NEW ZEALAND'S NEW WEATHER DATA – HOW DIFFERENT?

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ABSTRACT

The Test Reference Year (TRY) weather file was developed in 1993; in 2009 the Typical Meteorological Year (TMY) became the new standard weather file to use in energy based simulations. The TRY weather file has been used in the development of New Zealand's Building Codes and Standards that are still current today.

This paper describes the differences between the two weather files and how they influence the results of the energy consumption and thermal performance calculated through simulation. This comparison has been made with reference to both residential and commercial buildings.

INTRODUCTION

New Zealand's Building Codes and Standards have been developed through simulating 'typical' buildings to determine the energy and thermal performance. One aspect that has a large influence on the calculated results is the weather file selected.

In 1993, the Test Reference Year (TRY) weather file was developed. The creation and use of this file was reported on at the 1993 IBPSA conference. Since then a new, internationally acceptable method of creating weather files has been developed; the Typical Meteorological Year (TMY) file. These weather files became available within New Zealand in 2009.

As well as using a new method of creating a weather file, New Zealand has also improved the recording and availability of data which is used within the files. This is because the National Institute of Water & Atmospheric Research (NIWA) has more weather stations around the country that records data which previously was not gathered. For example, the solar radiation measurements were not gathered and thus not used in the TRY weather files; also the number of locations have increased. There are now 18 locations for TMY weather files which are more representative of the different micro climates throughout New Zealand. The TRY files only had 16 locations available.

Although there are 18 climate locations available for use within New Zealand, the Building Code and Standards have only divided up the country into three climate zones. These are based around the three main centres: Auckland, Wellington, and Christchurch.

This paper documents the difference and the impact these new weather files have on the performance of a range of 'typical' residential and commercial buildings. The differences between the TRY and the TMY files are calculated through simulation and are identified as being a result of three separate aspects within the weather files:

1) the differences due to the TRY/TMY construction of the files;
2) the differences in the temperatures and other measured data due to the differences in time period for the base 30 year data;
3) differences in the solar radiation due to the now measured, previously estimated nature of this data.

Both residential and commercial buildings were selected for testing the weather files as each naturally perform differently due to construction differences. Residential are smaller, light weight, low mass buildings which therefore make them a building which require heating dominant loads. Commercial buildings with high mass construction materials, deep floor plans, and greater equipment and occupancy loads require cooling as a dominant load.

WEATHER FILES

Importance of the Files

Weather files are used in conjunction with energy and thermal simulations as they increase the accuracy and reliability of the calculated results as they include the influence of weather acting on the buildings. Ideally, this "helps architects and engineers during early stages to design energy efficient buildings" (Westphal and Lamberts, 2004), for the climate where the building is located.

Because of this increase in accuracy, the calculated performance of buildings when modelled and simulated become highly reliable and representative of the expected performance when the building is built. For this reason, the Building Codes and Standards of New Zealand were developed using the results of simulated models. Current Codes and Standards are based on the calculations performed using the 1993 TRY weather files and therefore considered outdated.

Weather File Locations

There are 18 TMY locations and 16 TRY locations available for the weather files. Out of these locations, only 11 match in both the TMY and TRY file types. This is because of availability of where the weather stations are located for collecting the data. In the case of the TMY files, new weather stations and/or new monitoring equipment was installed to collect data that was not previously collected. Because of this, some different locations that represent micro climates throughout New Zealand were able to be included.

In contrast to the micro climate locations that the weather stations are located, and weather files created for, the New Zealand Building Codes and Standards only divide the country into three geographical zones. Each zone contains one of the main centres; Auckland, Wellington, and Christchurch. Because of this broad division of the country, the micro climates within these main climate zones are neglected. An example of this is how the whole of the South Island is a single zone and therefore Nelson, at the top of the island, is required to contain the same minimum insulation level as Dunedin: Dunedin is known to be significantly colder during the winter months due to the southern location.

For this study, only the three main centres were used in the simulations: Auckland, Wellington, and Christchurch. This is to match the way New Zealand Building Codes and Standards divide the country in terms of climate locations.

Test Reference Year

The Test Reference Year file, developed and released in 1993, consists of hourly measured data for an annual period that has been collected since the 1960's. The file uses a single year's data to represent different conditions (Amor et al., 1993).

There are two great limitations involved in the creation of a TRY weather file. The first being the data that is and is not included within the file. The file does not contain any measured solar radiation values, the "simulation program typically estimates the amount of solar radiation based on the cloud cover and cloud type" (Crawley and Huang, 1997). After the program calculated this, the values were extracted and input into the file as raw data. The second limitation is the process used in selecting what data to include.

An average year is created by taking the "years in the period of record and having months with extremely high or low mean temperatures progressively eliminated until only one year remained" (Crawley and Huang, 1997). Because of this crude method of selecting the data to represent a typical year, multiple TRY weather files were created for different common conditions.

There are eight different conditions that are available ranging from a cold and windy year to a hot and calm year; for the purpose of this research the average year TRY weather file was used for all three locations tested.

Typical Meteorological Year

In 1978, Hall et al. developed a new method for creating a weather file. It is now the most commonly accepted methods for generating typical weather years (Jiang, 2010). This is the Typical Meteorological Year (TMY) weather file. The file is created through "selecting, by statistical methods, one Typical Meteorological Month (TMM) for each of the 12 calendar months from a period of years of data and concatenating the 12 months to form a TMY" (Jiang, 2010).

The way the file is created eliminates the two greatest limitations identified with the TRY weather files. This is achieved by: 1) using measured solar radiation values and 2) compiling monthly data into a single year to make it representative of a 'typical' year.

Until 2009, New Zealand did not have weather files in the TMY format due to the availability of data. In particular, the solar radiation data. The recorded data used to create the TMY files date back approximately 30 years prior to 2009: the development and release year. The values for each of the weather parameters are selected through a comparison of the data to the long term distribution of the values and selecting the months that represent the average (Crawley and Huang, 1997). The final TMY files consist of hourly data for an annual period but each month is from a different year. Both the TRY and the TMY files contain 8,760 hours of data.

Raw Data Comparisons

Out of the nine parameters within the files, the two that are of the greatest interest are the global radiation and direct normal radiation. This is because, as previously mentioned, the TRY weather file does not contain any measured data for solar radiation, and is estimated from the amount of cloud cover and cloud type that had been monitored.

As an example, the Wellington weather files have been used to illustrate the differences between the two file types. The other climate zones show a similar difference trend between the two types of files. A comparison of the dry bulb temperature and the global solar radiation are shown.

Figure 1 shows the comparison of hourly dry bulb temperature over a year for the TRY and TMY weather files. As it can be seen, they both show a very similar trend throughout the year. Both have the highest temperatures in February and the lowest in August.

The average annual dry bulb temperature for the TRY file is 13.2^{oC} and 12.8^{oC} for the TMY. The minimum temperatures are also closely matched with 2.2^{oC} and 2.0^{oC} for the TRY and TMY file respectively. The maximum temperatures have a greater difference between the files. The TMY file achieves a maximum value of 24.8^{oC} while the TRY reaches 27.2^{oC} and experiences 44 hours (out of the 8,760) that are above the maximum of the TMY file.

Direct normal solar radiation is the radiation that has not been 'scattered' or diffused through the earth's atmosphere. It is therefore the strongest in terms of energy per square meter experienced at a location. (Uoregon solar radiation monitoring laboratory, 2002). Other types of solar radiation are diffuse and extraterrestrial.

When comparing the difference between the TMY and TRY files with relation to the direct normal solar radiation, there is one difference that is significant. Other than the values of the data within the files, the TRY file has a seasonal trend similar to that of the dry bulb temperature while the TMY file has very minimal seasonal trend. It remains fairly constant throughout the year with an average value of approximately 3,700Wh/m^2.

This large difference between the two files is a result from how the direct normal radiation is estimated within the TRY file and measured data used in the TMY file. As the TMY file uses measured data, it is assumed to be more reliable.

Global radiation is the sum of the direct, diffuse, and extraterrestrial radiation experienced at a single spot (Uoregon solar radiation monitoring laboratory, 2002). Figure 2 shows the difference between the global radiation values within the two weather files for the year; TRY minus the TMY values. The greatest difference between the files is experienced during the warmer months, November through to March. This is assumed to be because there is typically less sky cover and therefore greater solar radiation experienced which is over estimated within the TRY weather file.

The TRY weather file ranges from a maximum of 5,000Wh/m^2 greater and a minimum of 3,500Wh/m^2 less than the TMY weather file. The general trend over the year is that there are a similar number of hours where the TRY is greater and less than the TMY weather file; 2,179 hours and 2,410 hours respectively. It is therefore this difference between the two files that make the largest influence to building energy consumption when calculated.

The other parameters of the weather files were also compared to each other, this includes the wind speed and dew point temperature. Both the TRY and the TMY files illustrate a similar trend throughout the year with no significant difference between the two files. Because of the similar trends identified with the other parameters of the files, it is assumed that the difference in energy and thermal performance of buildings when simulated with TRY and TMY weather files is predominantly a result from the difference in solar radiation, both direct and global, when using the latest (TMY) weather file.

TEST BUILDINGS

To make a valid assessment between the two weather files, two types of buildings were used: residential and commercial. These two types of buildings were

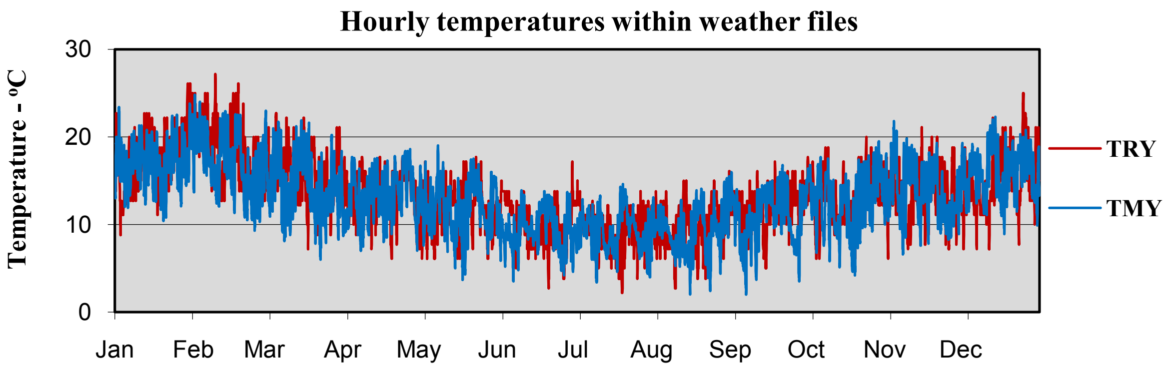

Figure 1. Hourly dry bulb temperatures over a year.

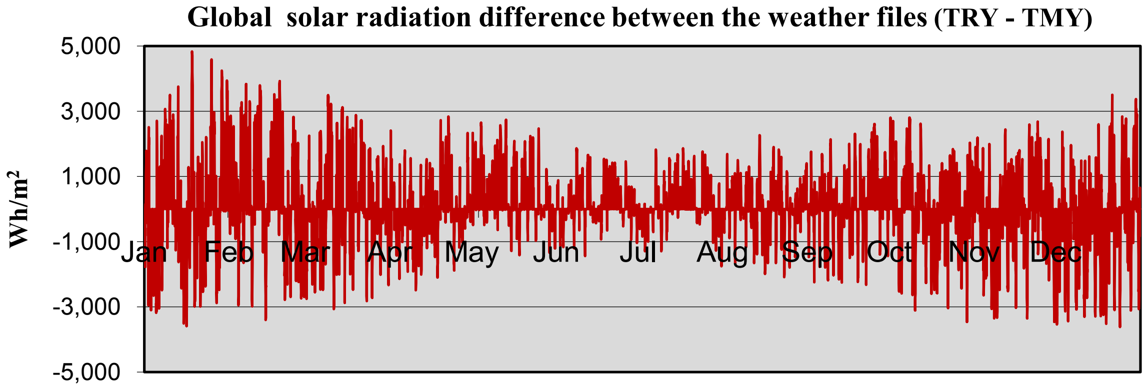

Figure 2. Hourly global solar radiation difference over a year.

used as a comparison as the residential require heating dominant loads while the commercial are cooling dominant. By selecting these types of buildings, it is demonstrated how the weather files affect the performance of the different types of buildings. Both types of buildings were simulated in Auckland, Wellington, and Christchurch.

Residential

For residential, a single storey and a two storey house which are representative of new homes built within New Zealand were selected for testing the residential performance. For consistency, the two storey building has a similar total floor area as the single storey building. "Performance will, of course, be different for each individual house design. However, the example houses should provide good guidance on the general effects of various design options" (Donn and Thomas, 2010). Both buildings were modelled and had the energy and thermal performance calculated within the computer program SUNREL.

Overall, there were 162 calculations performed for the residential buildings. This is a result of using a combination of three levels of glazing, insulation, and mass (3x3x3=27), a one storey and two storey house (27x2=54), three New Zealand climate zones (54x3=162).

The three levels of glazing modelled are a percentage of the north facade which is simply 25%, 40%, and 55% of the total surface area.

Insulation levels were based on a minimum level allowable by the Building Code for the climate zone and each level is a reasonable step up improvement of the total R-Value of the floor, walls, roof, and windows. Each level of insulation is labelled as code, good, and best. For example, a high mass house in Auckland would have a total wall R-Value of R0.8, R2.7, R4.5 for insulation steps of code, good, best respectively.

The mass of the buildings were defined as being low, medium, or high. This was based on the floor and wall types that were modelled. A low mass wall would be timber framed while a high mass is concrete.

Heating schedules and temperature set points within the residential buildings were kept constant for all of the calculations performed. The living areas were heated up to 20^{oC} between 0700 and 2300 and the bedrooms heated to 16^{oC} overnight (2300 – 0700). No mechanical systems for cooling were modelled as it is expected that the occupants would open windows and doors and use natural ventilation. The natural ventilation has been modelled to be used when the internal temperatures exceed 26^{oC}.

Commercial

The commercial building selected was calibrated to an accuracy of approximately 5% of the actual monthly energy consumption for the year 2009. It had been modelled within EnergyPlus so this was the program used when calculating the difference between the two weather files.

The total floor area of the building is approximately 2,800 square meters. This consists of two storeys of the building being used with an office end-use and a basement of half the floor area containing car parking.

As the building had been calibrated using collected data, the model included all loads influencing the total energy consumption. This includes occupancy, lighting, and electrical equipment. As these aspects are independent of the weather file, in other words, not influenced by the change in temperature, they are ignored in the breakdown of the calculated energy consumption.

The building has mechanical Heating, Ventilation, and Air Conditioning (HVAC) systems which provide both heating and cooling to the building at a set comfortable temperature during the hours of operation. The parameters for the system is a set point temperature with a dead band between 22^{oC} and 25^{oC}, and the hours of operation are between 0700 and 1900 for the majority of equipment. Some HVAC systems are in operation 24 hours a day; this is for the server room and the call centre.

RESULTS

Through simulation, the performance of the test buildings with relation to the influence of the different weather files was measured through various methods. The measurements used are all annual measurements and consist of; energy consumption required to maintain a set temperature; degree hours either too cold or too warm; and heating gains and losses.

The commercial building only had the energy consumption calculated as the degree hours would not be a suitable measure due to the mechanical HVAC systems maintaining a set temperature range and the solar gains and losses would be minimal as the building is more internally load dominant due to the size and use.

Residential – Annual Energy Consumption

A summary of the annual energy consumptions for the building variations can be seen in Figure 3. The results of the various levels of glazing and mass has been averaged with respect to the level of insulation. As the results show, the climate zone, level of insulation, and weather file used can have a significant effect on the annual heating energy consumption.

One of the main points that this graph highlights is that the colder the climate and the worse the level of insulation level is, the greater the difference is between the weather file results. Comparing the two extremes of this, Auckland with best level of insulation and Christchurch with only code level insulation: Auckland uses 1,545kWh and 1,522kWh annually, a difference of 23kWh. Christchurch uses 13,649kWh and 15,022kWh annually, a difference of 1,374kWh. These values are for TRY and TMY respectively.

Apart from Auckland with the best level of insulation, the annual energy consumption for the other building types show that energy consumption calculated using the TMY weather file results in greater energy consumption than the TRY weather file results. This ranges from 23kWh to 1,374kWh which is a difference of up to 15%. The same trend is seen when comparing the one storey and the two storey building results individually.

Residential – Degree Hours

The second method of testing the difference the weather files make to the performance of the buildings is through calculating the degree hours either too cold or too hot. Degree hours are an indicator of the number of hours that are experienced below or above a set temperature. It is a more accurate measurement than just counting the number of hours under or over a temperature as it takes into account the temperature difference.

For degree hours which are considered too cold, the formula is: (16^{oC} – actual temp) x total hours <16^{oC}. Degree hour which are considered too hot, the formula is: (actual temp – 26^{oC}) x total hours >26^{oC}. The total hours greater than 26^{oC} and less than 16^{oC} are all hours throughout the year which are those values.

Figure 4. shows a comparison between the TRY and the TMY weather file with relation to the number of degree hours experienced that are too cold over a year. As it could be predicted, the number of degree hours too cold increase as the climate changes to a colder zone and the insulation level is reduced.

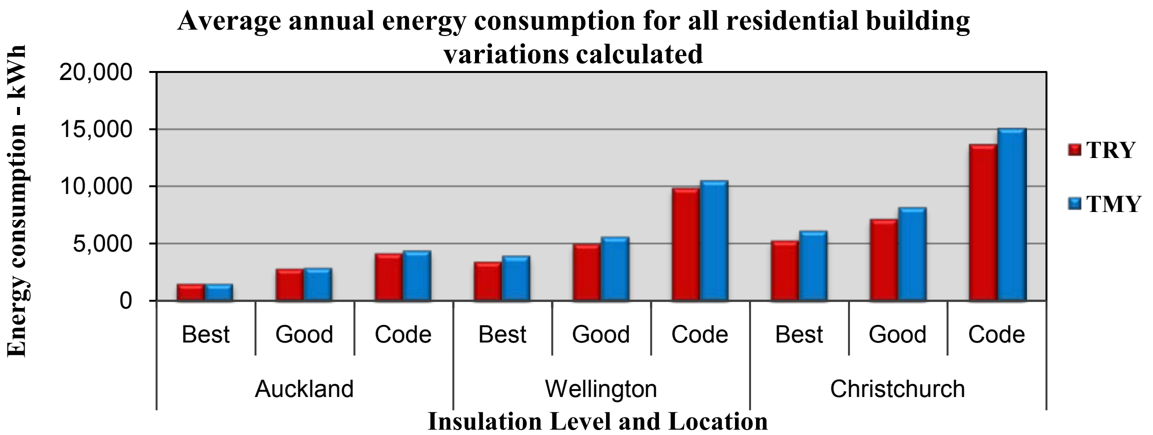

Figure 3. Residential annual heating energy consumption.

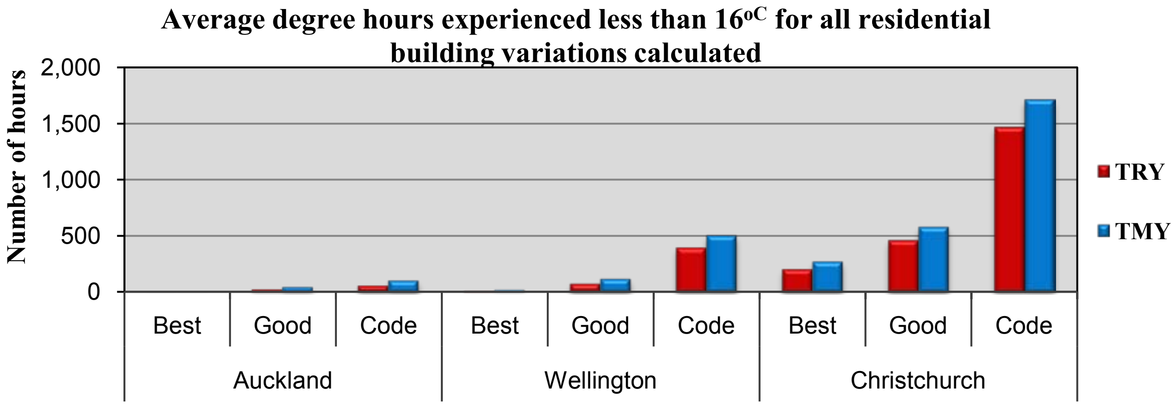

Figure 4. Residential degree hours experienced - too cold.

Overall, every building variation experienced greater degree hours less than 16^{oC} when the TMY weather file is used in comparison to the TRY weather file. As it was discussed when comparing the raw data, the TMY weather file contains less solar radiation so this is the effect of that.

The greatest absolute difference between the two weather files can be seen in Christchurch with the code level insulation. This is a difference of 242 degree hours, which is 16%. Other averaged building variations have a difference ranging between 30% to 80%. One variation, Wellington – best insulation, has a difference of 150%; however this is only an absolute difference of 11 degree hours.

When comparing the weather files in relation to the degree hours greater than 26^{oC}, the TMY weather file for all building variations has less overheating.

The greatest difference is 93%. This is for Wellington with code level insulation. For this building variation, the TRY file has 427 and TMY has 32 number of degree hours greater than 26^{oC}, a difference of 395. The smallest difference is seen with the building Auckland – best insulation; there is a difference of 30% (278 degree hours) between the two weather files.

Because there is less solar radiation within the TMY weather file, this results in the building variations experiencing less overheating. The heat gains and losses further analyse this.

Residential – Heat gains and Losses

Figure 5 shows the averaged heating gains and losses for all of the residential building variations simulated. Each attribute within the graph is an aspect that influences the building's internal temperature. All of the aspects have been calculated as energy gains (positive values) or losses (negative values).

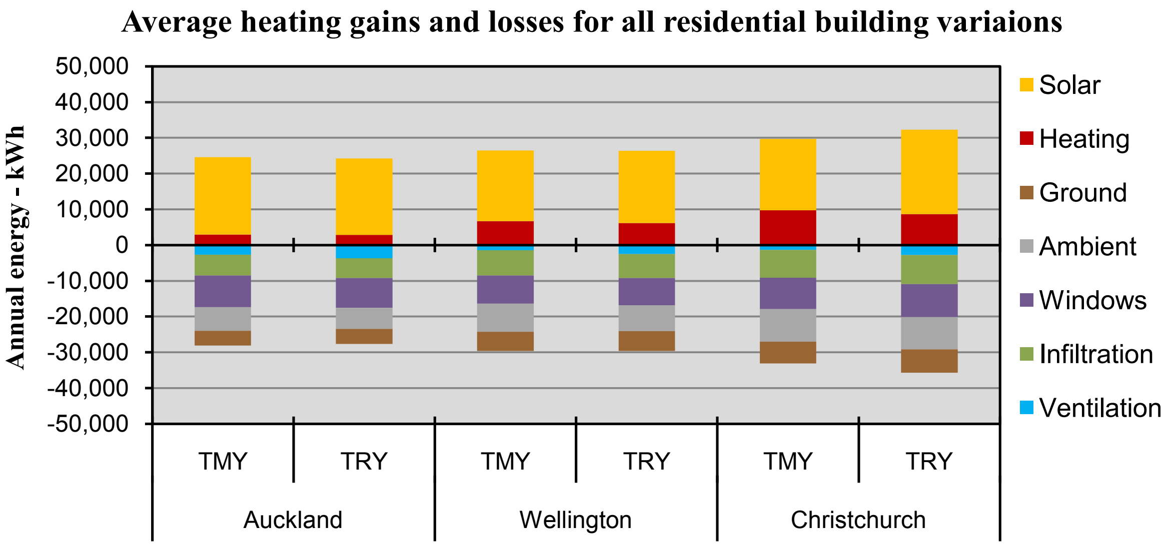

Figure 5. Residential heating gains and losses.

Solar gains in all climate zones contribute to the biggest heat gains within the buildings. The graph highlights the fact that there is greater solar radiation included within the TRY weather file as previously discussed with relation to the raw data. As a result, the purchased heating energy required to maintain a comfortable temperature during the scheduled hours of operation are reduced.

The solar gains are very similar in size for each of the climate zones when comparing the same weather file format; however the heating energy changes significantly. This suggests that the difference in external air temperature has a significant influence on performance of residential buildings due to the high heat losses they experience through the building's fabric.

An example of this is comparing the TMY weather file results of both Auckland and Christchurch. Both locations experience solar gains of around 20,000kWh (a difference of 1,775kWh), while the heating energy has a difference of over three times the amount (6,800kWh). This identifies that the although similar solar gains are experienced within the buildings, greater heat losses due to the temperature difference between inside and outside will result in an overall required greater heating energy consumption.

Commercial

The commercial building results highlight the effect weather files have on the calculated energy consumption of a cooling dominant building. To identify how the weather files are influencing the performance of the building, a breakdown of the HVAC equipment is done for the building within each of the climate zones. As this equipment is influenced by the climate conditions, meaning that it consumes more or less energy depending on the weather conditions, it clearly shows how much change can be expected by using the latest TMY file. For simplicity, the HVAC has been broken down into three categories: cooling, heating, and fans. This can be seen in Figure 6. Other equipment such as lighting and appliances are independent of the weather file so therefore are not shown.

To minimise uncertainties of weekend and holiday occupation within the building, the annual calculated energy consumption has been divided by 365 days to provide values that are the average annual energy consumption per day.

Although commercial buildings have high internal loads and deep floor plans which generally result in the weather having minimal influence on the internal environment, the calculated results show that the total energy consumption still changes when the weather file is changed from the TRY to the TMY.

Within the graph it can immediately be seen that the new TMY weather file uses less annual energy per day than the TRY file. This is opposite to the residential buildings due to the commercial being a cooling dominated building. Similarities to the residential building are the fact that there is an increase in heating energy required when using the TMY weather file. However due the greater reduction in cooling energy experienced within the building, this outweighs the increase in heating energy and the overall energy consumption is significantly reduced.

Auckland is seen to have the greatest total energy consumption with approximately 4,000kWh being

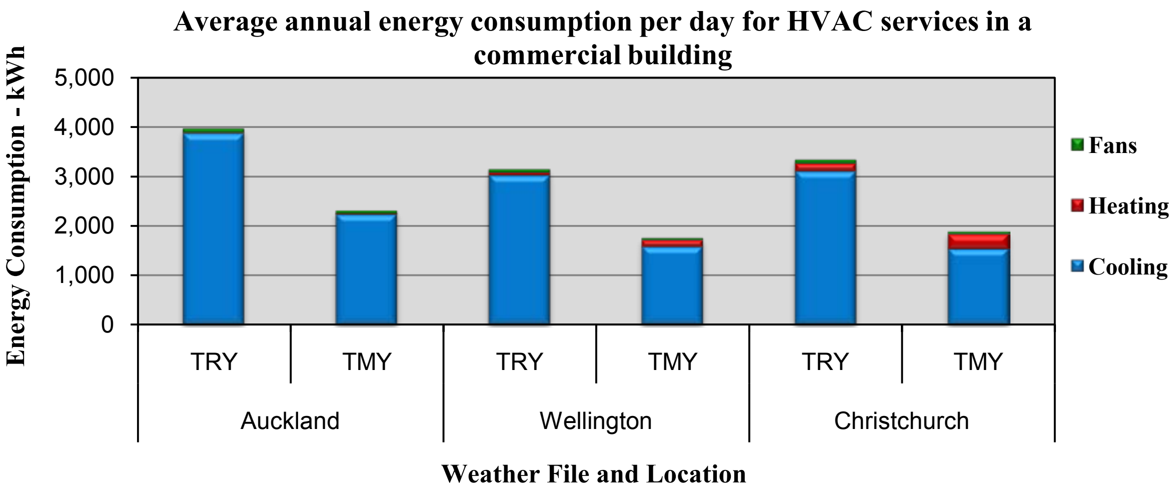

Figure 6. Commercial building HVAC energy use.

consumed daily when using the TRY weather file. By changing to the TMY weather file, this total energy consumption is reduced to a total of about 2,300kWh; a difference of 40%.

The other two climate zones also experience this kind of difference between the two weather files. 45% reduction of energy by changing to the TMY file for both Wellington and Christchurch.

Because the commercial building has a deep plan, core zones within the building are barely influenced by the external weather conditions. Therefore the building's perimeter zones are the areas which contribute to the large change in total energy consumption between the two weather files.

CONCLUSION

With the various comparisons that have been made, there is clear evidence that the change in the weather files have made a difference to the performance of the buildings used for testing.

As it was seen with the raw data analysis, the TMY weather file has less solar radiation, both direct and global, while still containing similar air temperatures and wind speeds. It is this difference in solar radiation that is having the greatest affect on the calculated performance on buildings.

When considering the energy consumption for heating within residential buildings, an increase of up to 15% in annual energy consumption is experienced by using the latest TMY weather file. This result is supported by the calculated degree hours which are considered too cold and too hot.

There are more degree hours in the range considered too cold when the buildings are calculated using the TMY weather file. This compliments the values calculated with regards to the energy consumption. The number of degree hours considered too hot are less when calculating performance with the TMY weather files. This is because there are less heating gains experienced within the buildings.

The breakdown of the heating gains and losses identified that the solar gains within the TMY weather file were less than the TRY weather files and therefore required greater purchased heating energy. However a positive impact of the TMY weather file is that with having less heat gains, there is less temperature difference between the internal and external temperature and therefore results in less total heat losses through the fabric of the buildings.

In general, the residential buildings receive a negative impact due to the increase in energy consumption through heating. In contrast to this, the commercial building experiences a reduction in energy consumption when calculated using the TMY weather file. This is a reduction of between approximately 40% and 45% less energy being consumed annually, this is due to less cooling being required.

The results of the commercial and the residential buildings highlight the difference between a cooling dominate and a heating dominate building and how the weather files affect their performance accordingly.

Given the results and comparisons between the two types of weather files, consideration should be given to revising the current Building Codes and Standards by using the latest, up-to-date weather file. This is so buildings are designed and specified to more reliable New Zealand conditions as provided by within the weather files.

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