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A Typical Meteorological Year for Energy Simulations in Hamilton, New Zealand

1. ABSTRACT

Typical Meteorological Year (TMY) data is used extensively in building energy simulations and solar energy analysis. TMY data for New Zealand, however, is relatively limited and no such data existed for Hamilton.

Ten years of hourly meteorological data was analysed, and a TMY was developed. Simulations using the TMY data were conducted to determine the performance of a solar pool-heating system. It was found that the TMY was able to predict the annual performance of this system to within 2% of the long-term mean.

It is intended that this TMY could be used to perform simulations on building energy use and solar heating systems in Hamilton.

Key words: typical meteorological year, Hamilton, solar energy, system performance, energy use

2. INTRODUCTION

Reliable engineering weather data is of significant importance when undertaking transient simulations of solar energy systems and energy use in the built environment. Furthermore, there are a significant number of programs, such as BLAST and TRNSYS, which rely on this data to predict the performance of different energy systems.

In order to conduct these simulations there are a number of variations on “typical” weather data that are used in building and solar energy simulations, such as ASHRAE’s Weather Year for Energy Calculations (WYEC), Typical Meteorological Year Type 2 (TMY2) and the National Research Centre of Canada’s Canadian Weather for Energy Calculations (CWEC). However, this study concentrated on the development of a TMY which could be used in a range of simulation programs.

Currently, the availability of “typical” weather data for New Zealand locations is relatively restricted. Van der Werff et al (2003) attempted to address this issue by developing a series of Test Reference Years (TRY) and “design days” for use across New Zealand, including Hamilton. They identified years which could be categorised as hot, cold or average, as well as days satisfying similar parameters.

Crawley (1998), however, suggested that the disadvantage of TRY data is that it tends to result in mild years being used. Furthermore, Crawley noted that TRY data does not contain measured values for solar radiation, but calculated values based on cloud type and coverage.

Crawley also noted that the TMY developed by the National Climatic Data Centre (NCDC) and Sandia National Laboratories (SNL) tends to overcome the limitations of the TRY by using a series of “typical” months of data, rather than a single year, to represent a typical year.

The validity of TMY data for use in long-term energy simulations for the Australasian region was demonstrated by Morrison and Litvak (1988). They developed TMY data for 22 locations across Australia and found that they were able to accurately predict the long-term performance of solar water heating systems.

As mentioned, the work of Van der Werff et al (2003) has partially addressed the limited availability of “typical” weather data in New Zealand; however, only “design days” are given for use in Hamilton.

By population, Hamilton (37.5 S, 175 E) is New Zealand's fourth largest urban centre (Statistics New Zealand, 2001) and forms the main service centre for the Waikato region. Waikato and its surrounds form the centre of production for the New Zealand dairy industry and, according to the Energy Efficiency and Conservation Authority (2006), the Waikato region uses approximately 10% of the nation's energy.

The National Institute of Water and Atmospheric Research (NIWA), cited by EECA (2004), found that the daily global radiation for Hamilton varies between 6.2 and 22 MJ/m^2day, with an annual total of approximately 5100 MJ/m^2. According to EECA (2001) this is comparable with a location such as Melbourne and significantly higher than a typical German location. Hamilton is therefore a good location for solar energy utilisation.

Given Hamilton's large population base, and the energy consumed in the surrounding Waikato region, it is important that a better understanding of its meteorological conditions is established to aid in the design of solar and building energy systems.

3. DATA COLLLECTION

To develop the TMY for Hamilton, continuous hourly weather data was collected from an automated weather station located south of Hamilton for the period January 1997 to June 2006.

Data was collected for four variables needed to formulate the TMY: global solar radiation on a horizontal surface, ambient temperature, relative humidity, and wind speed.

Other than convention, there are several reasons for selecting these parameters. In energy simulations, solar radiation levels determine the heat gain; the ambient temperature and wind speed determine heat loss by convection; and relative humidity is important in determining latent energy, for air-conditioning systems and evaporation levels.

4. METHODOLOGY

In order to produce the TMY for Hamilton, the data was divided into 12 monthly sets, each containing the four meteorological parameters.

To determine the most suitable months a short- and long-term mean were determined for each of the parameters.

The short-term mean was developed by taking the mean of the hourly values of a particular parameter for the entire month of a particular year.

The long-term mean was determined by taking the mean of the monthly parameter values over the entire data set of 10 years. Additionally, where a leap year occurred, the hourly values for 29 February were removed from the calculations so that each February was assumed to have only 28 days.

Subsequently, each of the parameters was qualitatively ranked in terms its perceived importance for energy simulations. Solar energy was taken as the main parameter followed by ambient temperature, relative humidity and wind speed.

Although wind speed tends to have a notable influence on heat loss, especially when examining solar collectors, the measurements were taken in a comparatively rural environment and so were not believed to be representative of those that would be experienced in Hamilton's suburban areas. Kind and Kitaljevich (1985) noted that there are significant variations between rural and urban wind velocity profiles thus supporting the decision to place a lower emphasis on wind speed.

Subsequently, the short-term means were compared to the long-term mean for the month. The month with the closest match between the mean values of the parameters was thus selected as the "typical" meteorological month for the TMY.

Although various statistical methods for determining best fit have been used in analysing meteorological data (for example Finkelstein-Schafer (FS) statistics) these were not employed in this study. It was found that for the two main parameters, solar radiation and temperature, the mean monthly values closest to the long-term mean monthly value typically occurred in the same month, thus making the selection of each month appropriate.

Having determined each typical month, linear interpolation was performed to correct any significant differences between the parameter values from different months of different years. This operation only affected a maximum period of three hours in each month and as such should not significantly influence the long-term output from any simulations.

To validate the TMY, a mean year consisting of the mean hourly values for each day was developed. Both the TMY and the mean year were then used in a performance simulation of a solar water heating system for pool heating, using the Canadian Renewable Energy Network's (2006) Enerpool Pro package. It should be noted that a constructed "mean" weather year tends to remove natural meteorological variations, such as fast-moving storm fronts, that would occur during a typical year. Using a TMY allows the impact of these variations to be observed in simulation models.

In these simulations, the performance of a 100m^2 glazed solar collector array was analysed for both the TMY and the mean year. In the simulations, the solar collector was assumed to have an efficiency given by Equation 1, where the efficiency (η) is a function of the inlet water temperature (T_{in}), the ambient temperature (T_A) and the global solar irradiance (G").

$$\eta = 0.75 - 5\frac{T_{in} - T_A}{G"} \qquad (1)$$

The values in this equation were assumed to be representative of values for a glazed solar collector that may be used for swimming pool heating applications.

In the simulations it was assumed that the collectors were mounted on a roof with an elevation of 37.5 degrees, equal to Hamilton's latitude. Additionally, simulations were conducted at elevations of 60 degrees and 14 degrees to determine the performance of the system when biased for mid-winter and mid-summer performance.

5. RESULTS

Having selected the typical months for the TMY, as shown in Table 1, a comparison was made between the long-term mean and the TMY for the four parameters. Figures 1 to 4 (page nine) show how the TMY compares to the long-term means.

Table 1: Months selected for TMY

Month	Year
January	1998
February	2002
March	1998
April	2004
May	2004
June	1998
July	2002
August	1998
September	1997
October	1997
November	2003
December	2003

Figure 1 shows that the relationship between the long-term mean and the TMY values for the solar radiation is excellent, with the deviation in the values being negligible. This is appropriate, as there was a heavy emphasis placed on the selection of solar radiation that was close to the long-term monthly mean.

Furthermore, the relationship between the ambient temperature (Figure 2), relative humidity (Figure 3) and wind speed (Figure 4), is reasonable. This suggests that the data selected for the TMY can represent the long-term meteorological conditions of Hamilton.

The output from a simulation using TMY data and a mean weather year were compared to validate the assumption that the TMY could accurately represent the long-term performance of a solar pool-heating system.

From the simulations that were conducted, it was found that the TMY was able to predict the performance of the solar pool-heating system to within 2% of the mean weather year annual total. In addition, it was found that the monthly values were predicted to within 3%.

In Figure 5 it can be seen that, for a collector oriented at 37.5 degrees, the difference between the mean year and the TMY does not vary significantly. As such, the TMY can be used in performing accurate long-term simulations of solar energy and building energy simulations.

In addition, it was found that the energy collected could be improved by biasing the collectors at 14 and 60 degrees for either summer or winter performance.

In Figure 6 it can be seen that at lower elevations performance is much better during summer. However, during winter the collector with the highest elevation performs the best.

Furthermore, at an elevation of 14 degrees it was found that the annual energy collected was the maximum of the three values simulated. However, at an elevation of 37.5 degrees the collectors offered a compromise between summer and winter performance.

6. DISCUSSION AND CONCLUSION

As New Zealand's fourth most populous urban centre, there was a need to develop a typical meteorological year for Hamilton.

Previously, Van der Werff et al (2003) had identified "design days" for Hamilton; however, these were felt to be inadequate to accurately predict the long term annual performance of solar and building energy use in simulation models.

Ten years of meteorological data was collected for Hamilton. By taking the data for months which closely represented the long-term mean weather patterns, a TMY was formulated.

Using a computer simulation, it was found that the TMY was able to predict the output from a solar pool heating system, to within 2% of the long-term mean.

Additionally, it was found that by orienting the collectors at an angle equal to Hamilton's latitude, a good yearly performance could be obtained from the solar heating system.

Based on the data presented, Hamilton is well suited to solar energy use, and the development of a TMY allows accurate predictions of solar and building energy use to be made in the future.

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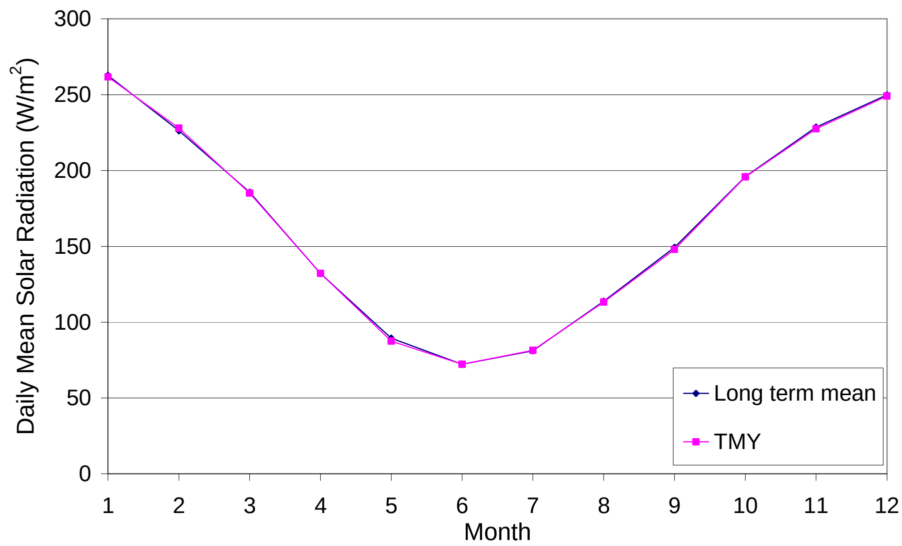

Figure 1: Solar radiation for TMY.

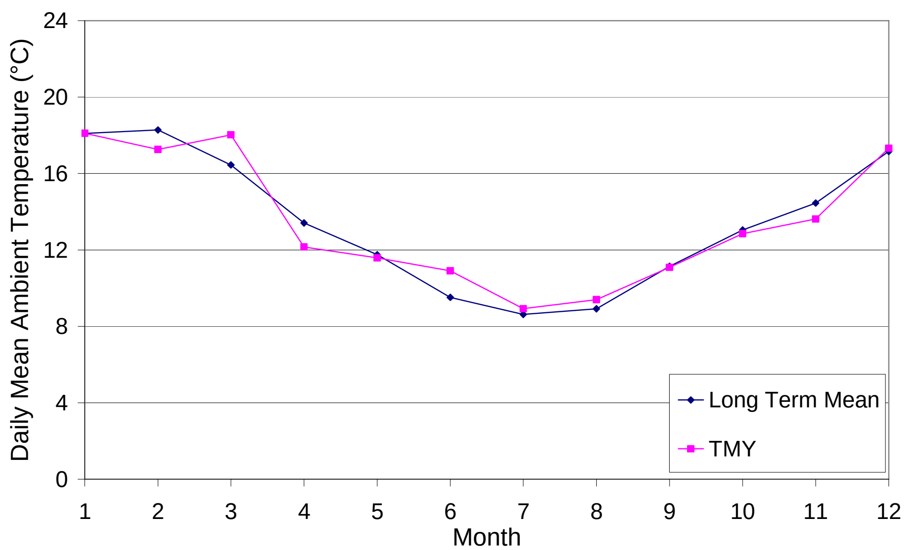

Figure 2: Ambient temperature for TMY.

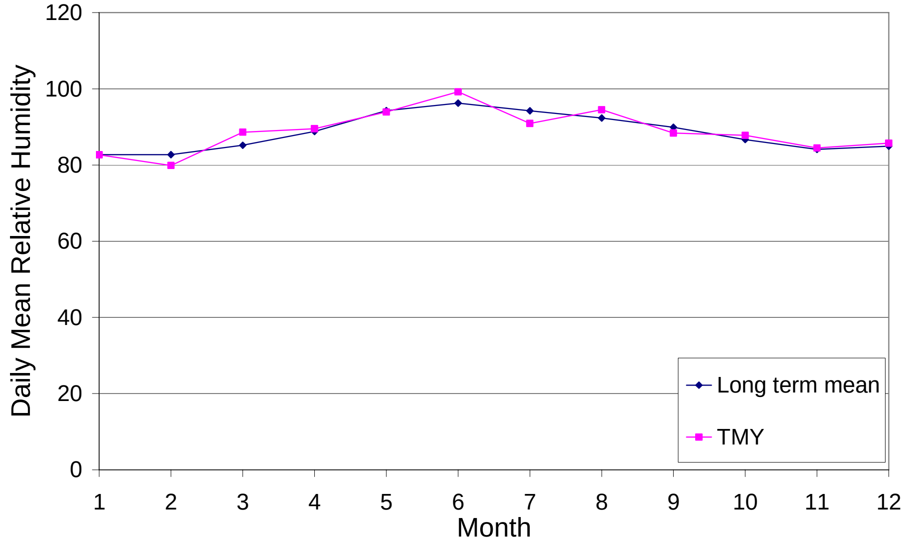

Figure 3: Relative humidity for TMY.

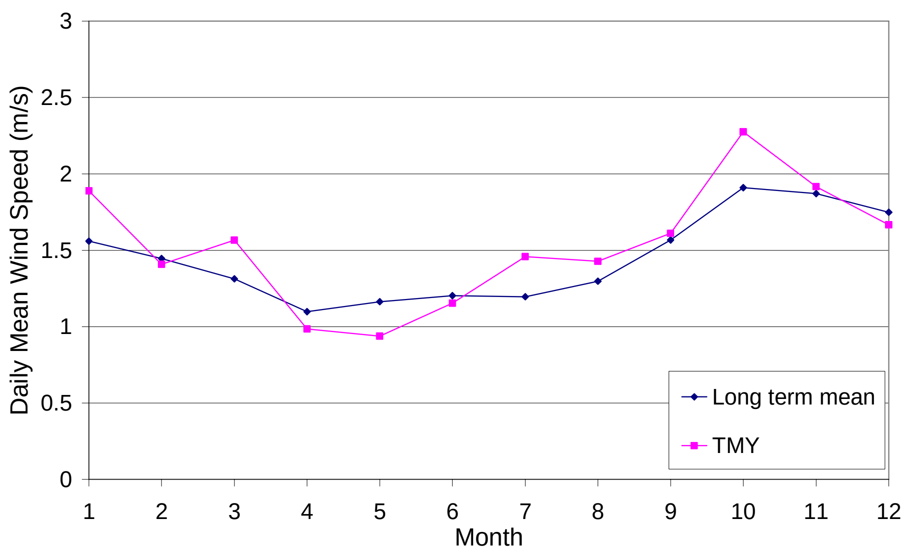

Figure 4: Wind speed for TMY.

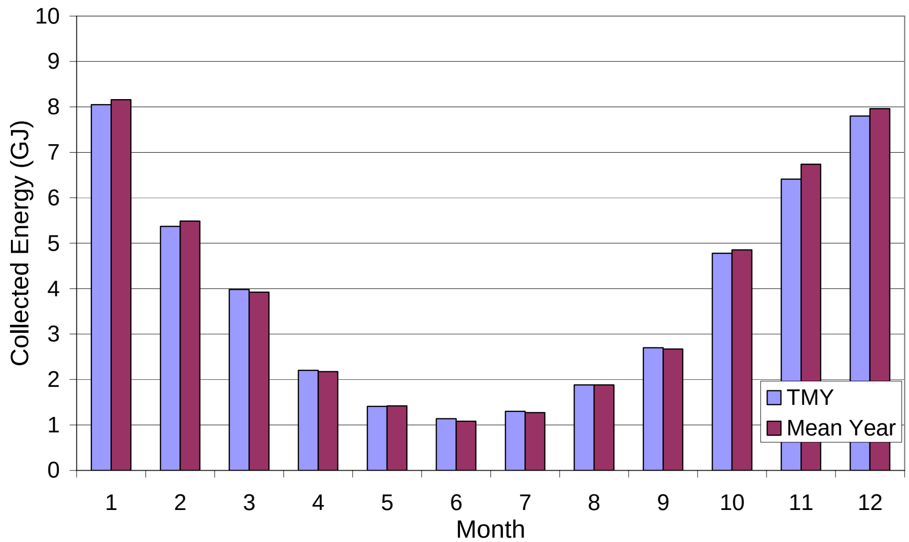

Figure 5: Collected energy for TMY and mean weather year.

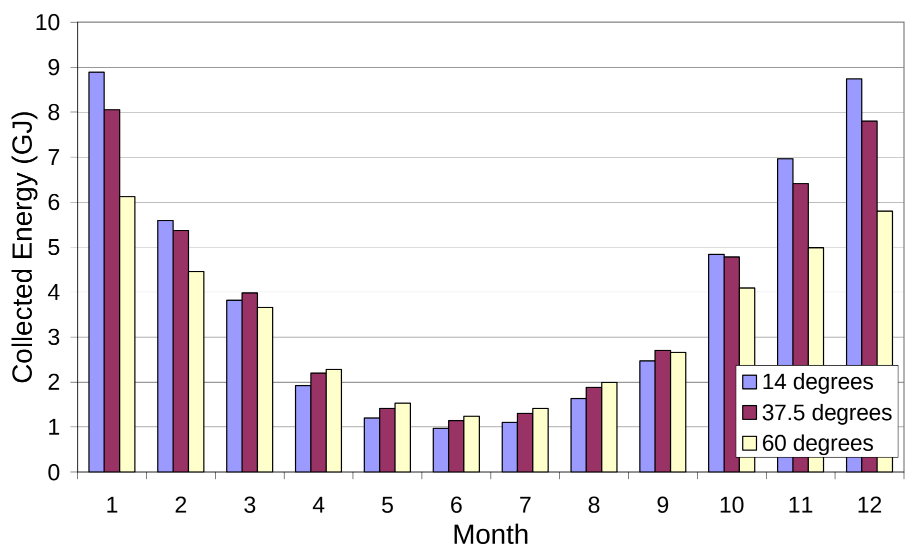

Figure 6: Collected energy for solar collectors at varying elevation angles.