 32 collector-roof configurations built in to the program or test results for particular collector-roof systems may be specified. The built-in configurations are selected from two lists, the first list, **solar collector type,** allows selection from a range of collector types, the second list allows selection from a range of collector-roof configurations and more detailed collector construction details.

As the solar collector-roof configuration selection is changed the coefficients in the collector efficiency equation are shown on the screen. To specify the characteristics of a new solar collector, test data for the thermal performance must be available in the form

$$\text{Efficiency} = a - (b + c \times U)(T_w - T_a)/G_n$$

where a,b and c are coefficients evaluated from the test data.

U is wind speed (m/s)

G_n is the incident solar radiation (short wave and long wave) (W/m^2)

T_w & T_a are the pool water temperature and ambient temperature (°C)

Incidence angle modifier

Flat plate solar collectors

The incidence angle modifier $K_{\tau\alpha}$ is used to compute reflection from the solar collector surface

$$K_{\tau\alpha} = 1 - d\,(1/\cos(\theta) - 1)$$

where d = incidence angle coefficient (to be specified)

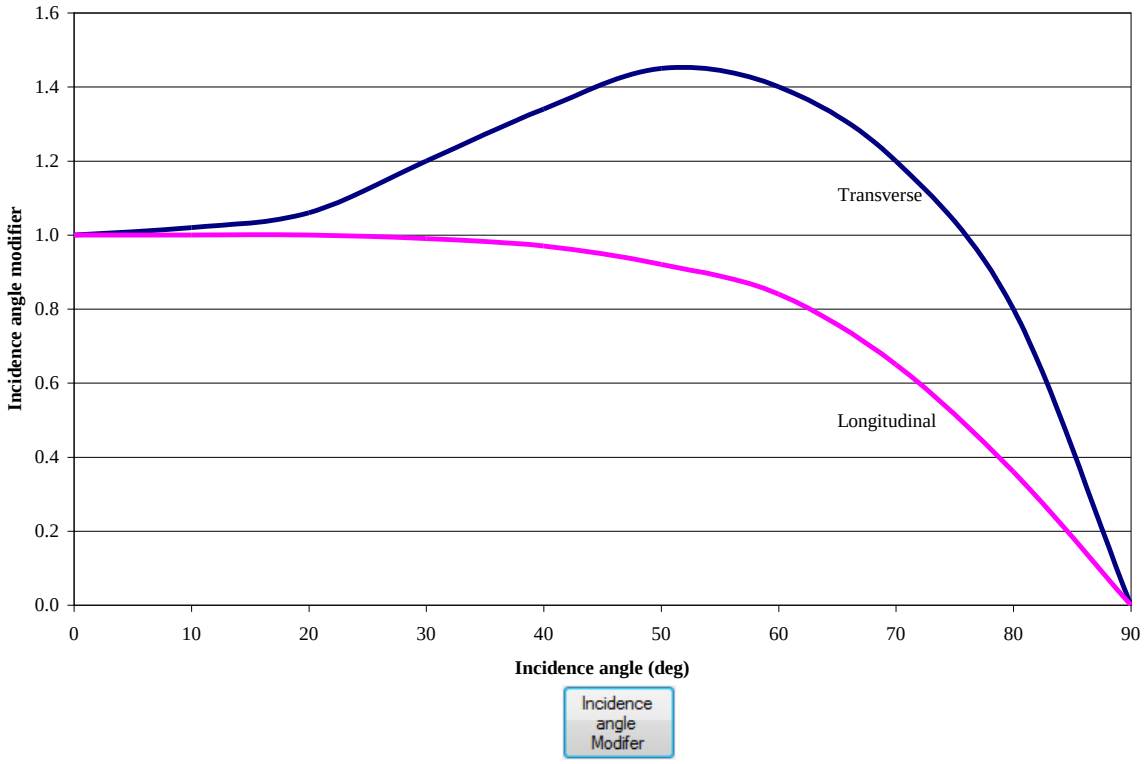
θ = incident angle (computed in the program)

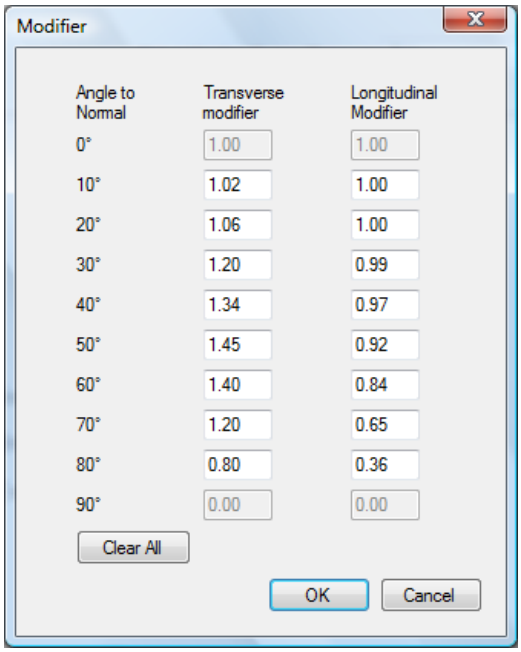
The measurement procedure to determine the performance of an unglazed solar collector is given in reference 6.

Evacuated tube solar collectors

The incidence angle modifier for evacuated tube solar collector is taken as the product of the transverse and longitudinal modifiers. Typical modifiers are shown below.

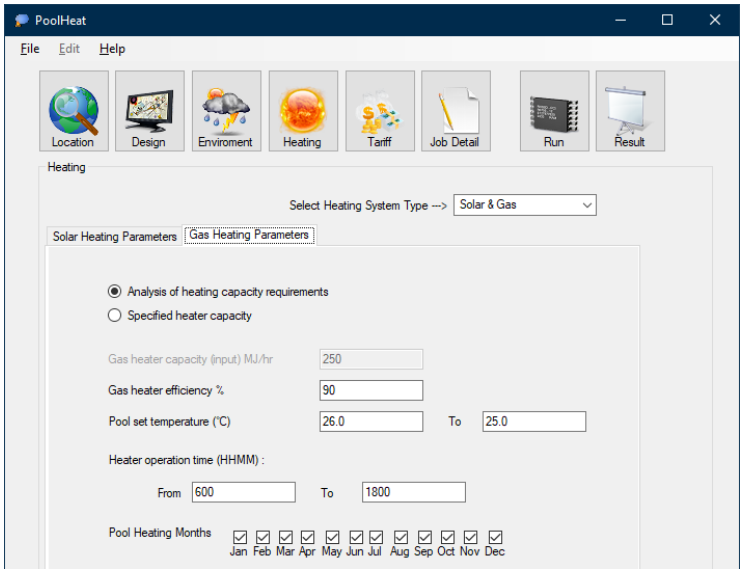
For a user specified evacuated tube solar collector the transverse and longitudinal incidence angle modifier test data is entered into PoolHeat via the following table selected by clicking on the Incidence Angle Modifier tab .

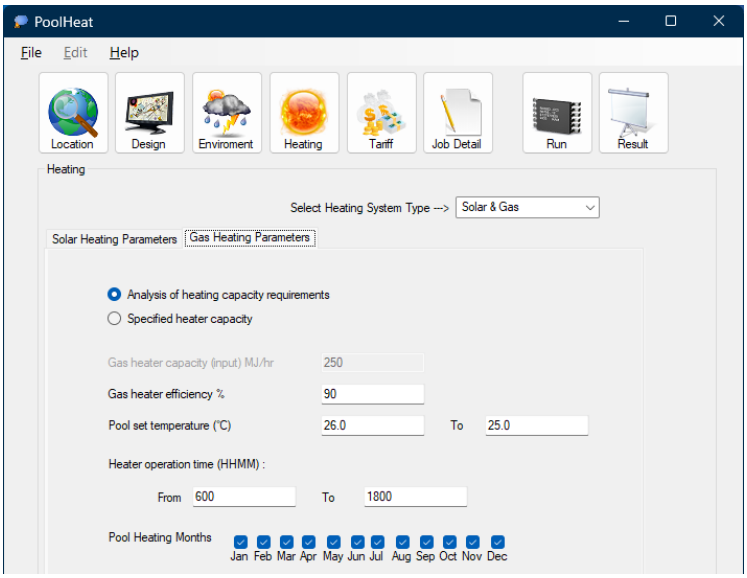




Combined solar and gas heating system specification

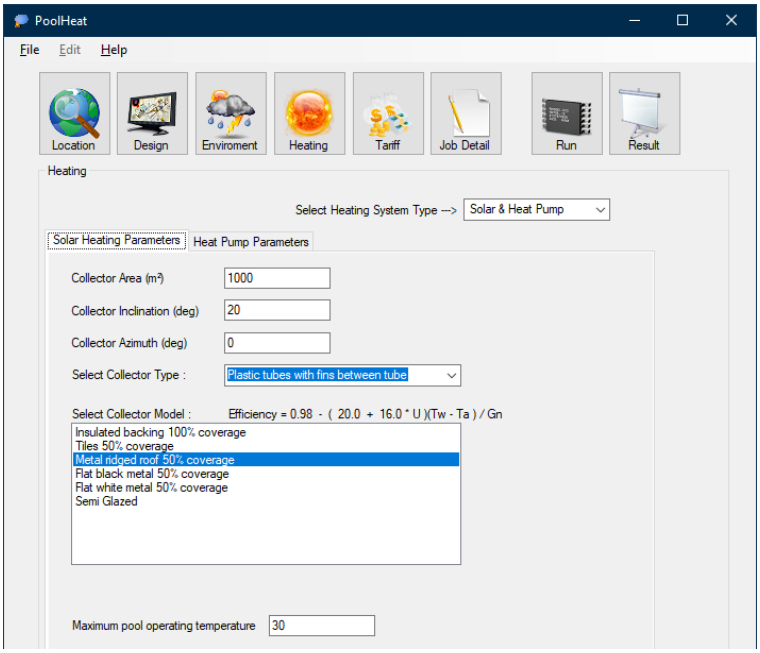
This screen has a toggle control at the top for switching between solar heating and gas heating screens for a dual heating system.

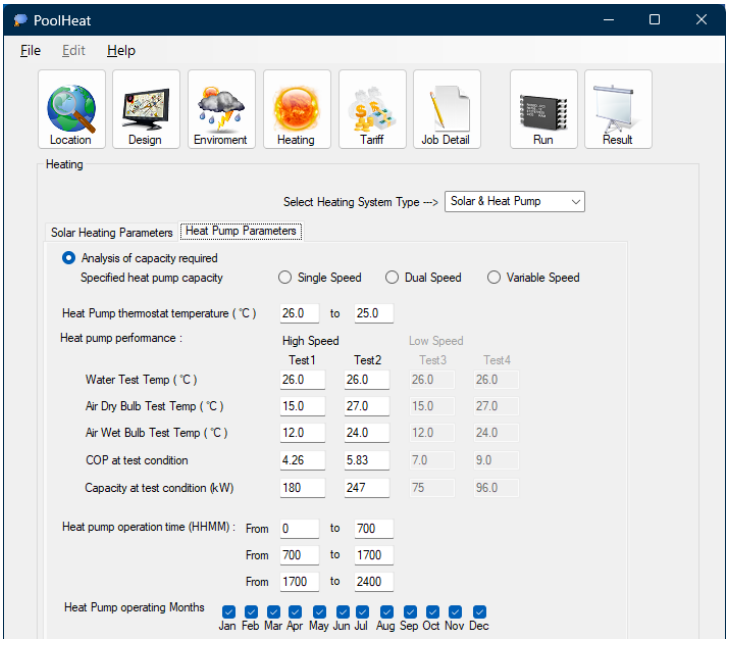




Combined solar and heat pump heating system specification

This screen has a toggle control at the top for switching between solar heating and heat pump heating screens for a dual heating system.





Pool heating season

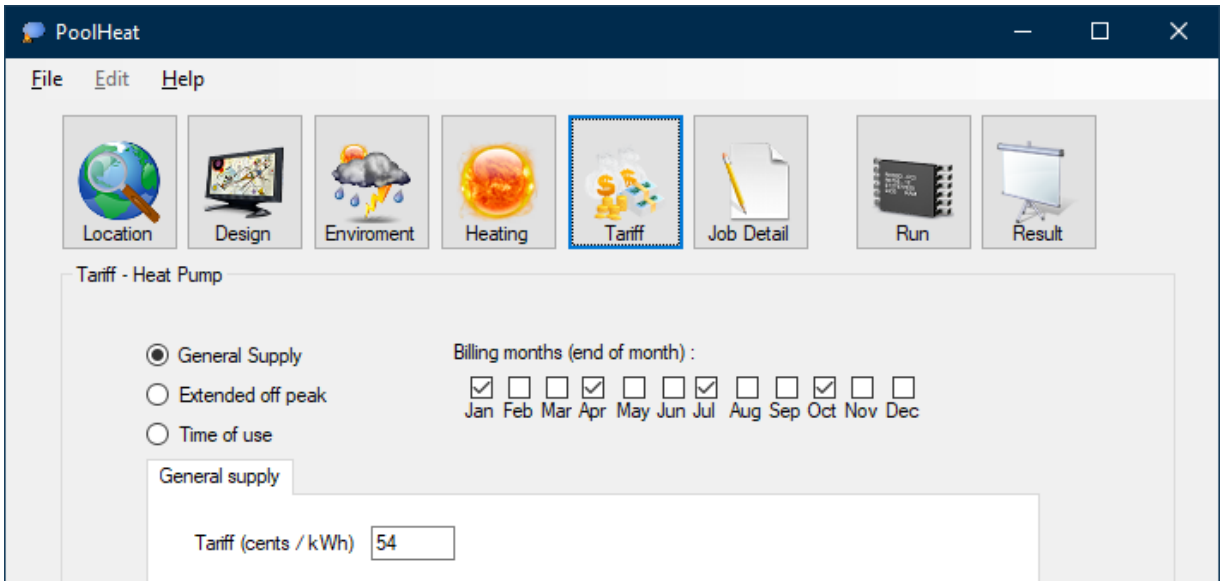
The operating months of the gas or heat pump heating systems can be specified in the "Pool heating months" list at the bottom of the gas and heat pump heating system screens.

For a combined heating systems both heaters (solar and gas or solar and heat pump) are turned off in the non-heating months.

Gas and electricity tariffs

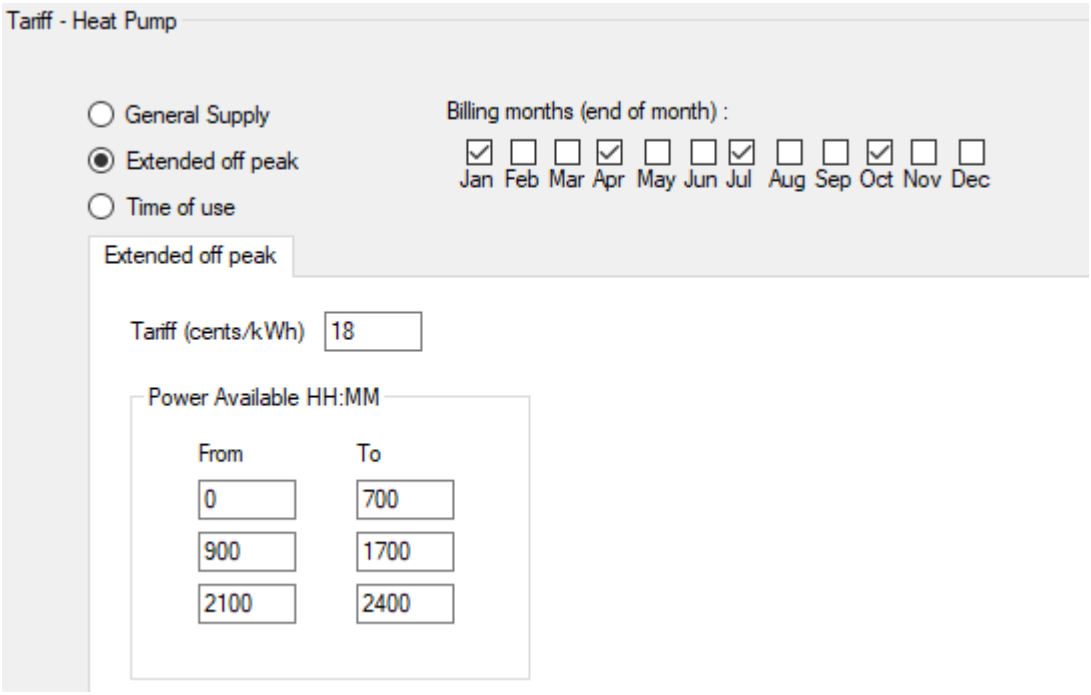
The gas and electricity tariff screens contain a series of forms for specifying gas and electricity tariff times and costs. There are three electric tariff screens corresponding to different tariff supply options, see below. For some tariffs there are secondary menus for detailed tariff availability schedules.

The **general supply electricity tariff** screen is

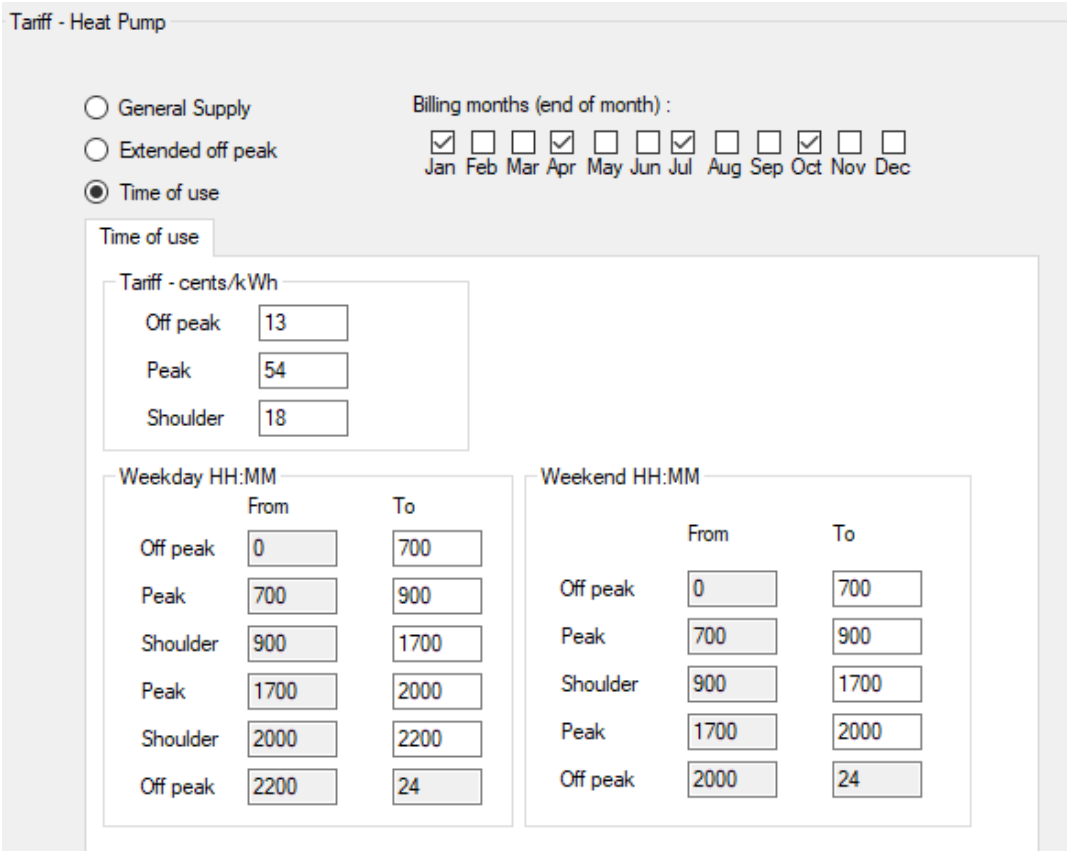


NOTE: The operating cost can be reported in the Result Summary output for selected "Billing months" (multiple months operating cost accumulated over billing periods). To display the monthly operating cost select all months for the "Billing months".

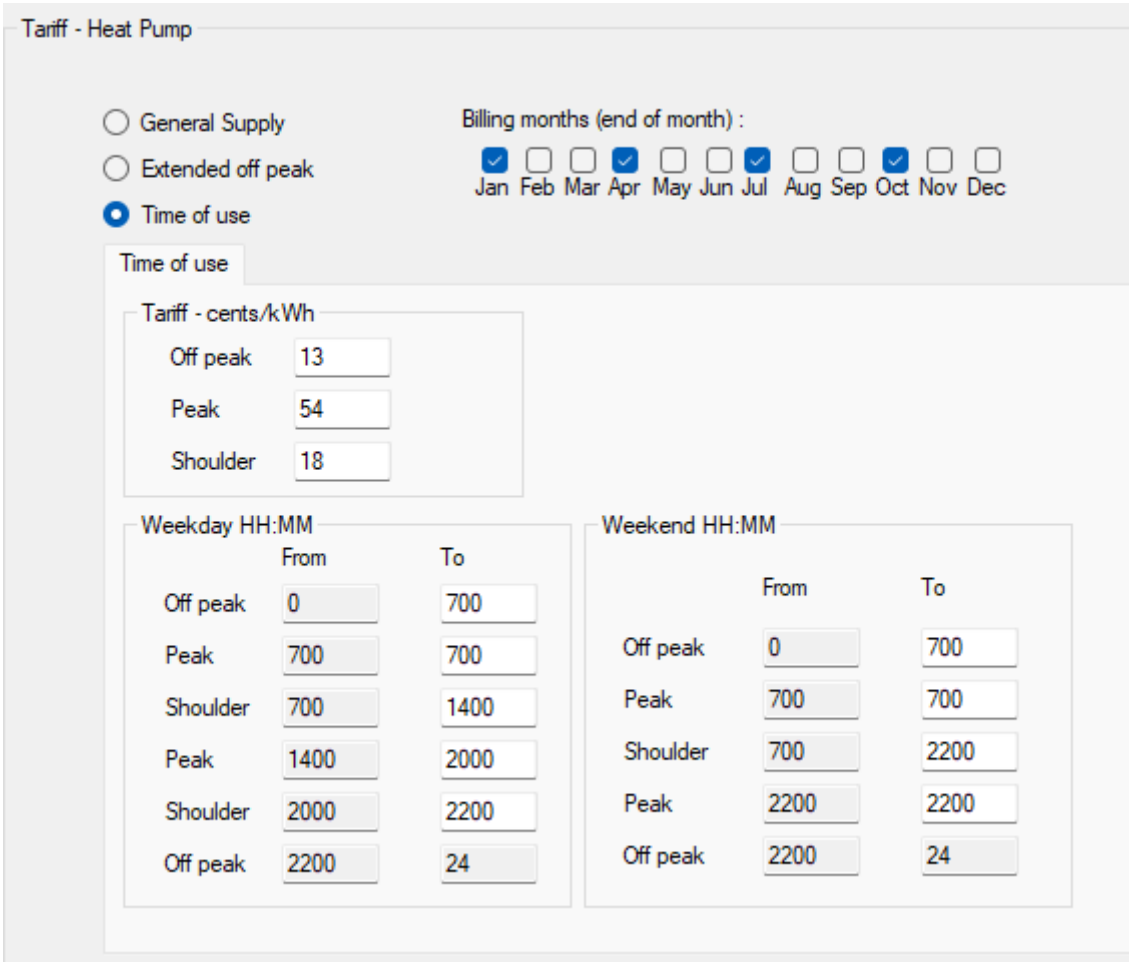
The **extended off peak electricity tariff** screen is



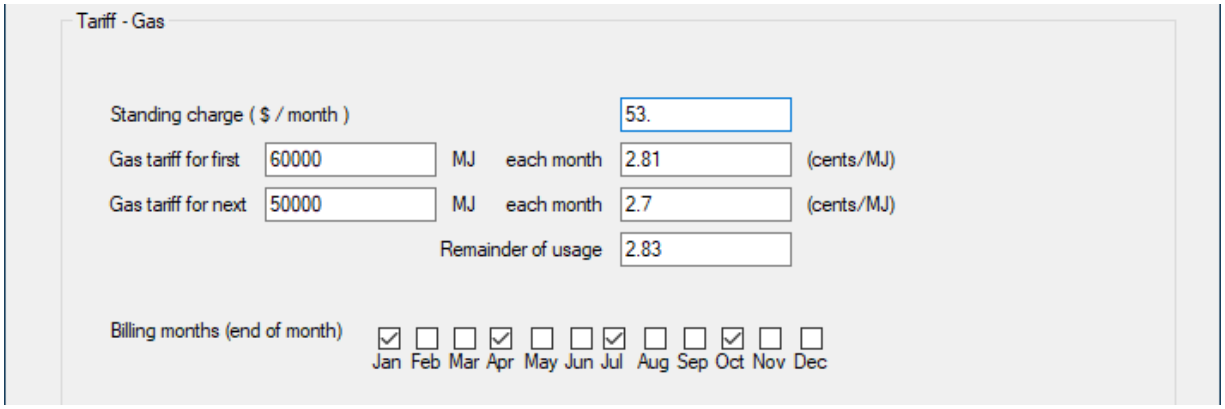
The **time-of-use electricity tariff** screen is



To disable a supply period the start and stop time for the period should be set to the same time. The following tariff definition specifies a single peak period during the week and no peak period on the weekend.

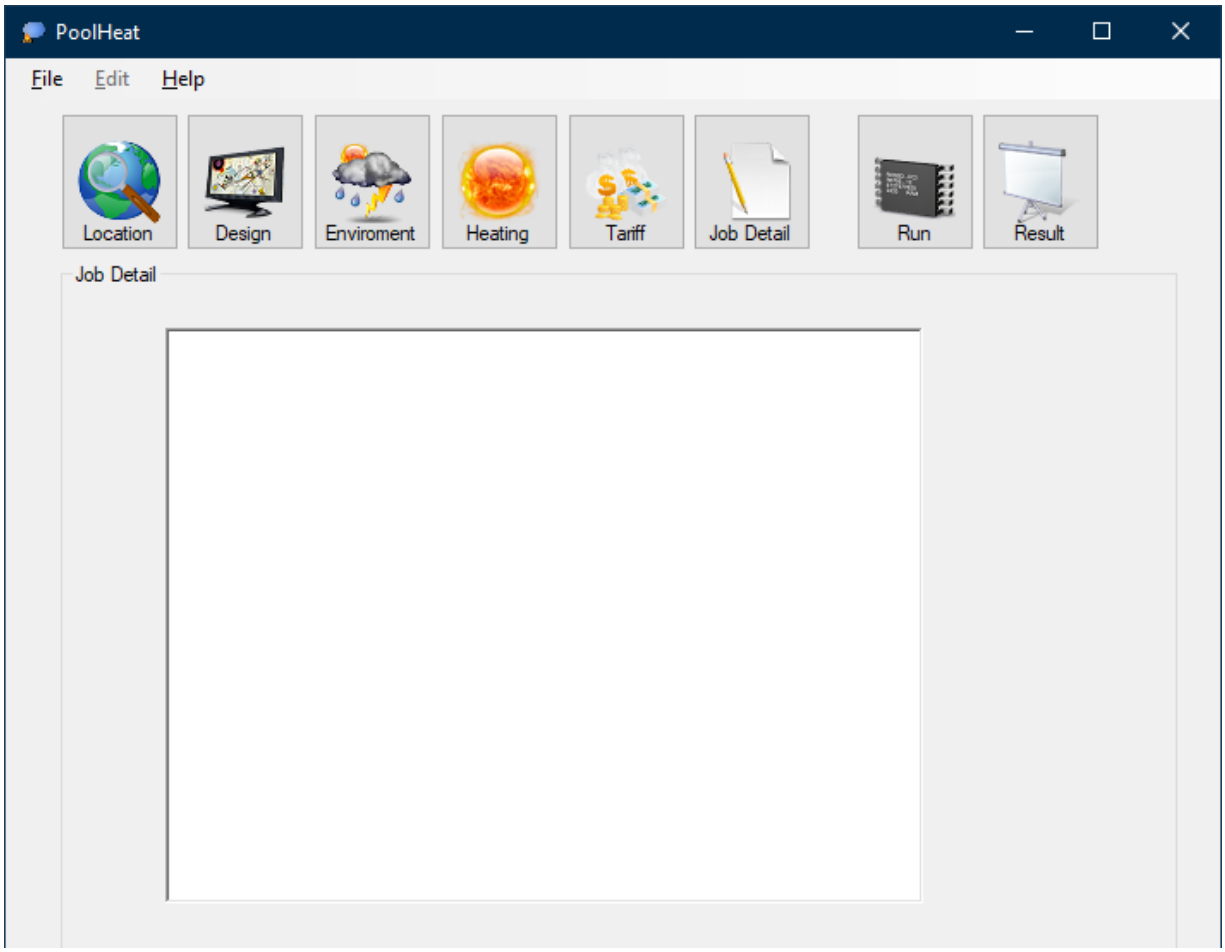


The **gas heating** tariff screen is



JOB DETAILS

The job screen provides a note pad for entering details of the current job. This input is copied to the top of the result file.



RESULTS

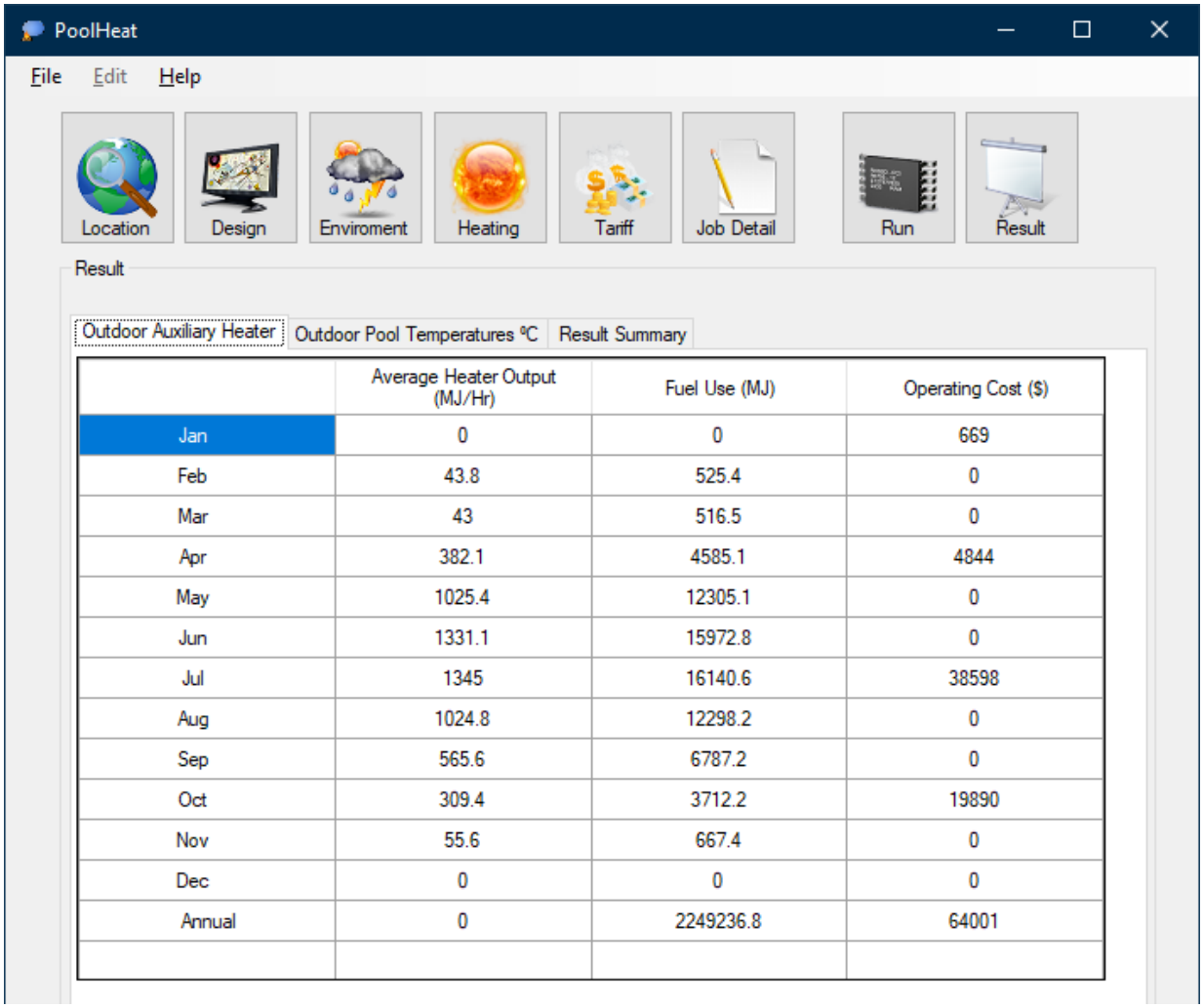
The results can be viewed and printed by selecting the **Result** menu after the analysis is complete Tabs are available for

a) heater capacity, energy use and cost

b) pool temperatures (minimum and maximum temperatures are specified as values that are exceeded for 5% of the operation time)

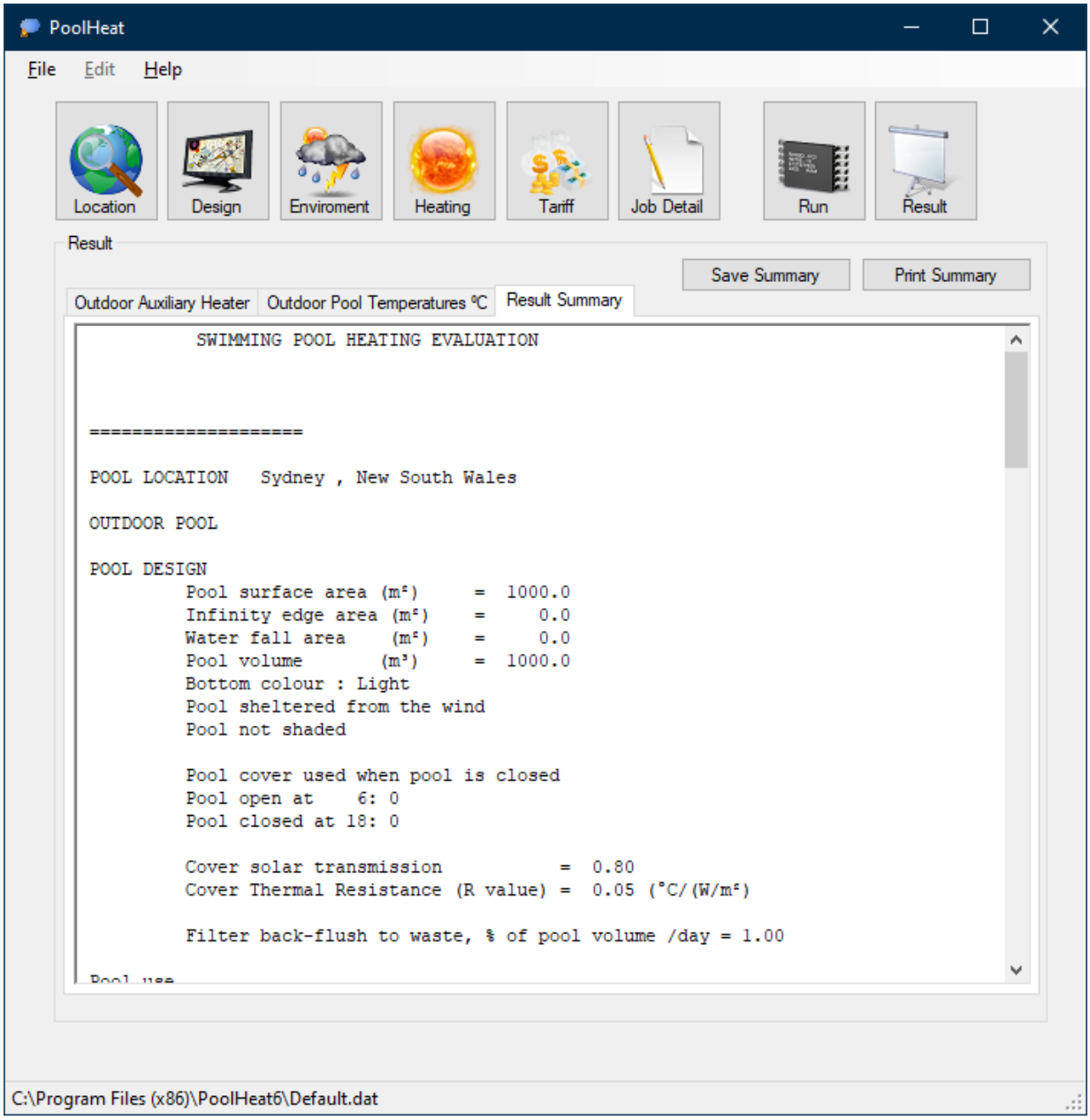
c) full result list.

Save and **Print** functions can be selected for the Result Summary file. The result file (result.txt) can also be saved using the **File / Save As** option. If a directory has not been specified then the result file is saved in the program installation directory.



	Average Heater Output (MJ/Hr)	Fuel Use (MJ)	Operating Cost ($)
Jan	0	0	669
Feb	43.8	525.4	0
Mar	43	516.5	0
Apr	382.1	4585.1	4844
May	1025.4	12305.1	0
Jun	1331.1	15972.8	0
Jul	1345	16140.6	38598
Aug	1024.8	12298.2	0
Sep	565.6	6787.2	0
Oct	309.4	3712.2	19890
Nov	55.6	667.4	0
Dec	0	0	0
Annual	0	2249236.8	64001

The result file can also be read into an editor or word processor.



Unheated pool temperature

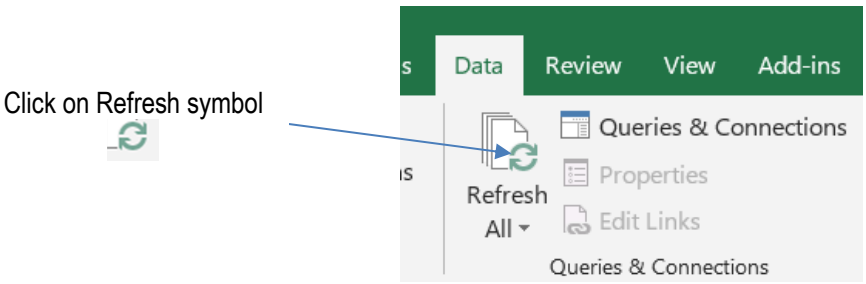
The result file lists the monthly temperatures of unheated and heated pools. The temperature analysis for an unheated pool is for an identical pool to the heated system except the added heating system and pool cover (if used) are removed.

ANALYSIS OF RESULTS IN EXCEL

In addition to the PoolHeat result file (file type .txt) there is an output file (file type .CSV) for transferring PoolHeat results into EXCEL for graphical display of the output. Two EXCEL templates for analysing and graphing the output produced by PoolHeat are supplied with PoolHeat (**poolheat-indoor-pool6.xls** and **poolheat-outdoor-pool6.xls**). These are separate from PoolHeat and a copy of EXCEL is required to use them.

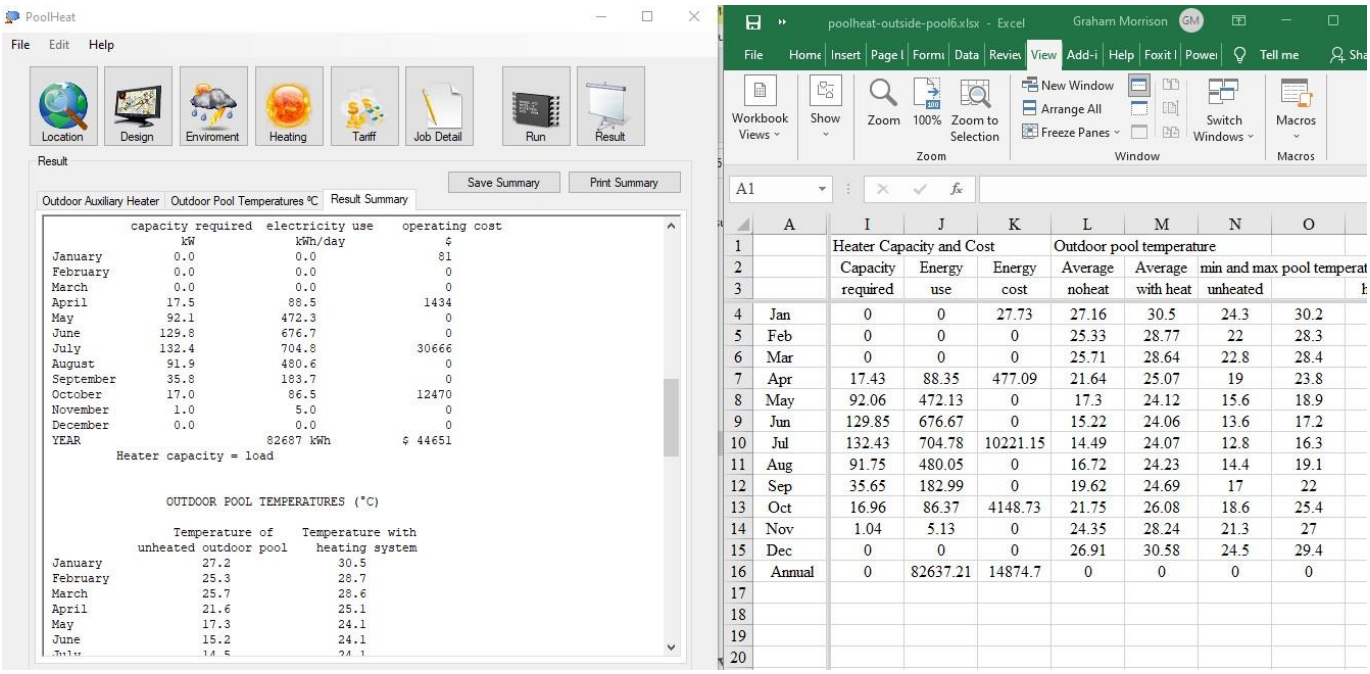
Once PoolHeat has been run the results can be loaded directly into the EXCEL template (note there is a different template for outdoor and indoor pools)

To read results into EXCEL select the "*Data*" menu in EXCEL and click on "*Refresh All*".



If the parameters in PoolHeat are changed and a new case run then click on "*Data /-Refresh*" again to load the new results into EXCEL.

PoolHeat and the EXCEL templates can both be open at the same time. Examples of PoolHeat and EXCEL running together are shown below.



PoolHeat

File Edit Help

Location Design Enviroment Heating Tariff Job Detail Run Result

Result

Save Summary Print Summary

Outdoor Auxiliary Heater | Outdoor Pool Temperatures °C | Result Summary

	capacity required kW	electricity use kWh/day	operating cost $
January	0.0	0.0	81
February	0.0	0.0	0
March	0.0	0.0	0
April	17.5	88.5	1434
May	92.1	472.3	0
June	129.8	676.7	0
July	132.4	704.8	30666
August	91.9	480.6	0
September	35.8	183.7	0
October	17.0	86.5	12470
November	1.0	5.0	0
December	0.0	0.0	0
YEAR		82687 kWh	$ 44651

Heater capacity = load

OUTDOOR POOL TEMPERATURES (°C)

	Temperature of unheated outdoor pool	Temperature with heating system
January	27.2	30.5
February	25.3	28.7
March	25.7	28.6
April	21.6	25.1
May	17.3	24.1
June	15.2	24.1

poolheat-outside-pool6.xlsx - Excel — Graham Morrison

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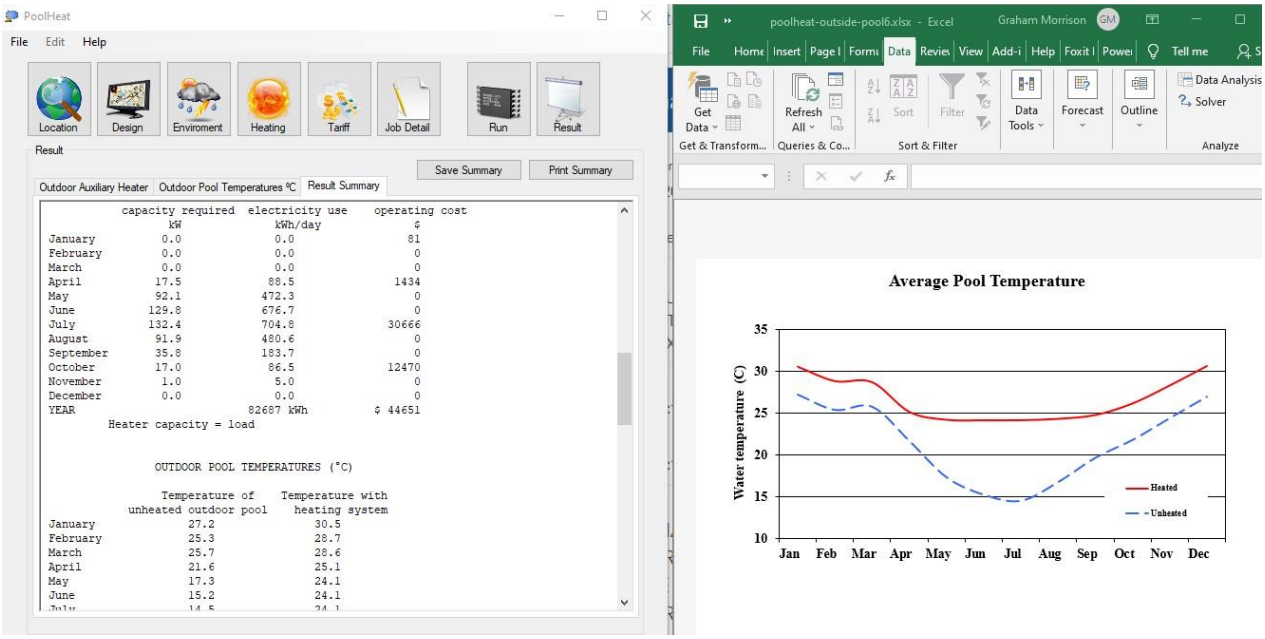
Zoom Window Macros

A1

	A	I	J	K	L	M	N	O
1		Heater Capacity and Cost			Outdoor pool temperature			
2		Capacity	Energy	Energy	Average	Average	min and max pool temperat	
3		required	use	cost	noheat	with heat	unheated	
4	Jan	0	0	27.73	27.16	30.5	24.3	30.2
5	Feb	0	0	0	25.33	28.77	22	28.3
6	Mar	0	0	0	25.71	28.64	22.8	28.4
7	Apr	17.43	88.35	477.09	21.64	25.07	19	23.8
8	May	92.06	472.13	0	17.3	24.12	15.6	18.9
9	Jun	129.85	676.67	0	15.22	24.06	13.6	17.2
10	Jul	132.43	704.78	10221.15	14.49	24.07	12.8	16.3
11	Aug	91.75	480.05	0	16.72	24.23	14.4	19.1
12	Sep	35.65	182.99	0	19.62	24.69	17	22
13	Oct	16.96	86.37	4148.73	21.75	26.08	18.6	25.4
14	Nov	1.04	5.13	0	24.35	28.24	21.3	27
15	Dec	0	0	0	26.91	30.58	24.5	29.4
16	Annual	0	82637.21	14874.7	0	0	0	0
17								
18								
19								
20								



PoolHeat

File Edit Help

Location Design Enviroment Heating Tariff Job Detail Run Result

Result

Save Summary Print Summary

Outdoor Auxiliary Heater | Outdoor Pool Temperatures °C | Result Summary

	capacity required kW	electricity use kWh/day	operating cost $
January	0.0	0.0	81
February	0.0	0.0	0
March	0.0	0.0	0
April	17.5	88.5	1434
May	92.1	472.3	0
June	129.8	676.7	0
July	132.4	704.8	30666
August	91.9	480.6	0
September	35.8	183.7	0
October	17.0	86.5	12470
November	1.0	5.0	0
December	0.0	0.0	0
YEAR		82687 kWh	$ 44651

Heater capacity = load

OUTDOOR POOL TEMPERATURES (°C)

	Temperature of unheated outdoor pool	Temperature with heating system
January	27.2	30.5
February	25.3	28.7
March	25.7	28.6
April	21.6	25.1
May	17.3	24.1
June	15.2	24.1

poolheat-outside-pool6.xlsx - Excel — Graham Morrison

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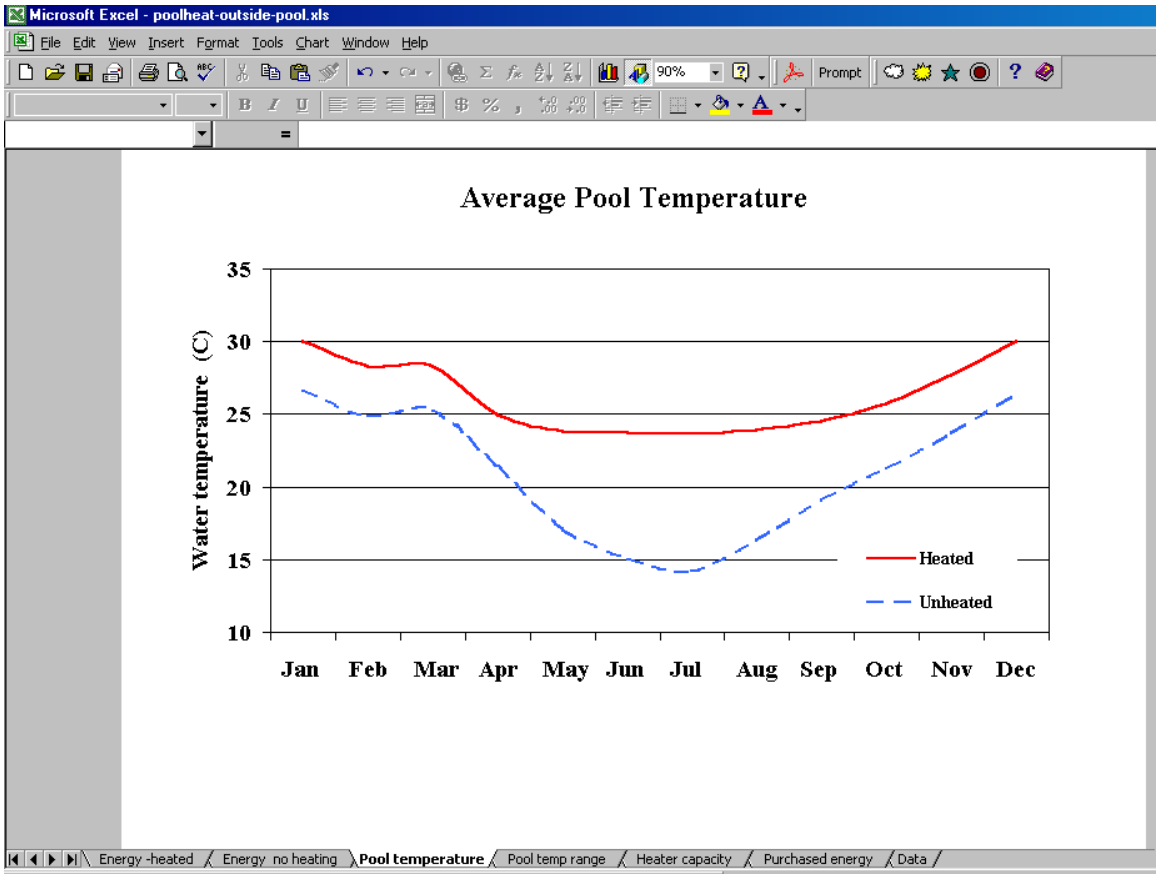
Get Data Refresh All Sort Filter Data Tools Forecast Outline Data Analysis Solver

Get & Transform... Queries & Co... Sort & Filter Analyze

EXCEL templates

One of the EXCEL template screens (poolheat-outdoor-pool6.xls) for an outdoor pool is shown below



The charts displayed for an outdoor pool are monthly values for

Energy flows in a heated pool.

Energy flows in an unheated pool.

Pool temperature.

Range of pool temperature (maximum exceeded for 5% of the time and minimum temperature exceeded for 95% of the time).

Heater capacity required (specified capacity can also be set in PoolHeat).

Purchased energy.

The charts displayed for an indoor pool are monthly values for

Energy flows for indoor pool.

Pool temperature during daytime operating period.

Space temperature during daytime operating period.

Space humidity during daytime operating period.

Pool temperature at night.

Space temperature at night.

Space humidity at night.

Heater capacity required (specified capacity can also be set in PoolHeat).

Purchased energy.

The templates display a typical data set when opened. The prepared graphs can be viewed by selecting the tags along the bottom of the EXCEL window. To view a graphical presentation of the case you have analysed in PoolHeat load your results into the relevant outdoor or indoor template using "*Data – Refresh*" in EXCEL.

This will produce an EXCEL "*PoolHeat Data*" worksheet as follows (partial view of worksheet shown)

	Weather			Energy Summary				Heater Capacity and Cost			Outdoor pool temperature					
	Ta	Gh	U	Total heat	Aux input	collector input	Solar contrib	Capacity required	Energy use	Energy cost	Average noheat	Average with heat	min and max pool temperatures 5% & 95% unheated		heated	
Jan	0	0	0.59	2148.32	0	2884.16	100	0	0	6	24.8	30.91	20.8	28.1	27.3	33.1
Feb	0	0	0.55	2961.79	0	1783.9	100	0	0	6	25.76	31.17	22.8	28.3	28.8	32.9
Mar	0	0	0.53	6540	0	6646.61	100	0	0	6	22.38	29.27	19.2	25.4	26	31.6
Apr	0	0	0.51	9394.83	1565.78	8090.68	83.79	144.98	1739.75	525.73	18.88	26.84	16.1	22	23.6	30
May	0	0	0.5	11171.52	5458.16	5000.81	47.81	505.39	6064.63	1704.03	16.37	24.69	14.6	18.7	23.2	27.1
Jun	0	0	0.48	14432.77	11499.56	3017.46	20.79	1064.77	12777.29	3364.21	13.1	23.89	11.4	14.6	22.6	25
Jul	0	0	0.55	16452.29	14390.99	1957.93	11.98	1332.5	15989.98	4319.36	12.33	23.73	10.4	14.3	22.5	24.7
Aug	0	0	0.59	13176.03	9446.78	4082.21	30.17	874.7	10496.42	2871.81	14.68	24.32	12	18.1	22.8	26.4
Sep	0	0	0.63	10454.1	4064.91	6819.91	62.66	376.38	4516.56	1257.72	16.76	25.3	14.8	18.9	23.1	27.9
Oct	0	0	0.65	8270.84	1141.01	6956.37	85.91	105.65	1267.79	399.02	20.24	27.9	16.4	23.9	23.9	30.9
Nov	0	0	0.65	5752.27	0	6190.12	100	0	0	6	22.64	29.52	19.6	27	26.8	31.9
Dec	0	0	0.65	3407.58	53.36	3030.94	98.27	4.94	59.29	24.38	24.43	30.31	19.6	28.2	25.8	32.9
Annual	0	0	0	3180113	1459107	1720824	54.11	0	1621230	14490.26	0	0	0	0	0	0

The EXCEL charts can be edited to suit your application provided the "*PoolHeat data*" sheet is not modified.

REFERENCES

1. AS 3634, Standards Australia, Solar *Heating Systems for Swimming Pools*.

2. AS 5348 *Pool covers*

3. AS 5352 *Swimming pool heat pump systems*

4. ANSI/AHRI Standard 1161 (SI), *Performance Rating of Heat Pump Pool Heaters*

5. ISO TR12596 International Standards Organisation *Solar heating - Swimming pool heating systems - Dimensions, design and installation guidelines*

6. ISO 9806-3, International Standards Organisation. *Test Methods for solar collectors. Part 3. Thermal performance of unglazed liquid heating collectors*.

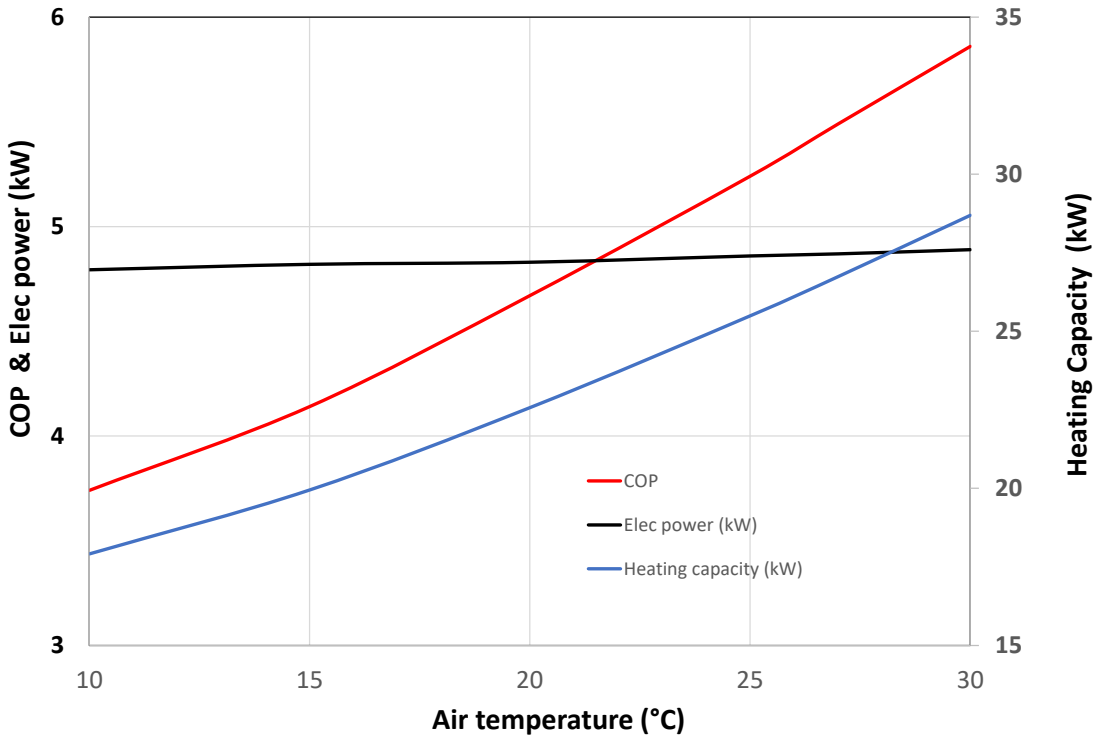
7. K.I. Guthrie. *Testing of Solar Swimming Pool Heaters*, Victorian Solar Energy Council 1984.

8. NF 414, AFNOR *Certification technical standard NF 414 Heat pump – NF mark*

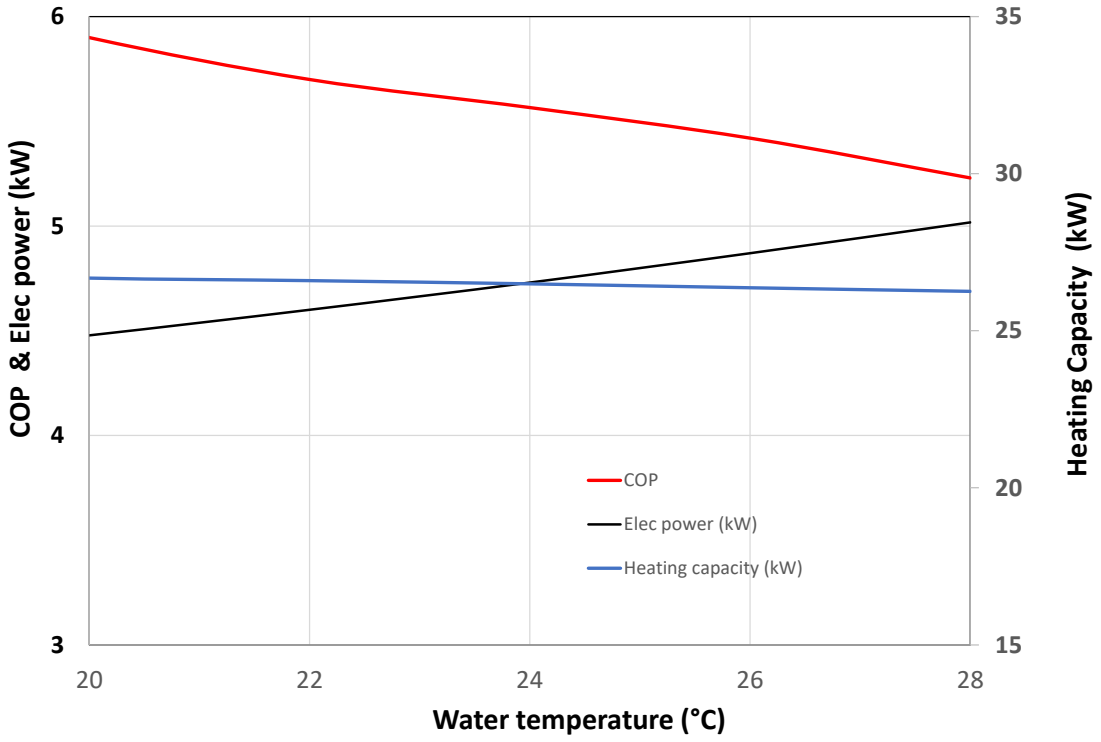
9. Umer Khalid Awan (2012). Experimental Analysis of Variable Capacity Heat Pump System Equipped with Vapour Injection and Permanent Magnet Motor (diva-portal.org). Royal Institute of Technology KTH Sweden

APPENDIX A
HEAT PUMP PERFORMANCE

Typical heat pump pool heater performance as a function of air temperature for constant pool temperature (26°C) is shown below. The COP increases strongly with air temperature and the Elec power increases only marginally with air temperature. The heating capacity (=COP* Elec power) also increase significantly with air temperature.



Typical heat pump pool heater performance as a function of water temperature for constant air temperature (25°C) is shown below. The COP drops as the water temperature increases while the Elec power increases as the water temperature rises. The heating capacity (=COP* Elec power) decreases slightly as the water temperature rises.



Modelling variation of heat pump performance with operating conditions

The variation of heat pump **COP** and electric power input (**Power**) is determined from the performance for two ambient test conditions using a linear model (see appendix for details of heat pump performance with operating temperatures and speed).

The variation of **COP** with operating temperature is modelled using the following function.

$$COP = a + b(T_w - T_a) + c(T_{wet} - T_{dp}) \qquad (1)$$

where

T_w = water temperature

T_a = dry bulb air temperature

T_{wet} = wet bulb air temperature

T_{dp} = dew point temperature

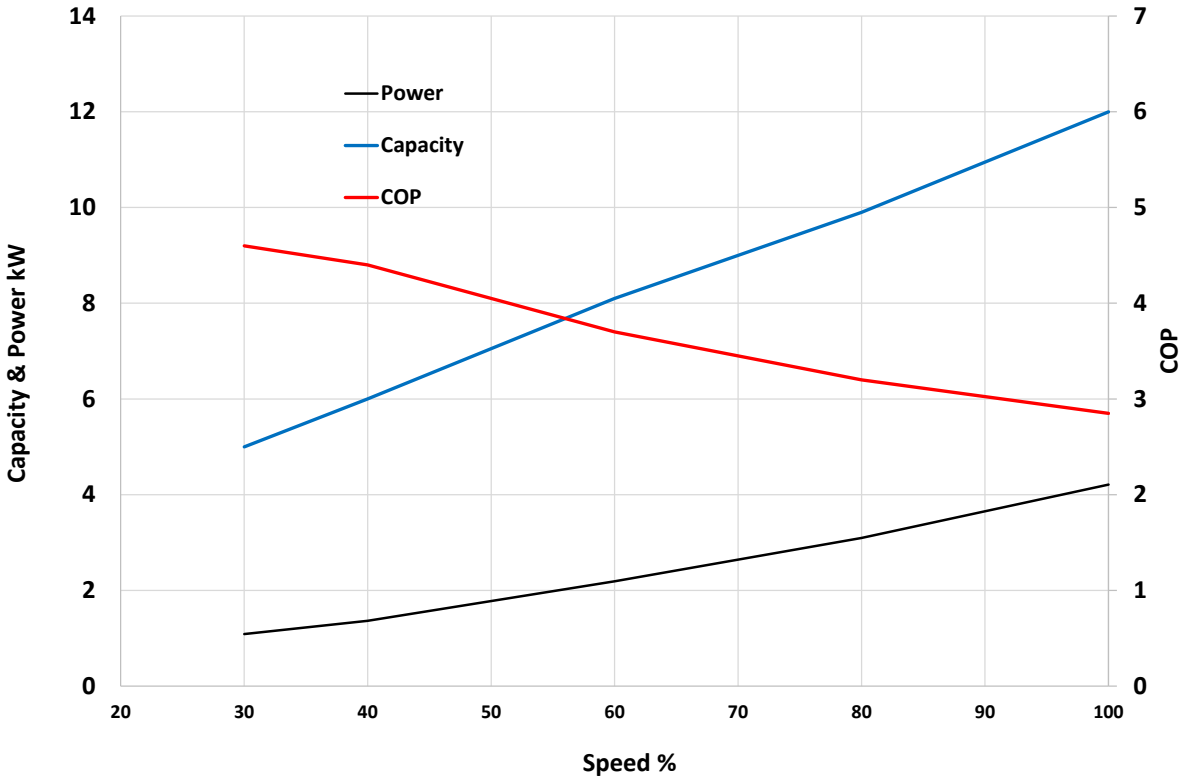
with b ≈ c.

The variation of heat pump electric **Power** input with operating temperature is modelled using the following function

$$Power = d + e * T_a \qquad (2)$$

Modelling variation of heat pump performance with heat pump speed

Typical variation of heat pump COP and Power with heat pump speed is shown below



Umer Khalid Awan (2012) showed that for compressor speeds from 100% to 30% the variation of COP and Power with compressor speed could be approximated by linear functions. The linear approximation was found to hold for a wide range of evaporator and condenser temperatures.

In PoolHeat two test points (AS 5352) at high compressor speed and two test points at low compressor speed are used to define the variation of COP and Power with ambient conditions at each compressor speed using functions (1) & (2).

For A variable speed compressor the COP and Power for speed conditions between the two test speeds is determined by linear interpolation.

If only one test condition is available for each speed then default values for the sensitivity of COP and Power to ambient conditions are applied.