A TEST REFERENCE YEAR FOR AHVAZ, IRAN

A thesis submitted to The University of Manchester for the degree of
Master of Philosophy
in the Faculty of Engineering and Physical Science

2011

VAHID ALIPOUR

School of Mechanical, Aerospace and Civil Engineering

Table of Contents

Word count: 18300

List of Figures

List of Tables

List of symbols

G_{sc}	Solar constant = 118.08 [MJ m^{-2} day^{-1}]
d_r	Correction to actual solar distance at any day in the year
m	Month
y	Year
i	Number of the day in the year between 1 (1 January) and 365
p	Weather statistic
Ny	All the years in database
R_a	Daily extraterrestrial radiation [MJ m^{-2} day^{-1}]
ψ	Zenith angle [radians]
λ	Latitude of the site
δ	Solar declination [radians]
hr	Solar hour of the day
hr_o	Hour of solar noon equal to 12
R_{ah}	Hourly extraterrestrial radiation [MJ/m^2.hr]
R_a	Extraterrestrial radiation [MJ m^{-2} day^{-1}]
R_{sh}	Hourly global solar radiation [MJ/m^2.h]
R_s	Solar or shortwave radiation [MJ m^{-2} day^{-1}]
R_{dh}	Hourly diffuse solar radiation
n	Actual duration of sunshine [hour]
N	Maximum possible duration of sunshine or daylight hours [hour]
n/N	Relative sunshine duration
a_s,b_s	Regression constants, expressing the fraction of extraterrestrial radiation reaching the earth
M	The maximum value of global solar radiation, assumed to occur at noon [MJ/m^2.h]
SR	Sunrise time [hour]

SS	Sunset time [hour]
t	Time [hour]
ω_s	Sunset hour angle [rad]
K_T	Clearness index equals to R_{sh}/R_{ah}
$\overline{X}$	Mean
N	Number of values
SD	Standard deviations
FS	Finkelstein–Schafer statistic
CDF	Cumulative Distribution Function
MHGSR	Mean hourly global solar radiation [MJ/m^2.h]
DGSR	Daily global solar radiation [MJ/m^2.day]

ABSTRACT

Building energy assessments have long been implemented in the construction industry throughout the globe. Having proper energy estimation and load calculations reduces the amounts of energy used from fossil based resources. To implement an accurate energy appraisal, a set of reliable and practical tools and data are essential. Particularly for building energy simulations, typical weather data such as a test reference year is necessary.

This research project is carried out for Ahvaz, a city located in the south west of Iran. New typical weather data has been selected from nineteen years of raw weather data collected from Iran's Met Office. After collecting three-hourly raw data, four parameters: dry bulb temperature, relative humidity, wind speed and sunshine durations, have been used to select typical months that are then merged to generate a whole typical year, representing a longer period of Ahvaz's weather conditions.

After that, daily sunshine durations have been converted into daily global solar irradiation before generating hourly global solar irradiation between sunrise and sunset. Hourly diffuse solar irradiation is then calculated from hourly global solar irradiation. Another three parameters: dry bulb temperature, relative humidity and wind speed, have been interpolated into hourly values. Subsequently, the hourly simulated weather data is converted into IES format so that it can be used for building simulation purposes.

A simple building is simulated using three sets of weather data in IES, Ahvaz, Kuwait and Tehran. Four main weather parameters have been used for a general comparison in which their mean and standard deviations are graphically shown. Kuwait, with close geographical and climate conditions to Ahvaz, has been found to have close but different weather conditions to Ahvaz while the northerly located city, Tehran, was found to be different as expected. As results, the need for a typical weather data for Ahvaz is the main aim of this thesis. At the same time, some issues have been recommended for future research including raw weather data quality control, and evaluating Tehran's typical weather year.

DECLARATION

No portion of the work referred to in this thesis has been submitted in support of an application of another degree or qualification of this or any other university or other institution of learning.

Signature Date

COPYRIGHT STATEMENT

ACKNOWLEDGMENTS

I am heartily thankful to my supervisor, Dr Jonathan Dewsbury, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject.

I also would like to offer my regards and blessings to Dr Rodger Edwards and my parents who supported me in any respect during the completion of the project.

CHAPTER 1: INTRODUCTION

1.1 Introduction

Due to the spread of industrialization and the large growth in the world's population, the levels of energy consumption and carbon emissions have rapidly increased. This has created significant problems in the world from global warming and its consequences, eradicating many plants and several animal species. A greater consideration of planning and design could make huge changes towards a greener environment. Computer simulation of energy in buildings is a very useful approach towards better design. For that purpose, a set of reliable and accurate typical weather data is essential for any computer simulation in this area. This thesis explains the procedure of selecting a typical weather year for Ahvaz, a city in south west of Iran. Before that, brief explanations about the main aim and objectives have been presented in this chapter.

1.1.1 Consequences of fossil based energy consumptions

There have been a number of analyses on how carbon emissions are produced and harm the environment. It has been found that energy intensity is not the main problem, but the carbon intensity of each unit of energy. In other words, the amount of energy used for each unit of output, energy intensity, is not the main issue while the amount of carbon dioxide produced per unit of energy used creates greenhouse emissions. Countries with hydro and nuclear resources, like Brazil and France, have low carbon intensities while others such as China and Australia have high levels of carbon intensity as a result of using coal. There are three main areas in which carbon emissions can be highlighted, electricity generation, transport and buildings. [1]

Electricity can be produced with various types of energy production techniques, including green and low carbon techniques, while transportation is currently dependent on oil. The majority of recent reductions in emissions are due to significant changes in electricity generation techniques. As a result, in the short to medium term, the majority of low or zero carbon technologies are only available in relation to electricity. On the other hand, the transport sector needs long term plans with more legislation together with significant technological changes to meet the carbon reduction requirement. At the same time energy efficient design (including passive solar design) in buildings can reduce energy consumption by up to 75%. In this area, position of the sun is studied and used for heating and shading for cooling within the buildings. [2]

Almost one fifth of the world's population produces 60% of the world's CO2 emissions. Within developing countries which are affected the most, China alone is responsible for 18% of total greenhouse emissions. Since 1990, developing counties with a high level of economic growth, India, Middle East, other Asian countries and China, have seen their CO2 emissions almost double. Europe, on the other hand, has tried to keep its emissions at a constant level as a result of climate change policies on the continent. CO2 emissions per capita vary around the globe but more than 40% of the countries in the world produce carbon emissions of more than 4t CO2 per capita per annum. [3]

1.2 Aim and objectives

For energy efficient design of buildings, a set of typical weather data is necessary as one essential element. Iran suffers from a lack of knowledge in this area. Meanwhile, there has been a typical meteorological year (TMY) generated for Tehran and this has been presented by the US Department of Energy. There is no such data available for southern cities with a very different climate. Ahvaz is an example of this and is the second largest Iranian city after the capital, Tehran. The main aim of this work is to develop a typical weather year for Ahvaz. For that purpose, the following objectives have been considered:

- Undertake a literature review on typical weather year selection procedures
- Develop a new typical weather year for Ahvaz using four weather parameters including sunshine durations
- Generate hourly global and diffuse solar irradiation from sunshine durations
- Convert the selected TRY into IES format
- Simulate a simple building using the selected test reference year for Ahvaz to show a practical example of using the selected TRY

- Compare the selected TRY for Ahvaz with Kuwait and Tehran typical weather years through their mean and standard deviations

1.3 Structure of the report

Chapter 1 is an introduction of the work, including aims and objectives that have been followed. Chapter 2 briefly explains the energy situation in the World and in Iran together with a summary of Iran's geography and climate conditions. Chapter 3 presents the explanation and selection of typical weather data selection methods. This starts by defining four available weather parameters (3-hourly values) collected from Iran's Met Office: dry bulb temperature, relative humidity, wind speed and sunshine durations. This is then followed by selecting a new test reference year for Ahvaz using 3-hourly raw weather data including sunshine durations.

Chapter 4 concerns solar radiation models, daily sunshine durations from Iran's Met office to calculate daily extraterrestrial radiation, hourly extraterrestrial radiation, daily global solar radiation, hourly global solar radiation and diffuse fraction of hourly global solar radiation from sunrise to sunset.

In Chapter 5, the new selected test reference year is converted into IES format to make it usable for simulation purposes. IES is then used for a simple building simulation of a building in Ahvaz to show that the selected TRY works. For evaluation of selected TRY, Ahvaz's hourly weather data have been compared with those for Kuwait and Tehran through calculating their mean and standard deviations.

Chapter 6 is the conclusion in which the techniques and weather data selection have been summarised. Some recommendations have been made to develop and improve this project. There is complementary information presented in the appendices.

CHAPTER 2: ENERGY IN THE WORLD AND IRAN

2.1 Introduction

Any long-term strategic decision requires an accurate plan and precise data. This can particularly be seen in the energy sector which is the heart of many nations' economy today. According to the World Energy Council, a large number of people, nearly 1.6 billion, experience a lack of modern energy technologies. Transportation of energy now eases the process of energy use in the world. However, energy has become a very important political agenda for many countries around the globe as a result of tight competition in the energy market and the current increasing tensions in the Middle East. On the other hand, environmental concerns are the other side of the story. These concerns have produced significant new regulations that usually restrict the use of fossil-fuel energies. As the main subject of this project is very much related to energy modelling, a short account of energy in Iran and around the world is presented. [4]

2.2 Global warming

2.2.1 Global warming

Global warming affects human life, wildlife and all habitats on earth. It also increases climate variability which then affects negatively on agricultural activities. It increases the incidence of malaria, dengue fever, and other diseases in the tropics and harms ecological systems. In addition, an increase in sea levels due to climate change can threaten thousands of lives of those who live in coastal areas and also very small islands around the globe. [5]

It is believed that greenhouse gases are changing the climate on earth. These gases act in a similar way to greenhouses that allow solar radiation to get in but not out again. This leads greenhouse gases, such as CO_2, to prevent solar radiation from returning back to space and heat remains over the surface of the earth so that the temperature increases. Solar radiation is in shortwave and most of it penetrates through the atmosphere to the earth's surface. The earth's surface emits long wave radiation which is absorbed by the greenhouse gases and hence does not easily escape into space. The amount of change in global temperature might increase slowly but the consequences can be catastrophic. Sea levels and weather patterns are subjected to change so that species could be in danger. [6]

In December 1997, the United Nations made an agreement (Kyoto Protocol) on climate change to reduce greenhouse gases. This was held in Kyoto, Japan, where currently 186 countries, including the EU, have signed the Protocol. The United States, the world's largest source of greenhouse gas emissions, did not sign the Kyoto Protocol. At the Copenhagen climate change conference, the US agreed to cut its emissions by up to 17% by 2020. Similarly, the European Union has produced regulations to cut greenhouse gases Specifically CO2. European countries agreed in 1990 that they would reduce 8 types of greenhouse gasses by 8%. Over that time, Europe produced about 3200 million tonnes of carbon dioxide emissions. It is also suggested that renewable energies and more comprehensive usage of thermal insulations can help in meeting the targets of the Kyoto Protocol. [6]

2.3 Energy in the world

2.3.1 Coal, oil and natural gas

Global reserves of the main fossil fuels, particularly coal, are large enough to ensure a very long future for energy consumption. Coal is the most widely available fossil fuel that is affordable, reliable and secure. However, growing environmental challenges have raised doubts about using this fuel [3] .Location and characteristics of coal reserves in most countries are well-established. There is another technology called coal-to-liquid (CTL) which is a liquid form of fuel like gasoline and is produced through different processes. [3]

The Middle East remains the principal location of oil reserves, with 61% of the global total reserves, followed by Africa with 11%, South America and Europe (including the whole of the Russian Federation) with 8% and North America at just under 5% [1]. Oil consumption from exporting countries, such as the Middle East, South and Central America and Africa, account for about two thirds of the world's consumption. [8]

Global natural gas reserves are large and are estimated to last for the next 50 to 60 years. It is expected that in the coming two to three decades, natural gas will overtake oil as the most important energy resource in the world. However, a number of experts believe that this could be a huge challenge and needs a massive amount of investment. Since 1980, the world's known natural gas reserves have increased by 3.4% annually compared with 2.4% of oil reserves. This has been the result of increased exploration and implementing more accurate assessments of existing fields. [2]

2.3.2 Uranium and Nuclear

According to the World Energy Council, there are nine countries that own about 95% of the world's uranium output, which is estimated to be about 41.7 thousand tonnes. There were many international efforts to reduce military forces and their weapons at the end of the last century. As a result, in many countries a large amount of military nuclear activity has been shifted to civil-based purposes to generate energy for civilians.

Nuclear power is currently used to produce about 16–17% of the world's electricity demand. [4]

2.3.3 Renewable resources

One of the most important sources of renewable energy is hydropower. This form of energy production takes advantage of being reusable so that several power plants can be installed on the same watercourse to reuse the water flow more effectively. In 2005, renewable energy provided almost one-fifth of the total global power generation, of which around 87% was attributed to hydropower. [1]

Although hydropower is used to generate electricity in 160 countries, five countries, namely Brazil, Canada, China, Russia and the USA, account for more than half of global hydropower generation[1]. It is estimated that only 33% of the global potential in hydropower has been developed so far. These can be seen more in Western Europe and

North America, while there is still significant potential for hydropower stations in Asia, Africa and South America. Biomass is believed to potentially be the world's largest and most sustainable renewable energy source. Furthermore, wind is often considered to be the most advanced method of producing renewable energy, after hydropower. [4]

Bioenergy is produced using materials derived from biological sources as a source of energy. It covers different forms of fuel, such as wood, crops grown for fuel, agricultural residues, municipal solid waste, landfill gases, etc. Biofuel can be used in a variety of ways including transportation, power generation, industry, households, and so on. The sun is the main source of energy for this planet. Solar energy is available in the form of direct energy, e.g. solar radiation, and indirect energy, e.g. power from the wind, biomass, hydro and marine sources. Solar thermal collectors are commonly installed on roofs as panels capable of producing temperatures of 100^oC, and are used by applications for heating and cooling. There is an industrial type of solar collector capable of producing temperatures as high as 2000^oC or more. [1]

2.4 Energy in Iran

Iran's economy is mostly run and controlled by state authorities. The Iranian economy is mostly based on oil exports, accounting for about 85% of the nations' wealth. In 2004, Iran opened its first wind power and geothermal stations. Iran has also worked on nuclear technology in order to meet the large growth in electricity demand over the last few decades [9]. As Fig.1 illustrates, Iran has produces a much higher level of carbon emissions compared to the world average level. This factor demands more comprehensive and reliable practical energy policies in Iran.

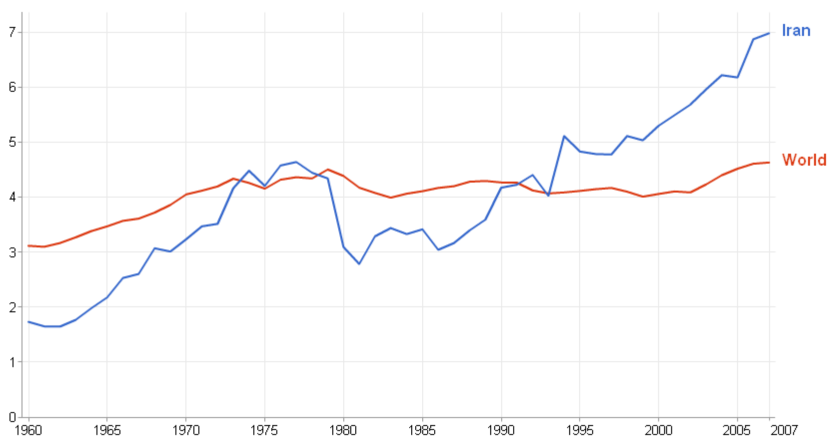


Figure 1 CO_2 emissions in metric tons per capita Iran and the World

Iran has the world's second largest proven oil resources after Saudi Arabia and the second largest gas resources after Russia. In 2008, Iran, with oil revenue of around $70bn, accounted for 5% of the world's oil market. Although Iran is a large oil exporter, it imports a massive amount of petrol each year. This is mainly because of shortages in petrol refineries together with a high level of wasteful consumption. Iran's new energies organisation has been allocated 0.2% of the annual oil income for developing research on new sorts of energy production [11]. It is estimated that Iran has some 90 billion barrels in its known reserves. [12]

2.4.1 Renewable energies

Iran has a large potential to offer renewable energy and is trying to expand its knowledge and budget towards more beneficial projects [13]. Biomass, Biogas, hydrogen energy, ceiling cooling systems, thermal heat pumps, thermal conversion and CHP systems (combined heat and power) are some of the technologies that are being considered by the Iranian Fuel Conservation Company. The Renewable Energy Organization in Iran (SUNA) is the body responsible for the research, provision and maintenance of renewable energies. The technical areas in which SUNA operate are photovoltaic power, wind and wave power, geothermal power and hydrogen power [14].

2.4.2 Wind energy

Wind energy has long been used in Iran for windmills, grinding grain and for pumping irrigation water. There are wind power stations in some windy areas of Iran, of which the Manjil Province in the north is the major one. A major issue of using wind energy is the cost of installation in a way that is able to compete with traditional energy sources. Transferring wind energy to customers is not easy, particularly in areas that are far from cities or inhabited areas. Although many suburban areas may have strong winds, the land is usually used for more economical purposes such as manufacturing and agriculture. [14]

2.4.3 Solar energy

Iran is located between two latitudes of 25° and 40°N and has one of the highest levels of solar radiation in the world. Solar energy is generally used for domestic solar water heaters and a number of new research subjects are being considered [14]. There have been several recently completed and in-process projects in the area of solar energy generation are being conducted by universities, research centres and the Ministry of Energy in Iran. Designing and simulating solar water pumps, solar water distillation in various forms, designing and manufacturing different types of solar collectors, solar refrigerators and air heaters are some examples [15]. The first solar project in Iran was in Yazd which started in 1993 with a capacity of 10kW. [16]

2.4.4 Geothermal energy

Generally, this energy can be created by pumping and transferring very hot water and vapour through pipelines into power plants to feed turbines. Iran has geothermal energy potential in its north provinces where the average temperature of the springs is estimated to be 85°C and up to 150°C with the most optimal conditions [15] When drilling, a large amount of water is extracted and wasted, while a proportion which is re-injected into the ground is feared to become poisoned. Another aspect that has been discussed in this project is the noise produced from power plant operations, mainly from cooling towers, transformers and turbine generators. [17]

2.4.5 Passive solar design

Buildings in Iran consume some 40% of all the energy provided by different resources. Within this 40%, around 70% of the energy is normally used for heating and cooling systems inside buildings. A large amount of CO^2 emissions are produced as a result of the air-conditioning used in many buildings. In many Middle Eastern countries, particularly in Iran, natural ventilation systems are used, such as wind catchers in buildings in order to ventilate indoor climates. Wind catchers are associated with a long underground water canal that cools the basement of a building and the air circulation continues so that the indoor temperature can remain much lower than outside. This can cool the indoor temperature down to 25°C when the outside temperature is 40°C. A wind catcher tower can be seen in the following figure. [18]

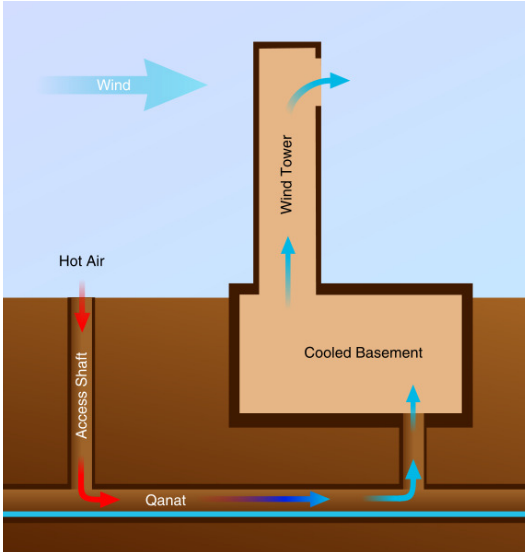


Figure 2 Wind catcher system in Iran

2.4.6 Thermal insulation

The use of thermal insulation in its very historical methods can be seen in many historical buildings in Iran, where they were insulated using simple and natural materials such as natural fiber based insulation such as sheep's wool. It should be noted that thermal insulation alone does not meet the energy saving requirements of buildings and many other considerations should be taken into account, such as windows to prevent heat transfer from and into the buildings. [13]

2.5 Geography and climate

Iran is located in the south-western part of Asia in the Middle East. It shares borders with three commonwealth independent states (CIS), Armenia, Azerbaijan and Turkmenistan. The Caspian Sea is located to the north, Turkey and Iraq to the west, the Persian Gulf and Oman Sea to the south, and Pakistan and Afghanistan to the East. A series of large mountains surround Iran in two different directions. Alborz and Zagross are the two mountain ranges located to the north and midlands accordingly. Most of the land is above 1500 feet, while one-sixth of it is above 6500 feet. Iran has arid plateaus which are extended to Central Asia. One of the most remarkable characteristics of these plateaus is the salt waste called Kavir, which is 200km long and half as wide. [19]

The Persian Gulf is located between the Arabian Peninsula and south-east Iran. The sea has an area of about 240,000 square kilometres. The Persian Gulf has a very harsh climate with very high temperatures and humidity. There are usually heavy rains between November and April. Thunderstorms and fog are rare but there are many dust storms particularly during summer. [19]

There are different types of climates in Iran, ranging from subtropical to subpolar. Also, Iran has very high and low pressures during the year. In winter, high pressure comes to the Iranian plateau from the high pressure belt in Siberia. In addition, low pressure is developed over the warm waters of the Caspian Sea in the north and the Persian Gulf in the south. In summer, Iran has one of the world's lowest pressure centres, occurring in the south. Low pressure systems in Pakistan create two types of wind in Iran, the Shamal blows in February to October and the 120-day summer wind that can reach 70 miles per hour in the south east of the country, mainly in the Sistan province. On the other hand, a warm and humid wind is also directed from the Persian Gulf. [19]

Temperature varies throughout the country. In summer, temperatures can range from 50^{o}C in Khuzistan near the Persian Gulf to 1^{o}C in the Azerbaijan Providence situated in the north-west. Precipitation also varies from less than 2 inches in the south to about 78 inches in the north and areas around the Caspian Sea [19]. Iran's total area is about 1.65 million sq km, including 1.636 million sq km of land and 12,000 sq km of water. Iran's climate is mostly arid and semi-arid with a humid forest zone near the Caspian Sea. Temperatures average between 10°C – 25°C in the winter and 19°C – 38°C in the summer. [20]

2.6 Energy policies in Iran

The Ministry of House and Urban Development provided a series of 20 guidelines for all national construction projects. Among them, Scheme 19 is about energy efficiency in buildings. In 1988, this scheme came into force and is mandatory for all public buildings. The government in Iran supports companies and organisations that follow Scheme 19 (Energy Efficiency in Buildings) of the Iranian Civil Engineering Organisation. There are currently 34 companies benefiting from this subsidisation. These firms mostly manufacture double-glazing, Unplasticised Polyvinyl Chloride (UPVC) windows, thermal insulations, etc. [13]

CHAPTER 3: WEATHER DATA, SELECTION AND ESTIMATION

3.1 Introduction

Weather data is an essential factor for predicting building performance. As the thermal simulation programmes become more complicated, more accurate and specific weather data is needed. For manual calculations within the building's thermal environment, three main factors are usually required: solar radiation, mean sol-air temperature and mean air temperature. On the other hand, for the thermal simulation of buildings, hourly data is necessary for a range of weather and solar parameters such as temperature, wind speed, humidity and solar radiation. [21]

Design data is for sizing heating and cooling systems, typical weather data is for estimating energy consumption. This thesis is concerned with typical weather data. Due to global warming, it is likely that the future climate experienced by buildings will be different from what represented by the available weather data. This problem is not dealt within this thesis.

Indoor and outdoor temperature difference for an unheated building is expected to be around 3°C. In other words, if an indoor temperature of 18.5°C is needed, the building should be heated for outdoor temperatures of below 15.5°C (18.5-3). This information can be used for the calculation of heat loss and energy consumption. [22]

3.2 Weather parameters

CIBSE Guide J introduces several parameters that are influential in the thermal behaviour of buildings and should be considered when performing a thermal simulation. Air temperature, atmosphere moisture content, wind, solar irradiation, sunshine duration and precipitation are the parameters suggested by CIBSE [23]. Meanwhile, air temperature and solar irradiation have the most crucial rules for thermal simulation purposes. [24]

Air temperature is defined in two parts: dry bulb temperature and wet bulb temperature, by which air moisture properties can be calculated. In addition, solar irradiation is defined as direct irradiation normal to the sun and diffuse irradiation. The air moisture parameter can be expressed in several ways such as moisture content as grams of water per kilogram of air (g/kg), enthalpy (latent heat content kj/kg) and the specific volume (litres/kg). [24]

3.3 Hourly weather data for simulation

Each parameter can have 8,760 hourly values over a year. By carrying out a simulation program, it is possible to predict the building's energy consumption and to design the building's equipment size according to the type of weather data used (typical or near extreme). As the weather data is usually available as proprietary files within software packages, it may be difficult to make any adjustments. Some software programmes, such as IES, supply the weather data in binary form, while some others, such as TAS and Arup E+TA, offer more access to weather data and can even be modified easily in Arup E+TA. [24]

3.4 Typical weather data for simulation

Thermal simulation sing hourly time steps over complete simulated year has made simplified methods obsolete, because it much more accurately considered the effects of building thermal capacity and fluctuating heat inputs, outputs and system operation. To model the long-term average or typical performance of a building, it is necessary to simulate the system behaviour using either a large number of years of real weather data or a year of typical weather with the most average values compared to the long term. The former offers a more accurate outcome while the process requires a large timescale. The latter, on the other hand, makes the calculation process shorter with relative confidence of producing reliable results. This is the approach usually adopted.

This chapter explores the generation of a year of typical weather data of the type known as a Test Reference Year (TRY) for Ahvaz, a city in the south west of Iran. A test reference year has never been generated for Iranian cities including Ahvaz, the second largest city in Iran. However, a typical meteorological year (TMY) is available for Tehran through the US Department of Energy. The method used will be described after a brief historical background of selecting typical weather years for simulation purposes is provided.

3.5 Typical weather data selection methods

The general procedure for selecting typical weather data has two main steps, choosing the best months from a number of different years and providing a smooth transition between months that are joined to form different years. The final constructed year of hourly values needs to have the following conditions: the mean value of individual variables, their frequency distribution and the correlation between different variables in each month are as close as possible to the calendar month of the long term data. [28]

There are several selection methods that have been applied by different countries, mostly in British and American scientific centres. The two main approaches, Typical Meteorological Year (TMY) and Test Reference Year (TRY), are defined below. The CIBSE Example Weather Year (EWY) is also explained as the previous method used in the UK [28]. According to the CIBSE (Guide J), a separate study provided a comparison between the EWY and the European Test Reference Year (ETRY). Independently, ETRYs were selected for four sites in the UK and a further 25 in other EU countries. The result was various UK weather years, obtainable from different sources and under different conditions. Quality control of the raw data is essential to make sure that there is no missing or faulty data that could cause simulation errors or software crashes.

CIBSE EWY method was based on simplicity of selection, required only monthly mean weather data. This method has been modified to develop a more precise and sensitive method of selection where daily weather data in the individual months of the raw data can be analysed with the long term mean and distribution functions. The new approach produces the basis of the CIBSE Test Reference Year (TRY).

3.5.1 CIBSE Example Weather Year (EWY)

In the early 1980s, the Chartered Institution of Building Services Engineers (CIBSE) concluded there was a need for typical weather data for use in the design stage in order to predict the energy consumption in building applications. This resulted in the creation of the Example Weather Years (EWYs) in which a whole year was selected as the typical reference year. EWY was made by the Example Weather Year Task Group at CIBSE and was determined by several essential criterion including: [25]

- A whole year was chosen
- CIBSE Example Year should be a real year
- The year should start on 1st October, the beginning of the heating season

3.5.1.1 Selection procedure

The main idea of the EWY is to select a year for which the monthly mean values of a number of pertinent parameters do not differ by more than a specified number of standard deviations from their long term mean. Hitchin and Holmes suggest that the number of standard deviations used should be two. There is a possibility that several years could be chosen as the EWYs. Therefore, the final selection would be the one with the lowest deviation from the long term mean values. The parameters that are used in this method are: [25]

- Global radiation on a horizontal surface
- Diffuse radiation on a horizontal surface
- Daily mean wind speed
- Mean maximum dry bulb
- Mean minimum dry bulb
- Mean dry bulb
- Infiltration number

EWY was superseded by other methods mainly because it was difficult to find a complete year with no missing data and all monthly means close to long term means.

3.5.2 Typical Meteorological Year (TMY)

Instead of attempting to find a complete typical year in the TMY and TRY methods, it is only necessary to find a complete typical January, a complete typical February, etc. The 12 selected months are then connected in a series to make a complete year. Because adjacent months are generally selected from different years, discontinuities occur at the month interfaces. These may be smoothed if required using simple linear interpolation or more elaborate methods. [29]

Hall and his colleagues developed the Typical Meteorological Year method. Similar to TRY, a Typical Meteorological Month (TMM) for each of the twelve calendar months is selected from the raw weather data using statistical methods. After that, twelve selected months are merged to make a TMY. Hall and his colleagues found a TMY for 26 SOLMET stations in the USA by hourly or tri-hourly weather data over 23 years from 1953 until 1975. [26]

3.5.2.1 Selection procedure

The selection procedure starts by choosing five candidates with the closest figure to the long term mean values for each twelve calendar months. Normally the following parameters are needed for generating TMY. [26]

- Daily min, max and mean dry-bulb temperature
- Dew point temperature
- Daily max and min wind speed
- Daily global horizontal solar radiation

The calculation starts by comparing the cumulative distribution functions (CDFs) of each year with the CDF for the long term database of all years. The closeness of each year's CDF to the long term CDF for each parameter is measured using the Finkelstien-Schafer (FS) statistics. This is the absolute difference between the long term CDF and the yearly CDFs. The smallest FS value shows the minimum difference between CDFs, so that the closest year to the long term data can be found. The main difference between the various selection approaches is the weighting factors used in estimating the FS statistics [27]

3.5.3 Test Reference Year (TRY)

The British Standard (BS EN ISO 15927-4:2005) suggests a procedure for generating a typical weather data comprising hourly values for several meteorological parameters which can then be used for the assessment of cooling and heating loads in the buildings. [28]

3.5.3.1 Selection method

According to British Standard, parameters that are usually used for generating a Test Reference Year are: dry bulb air temperature, direct normal solar irradiance and diffuse solar irradiance on a horizontal surface, Relative humidity, absolute humidity water vapour pressure or dew point temperature and Wind speed at 10m above the ground. TRY is based on the cumulative distribution functions of the parameters. [28]

In some cases, weather data may only be available in the form of e.g. daily or 3-hourly values rather than hourly. The TRY can be selected using the available measured data, and hourly values then estimated from the data. This approach is used in this thesis. [30]

According to CIBSE Guide J, TRY uses a quantity that shows the differences between cumulative frequency distributions (CFDs). This quantity, the Finkelstein-Schafer (F-S) statistic, which is shown in Eq.1, is applied separately to the frequency distributions of each month, in respect of meteorological elements. All candidate months from a long-term raw dataset are analysed, ranked and filtered for typicality in four stages:

1. The cumulative distribution functions of each of the meteorological elements in each source month are compared to the corresponding CDFs of the parent dataset (using the F-S statistic as a means of expressing differences between CDFs).

Cumulative distribution function is the rank order of the values of a parameter when drawn up in increasing order within a specified period. [28]

The FS statistic (Eq.1) sums the absolute differences between two cumulative distribution functions (CDFs) as follows: [31]

$$FS(p,m,y) = \sum_{i=1}^{Nm} \left| CDF(i,m,y) - CDF(i,m,Ny) \right| \tag{1}$$

The FS statistic determines how similar two distributions are. The more similar distributions give smaller FS-values and if the two distributions were identical then the FS-values would count zero. [29]

2. Equal weighting is assigned to the F-S statistics for each of the elements and the sum of the F-S values is calculated for each calculated month.

$$FS_{(min)\mathrm{sum}} = FS_{\mathrm{min}}\ (\mathrm{DBT}) + FS_{\mathrm{min}}\ (\mathrm{RH}) + FS_{\mathrm{min}}\ (\mathrm{WS}) + FS_{\mathrm{min}}\ (\mathrm{SH}) \tag{2}$$

3. The source-months (from different years) with the lowest sums if the FS values are chosen as typical months, which are then aggregated into a composite calendar year

4. If required, interpolation is used to smooth the transition between consecutive months that are selected from different years.

CDFs of the individual and long term data can be plotted and analysed visually. In some charts, the selected months may not be fully matched to the long-term CDFs. One reason is because the final selected months are chosen by considering all used parameters over the selection procedure. Another reason is that some of the selected months have to be replaced by months with the next closest FS-value to the long-term CDF since month with missing data can not be used in TRY. The two following figures prove the above explanation. In Figure 3 the selected month (April) for sunshine hours is not completely overlapped with the green curve (long-term CDF). The legend shows the best (b) selected month from 1991 (b-91), the worse selected month (maximum FS-value) in 2000 (w-00) and the long-term CDF (long). Fig.3 shows that even the best months are not always close the long term CDF. In Fig.4, in contrast, the selected month has a CDF very close to the long term CDF.

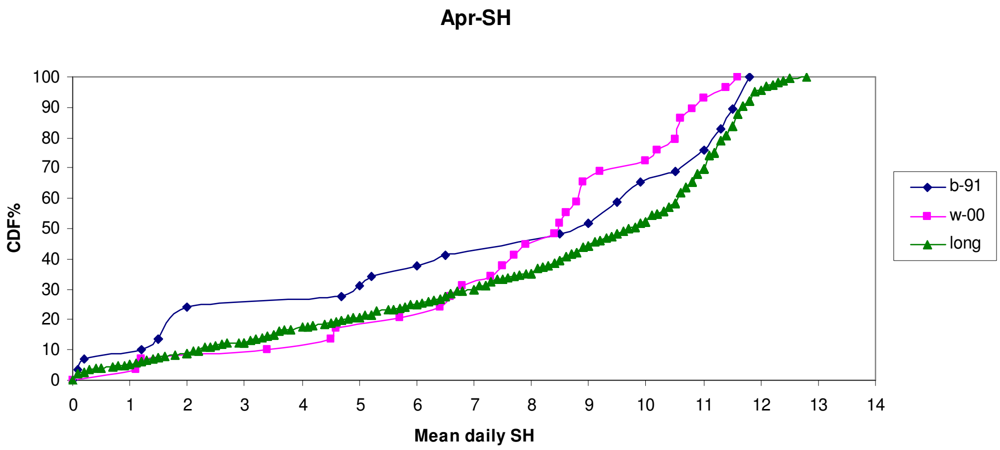


Figure 3 A sample in which the best month does not visually seem the best choice

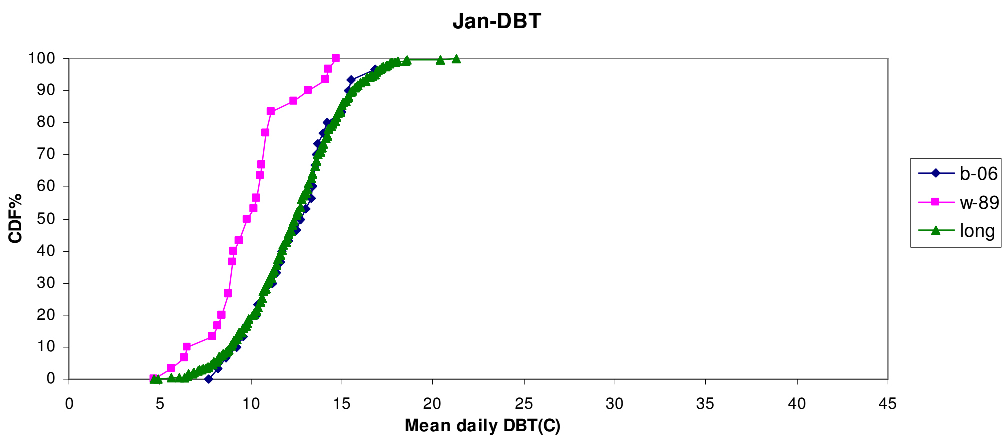


Figure 4 A sample in which the best month visually seems the best choice

3.6 Test Reference Year as the selection method

Test reference year (TRY) has been selected as the methodology for generating a typical weather year for Ahvaz as this method is accepted and suggested by the British, European and International Standards (BS EN ISO 15927-4:2005) together with a large number of researchers and scientists using it in their typical weather selection procedures.

3.7 Weather data for Ahvaz

Ahvaz is located in the south west of Iran where the climate is hot and humid. Ahvaz city is the capital of the province Khuzestan and it is built on the banks of the Karun River, the largest river in the country. Ahvaz, with a population of around 1,300,000, is the second largest Iranian city after the capital, Tehran. The average elevation of this city is 20 meters above sea level. Ahvaz has a very long summer with a maximum temperature of about 54°C and very short winter with a minimum temperature of around 2°C. The Iran Meteorological organisation (IRIMET) provides a number of weather data for all Iranian cities including Ahvaz. The weather data is available in two forms of three-hourly (Table.1), and average monthly values.

Four parameters, dry bulb temperature, relative humidity, wind speed and sunshine duration, have been considered for selecting TRY for Ahvaz. The raw data are in the form of tri-hourly values for the first three parameters, dry bulb temperature, relative humidity and wind speed, and daily values for sunshine durations. Table 1 and 2 show samples of temperature values in 2006. There is some missing data among the sunshine hours. Nineteen years of raw data, from 1987 to 2006, excluding 2005, have been used for selecting TRY. Weather data for 2005 was unavailable within the databases in Tehran's Meteorological office. The weather data was quality checked for missing data and errors. There are still some missing data shown by (*****), Table 2.

As was previously mentioned sunshine hour data has some missing data that should be tackled before going to the next stage. To deal with this issue, those months with missing data were removed from the individual cumulative distribution functions (CDFs) while the remaining available data were used in the whole long term dataset. Wind speed raw data is provided in (knot). CDFs for best, worst and the long term dataset (Appendix B1) and variations between months (Appendix B2) have been calculated in knots while the rest of the calculation; IES weather file conversion, building simulation and mean and standard deviations have been calculated in $m.s^{-1}$.

Table 1 An example of raw weather data provided by IRIMET

									January Year 2006												
									Hourly Dry and Wet Bulb Temperature												
HOUR		0		3		6		9		12		15		18		21	Mean				
DAY	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	MIN.	MAX.	MEAN DAILY
1	7.2	5.4	6.4	4.8	9.8	6.2	15.8	9	18.2	11	13.6	9.4	10.8	8.2	9.4	6.8	**11.4**	7.6	5.8	19.2	12.5
2	7	5.8	7.2	6.4	10	7.4	14.6	10.4	17	11.2	14.8	11	12.4	9.8	10	8.8	**11.6**	8.8	6	17.6	11.8
3	9.4	7.6	8.4	7	11.2	8.6	16.6	11	19.6	11.6	15	10.8	12.2	9.2	9.4	8	**12.7**	9.2	7.6	20.4	14
4	7.8	6.8	7.8	6.4	11	8.4	18	11.6	20.4	12.2	17	12.2	14.6	9.8	11	8.2	**13.4**	9.4	7.2	20.6	13.9
5	9.2	7	8	6.6	11	7.4	16.8	11.2	20.4	12.6	17.8	12.2	14	9.8	12	8.4	**13.6**	9.4	7.4	21	14.2
6	8	6	7.2	6	10.8	8.6	19.2	12.6	22	13.2	17	11.8	13.2	10.2	10	8	**13.4**	9.5	6.4	22.4	14.4
7	7.8	6.8	7.4	6.6	9.4	7.6	17.6	12.8	20.6	13	18	13.2	15.8	13.4	15.6	14.2	**14**	10.9	7	21.2	14.1
8	13.8	12.4	14	12.4	15.8	12.2	19.4	15	18.4	15.6	14.6	13	13.2	12.4	13.8	12.6	**15.4**	13.2	13.6	20.4	17
9	13.2	12	13.6	12.4	14	12.4	18.2	14.6	17.8	15.4	16.8	13.8	14.4	13	12	11.8	**15**	13.2	12.6	19.4	16
10	9.4	9.4	8.4	8.2	10	9.4	17	12.6	19.4	13.4	16	12	15.4	11.6	14.2	11.2	**13.7**	11	7.8	19.6	13.7
11	13.8	12.4	14.4	13	15.8	14.8	17.4	15.4	19.8	16.6	18.6	16	17.4	16.2	17.4	14.8	**16.8**	14.9	13.2	20.4	16.8
12	16	15	15.2	14.4	15	14	16	15	17.8	15.6	15.8	14.8	15.2	13.2	13.4	12	**15.5**	14.2	14.6	18.4	16.5
13	12	10.8	11.2	10	12	10.8	14.6	12.8	15	12.8	14	12.2	13	11.4	12.4	11.4	**13**	11.5	10.8	15.8	13.3
14	12	11.2	11.6	11.2	12.4	11.2	16	11.6	17.6	12	15	11.2	11.6	10.2	11.6	9.2	**13.5**	11	11.4	17.8	14.6
15	9.6	7.8	8.2	7	9	7.4	14	10.4	16.6	11.2	14.2	10.2	12.4	9	9.6	7.6	**11.7**	8.8	7.8	16.8	12.3
16	8	6.6	6.4	5.4	8.6	7	13.4	9.2	15	10.2	12.8	9.2	11.4	8.8	7.8	5	**10.4**	7.7	6.4	15.6	11
17	5.6	4.2	5.2	3.4	8.8	5.4	13.2	7.8	14.4	8	12.4	6.8	10.2	6	8.2	4.8	**9.7**	5.8	4.6	14.8	9.7
18	5.8	4	3.6	2	7.4	4	11	6	12	6	10.4	5.6	6.8	4	5	3	**7.7**	4.3	3	12.8	7.9
19	3.4	2.2	2.8	2	7.8	5.6	12.8	7.4	13.6	8	12.6	7.4	8.6	6.2	7.2	5.4	**8.6**	5.5	2.6	14.6	8.6
20	5.2	4	4.4	3.4	8.8	6.2	13.6	8.8	16.4	10.2	13.4	9.2	10.8	7.6	9.8	7.2	**10.3**	7.1	4.4	16.4	10.4
21	8.6	6.8	9.2	7.4	10.6	7.6	15.8	9.4	17.4	11.4	14.4	10.2	11.8	9	9.4	7.2	**12.1**	8.6	8.4	18.2	13.3
22	6.4	4	5	2.8	5	2.6	10	6.2	12.2	7.8	11.2	7.4	9	5.6	7	4.6	**8.2**	5.1	4.8	12.8	8.8
23	5.4	3.6	4.4	3	7.4	4.6	13.6	9.6	14.8	10.4	15	10.8	11.8	9	11	9	**10.4**	7.5	4.4	16.5	10.4
24	10.8	9.6	11.2	9.8	12.8	10.6	18.4	12.8	21	13	18.6	13	15.8	12.4	13.8	11.4	**15.3**	11.6	10	21.8	15.9
25	12.8	11.2	12.6	10.8	14.8	12.6	12.4	11.8	13.4	11.6	14.8	12	16	14	16.6	14	**14.2**	12.2	12.4	16.6	14.5
26	17.4	14.6	17.4	14.6	18	14.2	18.6	13.6	18.6	12.8	16.4	13.4	13.4	12.2	14.6	12.6	**16.8**	13.5	14.4	19.6	17
27	14.6	13.2	13.8	13	14	13.6	13.6	13.2	13.2	12.8	13.8	13.2	12.2	11.8	11.6	11.2	**13.3**	12.7	13.2	14.6	13.9
28	10.4	9.4	9.4	8.6	9.6	8.8	15.2	12.4	17	11.8	15	10.6	12.6	9.2	10.8	8.2	**12.5**	9.9	8.8	17.4	13.1
29	7.6	6.8	7.6	6.6	10.4	8	14	9.6	15.4	10	13.4	9.6	11.6	8.4	9.4	7.2	**11.2**	8.3	6.2	16	11.1
30	7.8	6.4	6.4	5.4	8.2	6.2	12.6	9.2	13.4	8.4	11.2	7.2	9.4	6.2	8	5.2	**9.6**	6.8	6.4	14.6	10.5
31	5.8	4	3.6	2.8	9.4	6	13.2	7.2	13.4	7.4	11.4	7	8.4	5.4	8.2	5.8	**9.2**	5.7	3.6	14.2	8.9
MEAN	9.4	8	8.8	7.5	10.9	8.7	15.2	11	16.8	11.5	14.7	10.9	12.4	9.8	11	8.9	12.4	9.5	8.2	17.7	12.9

Table 2 Presentation of missing data shown by **** within the raw data

									July 1990											
							Hourly	Relative Humidity And Daily Precipitation												
HOUR		0		3		6		9		12		15		18		21		MEAN		
DAY	DEW	HUM	DEW	HUM	DEW	HUM	DEW	HUM	DEW	HUM	DEW	HUM	DEW	HUM	DEW	HUM	DEW	HUM		SUN SHINE
1	10.7	33	12.2	39	9.6	22	9.6	13	9.2	11	9.2	12	6	14	7.4	18	9.2	20.3	25	*****
2	6.9	22	7.8	25	9	19	3.6	9	3.4	9	3.8	11	4.2	15	4.2	18	5.4	16	26	*****
3	4.4	20	5.6	25	6	17	5.8	12	3.2	9	3	10	5.6	16	8.3	22	5.2	16.4	26	*****
4	8.6	27	7.6	27	6.4	16	5.1	11	3.2	9	4.4	11	7.4	18	9.1	23	6.5	17.8	26	*****
5	8.6	27	11.2	37	12.6	27	12	18	1.8	8	4.4	10	10.6	22	11.7	27	9.1	22	22	*****
6	11.4	30	11.4	35	12.8	27	13.3	19	5.6	10	7.3	12	9.4	19	11.3	24	10.3	22	22	*****
7	11.8	31	11.3	32	10.6	20	8.4	12	9.6	12	9.3	13	8.7	17	8	21	9.7	19.8	24	*****
8	9.4	25	11	31	13.6	24	12	16	3.5	8	7.8	11	10.6	18	9.8	20	9.7	19.1	24	*****
9	10.2	23	11.7	27	17.7	29	15.4	19	13	14	10.2	12	9	15	12.5	23	12.5	20.3	30	*****
10	21	47	27	69	25	54	21	27	9.8	12	7.2	10	10	17	4.8	14	15.7	31.3	30	*****
11	9.1	22	11.5	30	7.6	17	7.2	12	*****	*****	-2	6	4.8	13	8.1	19	6.6	17	25	*****
12	8.7	24	8.1	25	6.3	17	5.6	12	4.4	9	8.4	13	11.3	21	4.8	16	7.2	17.1	27	*****
13	11.1	29	9.8	29	9.4	21	7.9	13	6	10	4.8	10	8.6	14	2	15	7.4	17.6	26	*****
14	3.7	19	13.4	42	15	28	12	16	1.7	7	0.9	7	6.3	15	12.5	30	8.2	20.5	24	*****
15	10.8	30	12.1	33	11.8	20	6.1	10	4.6	8	2.5	8	9.7	17	6.5	15	8	17.6	24	*****
16	7.2	19	9.6	26	5.4	14	3.3	8	4.5	8	3.6	8	8.9	15	10.3	20	6.6	14.8	27	*****
17	8.4	20	10.6	25	11.5	21	10.5	13	9.3	10	4.5	8	11.7	18	8.2	17	9.3	16.5	29	*****
18	8	21	9.5	25	3.1	8	2.8	7	7.7	9	4.9	8	6.4	13	-2.6	8	5	12.4	28	*****
19	6.4	19	9.2	26	6.4	13	1.7	7	5.2	8	2.2	7	-0.9	7	3	12	4.1	12.4	25	*****
20	3.4	16	6.2	22	3.8	9	8.5	10	3.3	7	6.1	9	4.4	11	7.4	20	5.4	13	25	*****
21	7.4	21	13	35	3.8	12	4.9	8	5.7	8	2.8	7	6.8	13	8.2	17	6.6	15.1	27	*****
22	24	65	23.7	71	25.6	58	18.9	25	8	10	2.2	7	5.6	13	6.4	15	14.3	33	28	*****
23	4.9	17	8.5	26	8.6	16	0.9	6	22	6	3.2	8	7.6	15	8.2	18	8	14	24	*****
24	5.8	20	7	23	9.5	19	6.8	10	3.6	7	4	8	4.4	11	8	17	6.1	14.4	27	*****
25	7.5	20	10.1	26	7.4	15	5.9	9	10.6	11	8.8	10	5.6	12	4.9	15	7.6	14.8	25	*****
26	20	49	26.2	78	22.8	47	17.9	24	8.5	10	4.4	8	21.8	16	5.8	15	15.9	30.9	24	*****
27	9.4	21	9.4	23	10.8	18	4.9	8	7.4	9	3.5	8	8.8	16	9	19	7.9	15.3	29	*****
28	9.3	22	9.9	27	9.5	18	9.8	13	0	6	2.4	8	12.2	22	10.4	22	7.9	17.3	26	*****
29	10.4	27	13.9	36	11	22	8.4	13	8.7	12	8.4	13	9.6	18	12.5	26	10.4	20.9	23	*****
30	12.4	28	11.6	31	11.7	24	10.7	15	8.6	12	6.1	12	6.5	16	8.1	20	9.5	19.8	26	*****
31	8.2	23	6.8	23	4.5	14	1	8	1.2	8	3	11	5.6	16	7.8	21	4.8	15.5	24	*****
MEAN	9.6	26.4	11.5	33.2	10.6	22.1	8.4	13	6.4	9.2	4.9	9.5	8	15.6	7.6	18.9	8.4	18.5	25.7	11.5

Those months with missing sunshine data and their alternatives are as follows. Also, for choosing the worst month, Jan 1987 is chosen instead of Jan 1989 that has SH missing values.

Table 3 Choosing the next best month after removing months with missing data

Next Best Month	Best month (including SH missing data)
Mar 1999	March 1989
May 2004	May 1989
June 1993	June 1994
Aug 2003	Aug 1993
Oct 2003	Oct 2004
Nov 1988	Nov 1991

All weather data collected from the IRIMET are in the ASCII form and can be seen with Notepad in Windows. The data are separated every two years or so in a single file. These data have been transferred into the Microsoft Excel form in order to analyse and carry out calculations. Each individual parameter in each year is then moved into a single Microsoft Excel file.

After that, the cumulative distribution function of each calendar month over all years of the dataset has been calculated from large to small before calculating their rank percentage in another table.

Table 4 Daily mean temperature for January (1987-2006) ranked from highest to lowest

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2006
1	17.3	14.8	14.7	14.9	16.4	13.9	15.8	21.3	17.2	17.5	17.6	16	17	17.8	14.9	17.7	16.7	17.9	16.8
2	16.9	14.4	14.3	14.6	16.3	13.6	15.6	20.4	16.6	17.1	17.5	14.9	16.3	16.3	14.8	17.4	16.5	17	16.8
3	16.9	13.5	14.1	14.3	15.9	13.2	15.4	20.4	16.2	16.9	17.5	14.8	15.8	16.2	14.1	17.2	15.9	16.9	15.5
4	15.8	13.5	13.2	14.3	15.6	12.4	14.6	18.6	14.6	16.3	17.1	14.2	15.7	15.4	14	16.3	15.4	16.8	15.4
5	14.6	13.2	12.4	14.2	15.4	12.3	13.9	18.5	14.6	15.9	16.3	14.2	15.4	15	13.9	15.5	15	16.7	15.3
6	14.4	13	11.1	13.5	14.9	12.3	13.4	18.1	14.5	15.9	15.3	14.2	15.4	14.9	13.9	13.7	14.9	16.5	15
7	13.9	12.8	10.8	13.4	13.8	12.1	13.2	17.2	14	15.2	15.2	13.8	15.4	14.2	13.7	13.2	14.9	15.8	14.2
8	13.9	12.7	10.8	13.2	13.6	11.5	13.1	15.9	13.7	15	15	13.7	15	14.2	13.6	13.1	14.7	15.6	14
9	13.8	12.7	10.6	12.2	13.3	11.4	12.7	15.6	13.5	14.9	14.9	13.4	14.8	13.8	13.6	12.7	14.5	15.6	13.7
10	13.8	12.5	10.6	11.7	12.4	11	12.7	15.5	13.4	14.6	14.5	13.4	14.7	13	13.6	12.2	14.3	15.1	13.6
11	13.6	12.4	10.6	11.4	12.2	11	12.4	15.4	13.4	14.2	14.2	13.3	14.7	12.6	13.5	12.1	14.2	15.1	13.5
12	13.4	12.3	10.5	11.2	12	10.7	12.2	15.3	13.3	14.1	14.2	13.2	14.7	12.5	13.4	11.9	14.1	15	13.4
13	13.3	12.1	10.3	11.2	11.7	9.8	12	15.3	13.2	13.9	13.9	12.6	14.5	12.4	13.4	11.7	14.1	14.9	13.4
14	13.1	11.9	10.3	11.1	11.6	9.7	11.7	15.2	12.7	13.5	13.3	12	14.5	12.3	13.3	11.6	13.5	14.6	13.3
15	13.1	11.9	10.2	10.9	11.5	9.6	11.6	14.8	12.7	13.3	13.1	12	14.2	11.9	13.3	11.6	13.5	14.5	13
16	12.7	11.5	9.8	10.4	11.4	9.6	11.6	14.4	12.7	13.1	13	11.3	14	11.7	13	11.6	13.4	14.5	12.7
17	12.6	11.4	9.4	9.9	11.4	9.5	11	14	12.6	12.8	12.9	11.1	13.7	11.6	12.9	11.3	13.1	14.4	12.5
18	12.6	11.2	9.4	9.3	11.3	9	10.6	14	12.5	12.8	12.9	10.8	13.6	11.3	12.7	11.1	12.8	14.4	12.1
19	12.2	11	9.1	9.3	10.4	8.9	10.4	13.8	12.4	12.2	12.7	10.7	13.2	10.8	12.7	11	12.8	14.2	11.7
20	12	10.9	9	9.2	10.3	8.3	10.2	13.6	12.2	12.1	12.5	10.1	13.1	10.8	12.5	10.9	12.6	14	11.6
21	11.9	10.8	8.8	9.1	9.9	8.1	10.2	13.5	11.8	12	12.4	9.9	12.9	10.7	12.4	10.9	12.4	14	11.4
22	11.6	10.6	8.8	8.9	9.9	7.9	9.9	13.1	11.3	11.9	12.2	9.6	12.7	10.6	12.3	10.9	12.2	13.9	11.2
23	11.5	10.5	8.8	8.9	9.8	7.1	9.6	13	11.3	11.7	12	9.5	12.6	10.5	12.2	10.7	11.9	13.6	10.4
24	11.5	9.7	8.4	8.8	9.8	6.8	9.5	13	10.8	11.4	11.9	9.3	12.6	10.4	11.5	10.4	11.3	13.6	10.4
25	11.4	9.5	8.4	8.7	9.8	6.6	8.7	12.3	10.7	11.3	11.6	8.9	12.5	9.9	11.1	10.3	11.1	13.5	10.3
26	11.2	9.3	8.2	8.3	9.6	6.6	8.6	12.2	10.6	11.1	11.5	8.7	12.4	9.8	10.5	10.2	10.8	13.4	9.7
27	11.1	8.8	7.9	8.3	9.2	6.5	8.3	12.1	10.5	10.9	11.3	8	11.7	9.7	10.4	10.2	10.7	13.2	9.6
28	10.8	8.7	6.5	8.2	9.2	6.5	8.2	11.8	10.5	10.5	11.1	7.7	11.7	9	9.9	9.8	10.6	12.9	9.2
29	10.2	8.1	6.4	7.7	9	6.4	7.8	11.8	10.3	10.5	10.6	7.6	11.5	8.9	9.5	9.2	10.5	12.8	8.6
30	8.5	7.5	5.6	7.2	9	6.1	7.5	11.7	9.6	9.2	10.6	7.3	11.4	8.1	9.3	9	10.4	12.8	8.2
31	8.2	6.9	4.7	7.2	7.4	4.9	6.9	11.6	8.6	7.9	9.7	6.9	11.3	8.1	7.9	8.8	10.3	12.2	7.7

Meanwhile, the cumulative distribution function of all values of each parameter over the whole dataset are calculated together with their rank order to determine the Finkelstein-Schafer (FS) statistics (Table.5), where the minimum value represents the most typical month for each calendar month. The table below shows the calculation of the CDF for the whole dataset for all four parameters used in the selection procedure. For each individual month, cumulative distribution functions have been calculated by presenting rank orders increasing from top to bottom. The third column is the rank order of values over the whole dataset. After that, rank percentages have been calculated for each rank order. At last, the rank percentages have been multiplied by 100 in order to make it clearer to show the comparisons on the charts.

Table 5 CDF of all parameters with their rank orders

Day Numbers	Temp Mean	Rank Order	Rank Percentg.	Rank Pcg. *100
1	8.5	4.7	0	0
2	8.2	4.9	0.001	0.1
3	10.2	5.6	0.003	0.3
4	11.4	6.1	0.005	0.5
5	11.1	6.4	0.006	0.6
6	13.8	6.4	0.006	0.6
7	13.3	6.5	0.01	1
8	11.9	6.5	0.01	1
9	10.8	6.5	0.01	1
10	12.6	6.6	0.015	1.5
180	6.6	10.9	0.297	29.7
181	6.5	10.9	0.297	29.7
182	7.1	11	0.307	30.7
183	7.9	11	0.307	30.7
184	8.1	11	0.307	30.7
185	9.7	11	0.307	30.7
186	11	11	0.307	30.7
187	9.5	11.1	0.316	31.6
188	11	11.1	0.316	31.6
189	12.4	11.1	0.316	31.6
190	13.4	11.1	0.316	31.6
579	12.1	17.5	0.979	97.9
580	8.2	17.6	0.984	98.4
581	10.4	17.7	0.986	98.6
582	15.3	17.8	0.988	98.8
583	14.2	17.9	0.989	98.9
584	16.8	18.1	0.991	99.1
585	13.3	18.5	0.993	99.3
586	12.5	18.6	0.994	99.4
587	11.2	20.4	0.996	99.6
588	9.6	20.4	0.996	99.6
589	9.2	21.3	1	100

Day Numbers	RH Mean	Rank Order	Rank Percentg.	Rank Pcg. *100
1	75	35.5	0	0
2	82.9	38.6	0.001	0.1
3	79.4	46.1	0.003	0.3
4	73.1	46.9	0.005	0.5
5	79.8	47	0.006	0.6
6	80	47.1	0.008	0.8
7	71.3	47.9	0.01	1
8	61.8	48	0.011	1.1
9	70.3	49.1	0.013	1.3
10	75.5	49.5	0.015	1.5
180	68.9	66.8	0.301	30.1
181	67.1	66.8	0.301	30.1
182	59.6	66.8	0.301	30.1
183	52.3	67	0.309	30.9
184	55.3	67	0.309	30.9
185	79.1	67	0.309	30.9
186	75.9	67.1	0.314	31.4
187	73.3	67.1	0.314	31.4
188	73.5	67.1	0.314	31.4
189	87.5	67.1	0.314	31.4
190	93.8	67.1	0.314	31.4
579	60.9	95.3	0.982	98.2
580	58.3	95.8	0.984	98.4
581	64.5	96.4	0.986	98.6
582	63.9	96.4	0.986	98.6
583	78.9	96.5	0.989	98.9
584	67.8	96.5	0.989	98.9
585	93	96.5	0.989	98.9
586	71	96.6	0.994	99.4
587	66.5	97.3	0.996	99.6
588	64.3	97.5	0.998	99.8
589	56.9	97.6	1	100

Day Numbers	Wind Mean	Rank Order	Rank Percentg.	Rank Pcg. *100
1	5.5	0	0	0
2	0	0	0	0
3	0	0	0	0
4	1	0	0	0
5	0	0	0	0
6	10.9	0	0	0
7	1.8	0	0	0
8	5.3	0	0	0
9	0	0	0	0
10	3.8	0	0	0
180	2.3	1.5	0.253	25.3
181	0.5	1.5	0.253	25.3
182	0	1.7	0.307	30.7
183	5.8	1.8	0.309	30.9
184	1.3	1.8	0.309	30.9
185	11	1.8	0.309	30.9
186	1	1.8	0.309	30.9
187	1	1.8	0.309	30.9
188	0.5	1.8	0.309	30.9
189	0.8	1.8	0.309	30.9
190	0.5	1.8	0.309	30.9
579	8.6	10.9	0.981	98.1
580	7.8	11	0.984	98.4
581	0.5	12.4	0.986	98.6
582	4	12.5	0.988	98.8
583	5	12.8	0.989	98.9
584	13.8	12.8	0.989	98.9
585	6.4	13	0.993	99.3
586	5.3	13.8	0.994	99.4
587	5	13.9	0.996	99.6
588	5.3	14.1	0.998	99.8
589	1.3	16.6	1	100

Day Numbers	Sunshine Hours	Rank Order	Rank Percentg.	Rank Pcg *100
1	8.9			
2	8			
3	6.3			
4	8.1			
5	6.6			
6	0			
7	3			
8	9	0	0	0
9	9.1	0	0	0
10	0	0	0	0
180	3.8	3.5	0.289	28.9
181	7.5	3.5	0.289	28.9
182	6.8	3.6	0.299	29.9
183	9	3.7	0.301	30.1
184	8.3	3.8	0.302	30.2
185	0	3.8	0.302	30.2
186	6.1	3.8	0.302	30.2
187	7.7	3.8	0.302	30.2
188	7.3	3.9	0.309	30.9
189	0.2	4	0.311	31.1
190	0	4	0.311	31.1
579	6.2	10	0.977	97.7
580	0.5	10	0.977	97.7
581	5.3	10	0.977	97.7
582	6.4	10	0.977	97.7
583	0	10	0.977	97.7
584	0	10.1	0.991	99.1
585	0.3	10.1	0.991	99.1
586	9.1	10.2	0.994	99.4
587	7.2	10.2	0.994	99.4
588	8.3	10.3	0.998	99.8
589	9.5	10.5	1	100

The most typical month for each calendar month was selected considering the sum of FS_{min} values of all parameters.

Table 6 Selected years for each month for the TRY for Ahvaz

Month	Best Year selected	Worst year	FS(min)
January	2006	1989	6.805
February	1998	1997	6.393
March	1999	2000	6.482
April	1991	2000	7.095
May	2004	1993	7.531
June	1993	1992	9.892
July	2004	1992	9.356
August	2003	1991	13.26
September	2002	1991	7.96
October	2003	1992	9.098
November	1991	1998	6.072
December	2003	1998	8.065

3.8 Hourly DBT, RH, WS from three-hourly data

After generating the test reference year, hourly values for these three parameters have been calculated through linear interpolation between the three hourly values supplied by IRIMET. Linear interpolation is simple and widely used by other researchers. Hour 24 of each day is the first hour of the next day because the hours are numbered from 0 to 23. The following graphs illustrate hourly values for DBT, RH for January 1st and WS for October 30th.

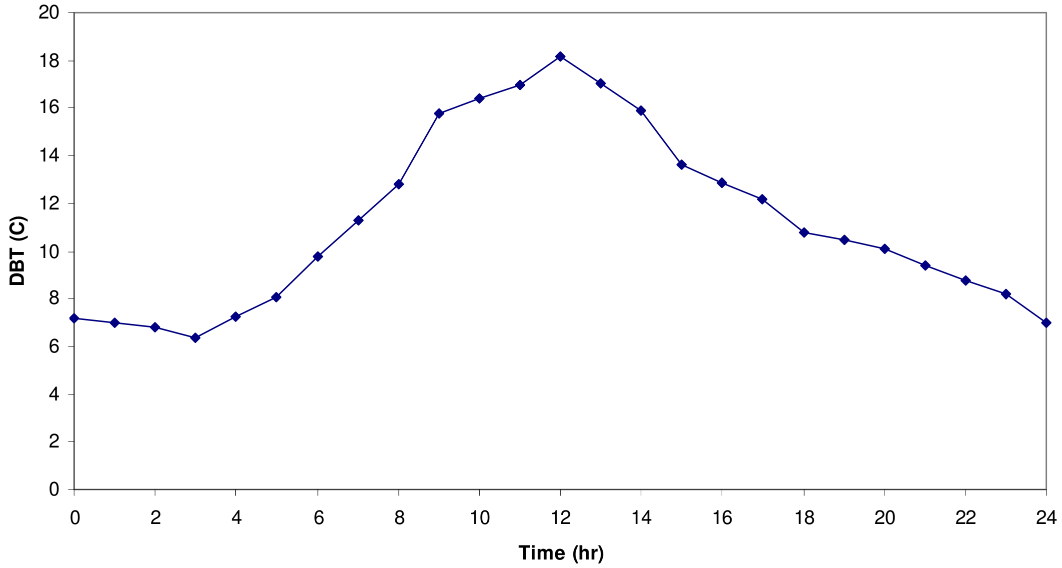


Figure 5 Hourly DBT January 1st generated from 3-hourly values

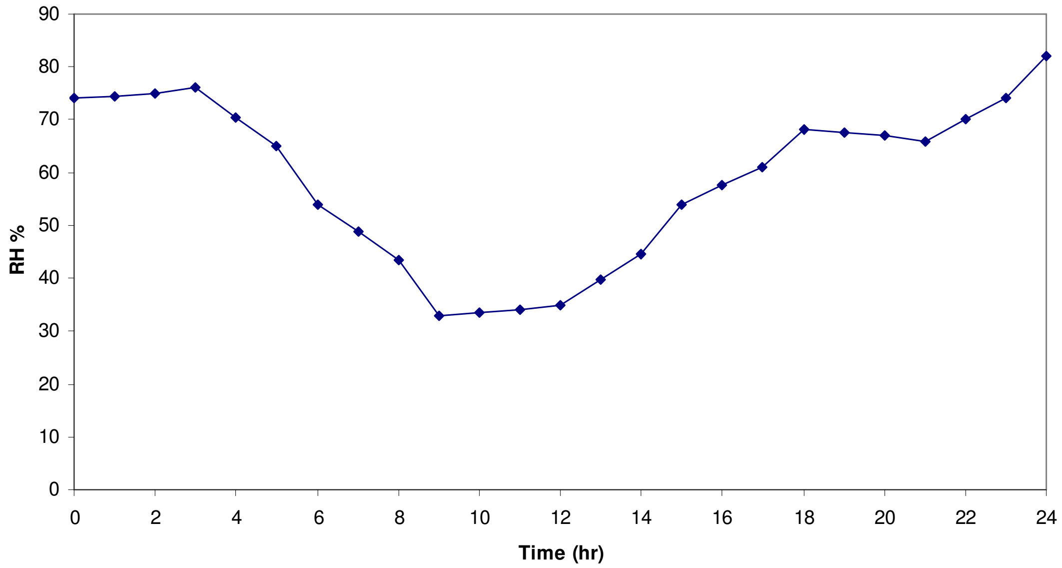


Figure 6 Hourly RH January 1st generated from 3-hourly values

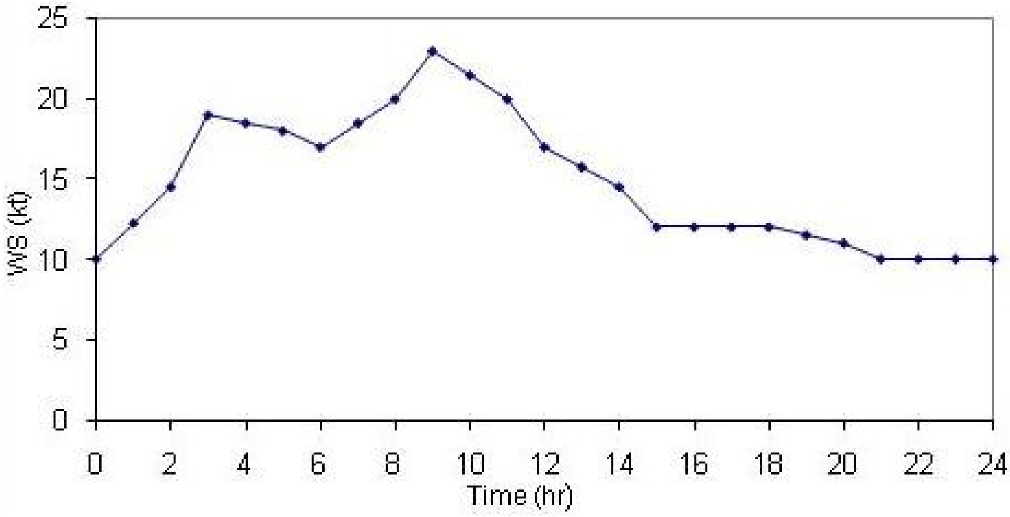


Figure 7 Hourly WS October 30th generated from 3-hourly values

Hourly values of solar radiation will be dealt with in the next chapter.

3.9 Smoothing between months

TRY includes the most typical months that are combined to make a whole typical year. As the selected months are from different years through the whole dataset, the joint between them could become mismatched. By showing TRY components, DBT, RH and WS on graphs, a number of variations are shown in Fig.5 to Fig.9. it will be seen that the joints between months are not noticeable among the normal day to day variations.

In order to examine the variations and jumps between any two selected months more closely, two days before and two days after the borders have been plotted and can be seen in appendix B2 and B3. Jumps between two selected months are not large so joints remain unsmoothed. Two examples are shown in Figures 8 and 9. In case one would want to carry out the smoothing process, a procedure is presented in reference number 31.

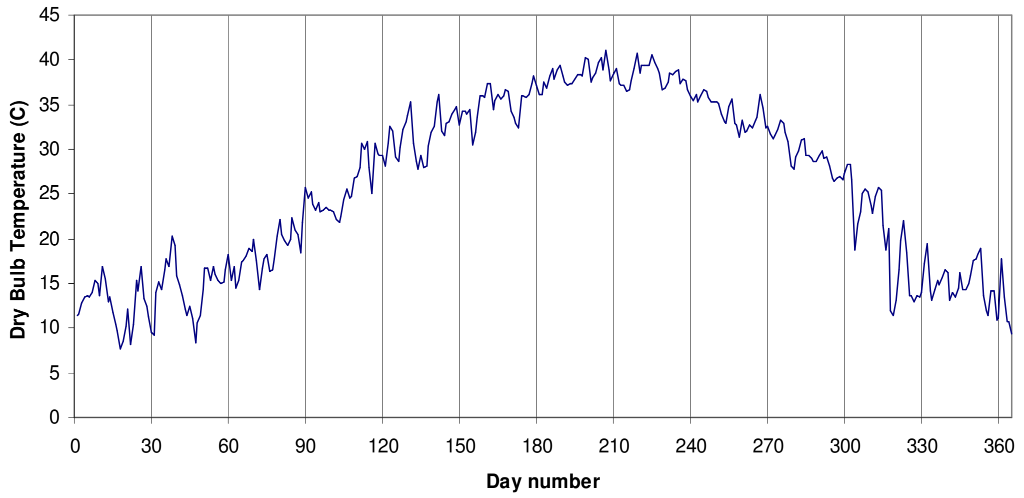


Figure 8 Variations of daily mean values of DBT over a whole year (TRY) for Ahvaz

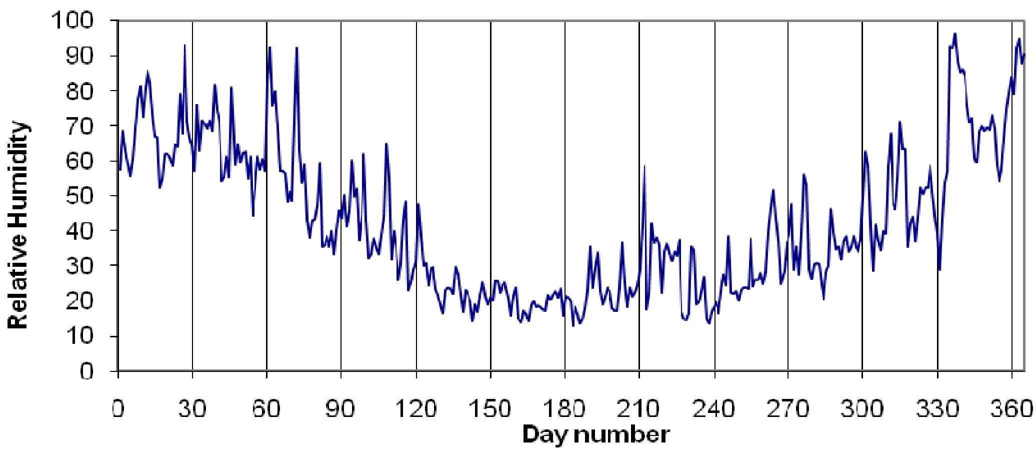


Figure 9 Variations of daily mean values of RH over a whole year (TRY) for Ahvaz

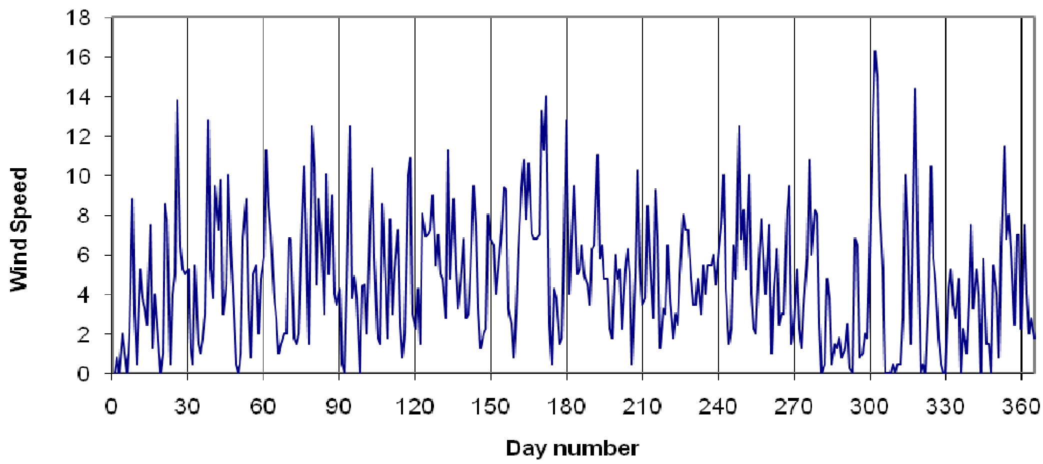


Figure 10 Variations of daily mean values of WS (kts) over a whole year (TRY) for Ahvaz

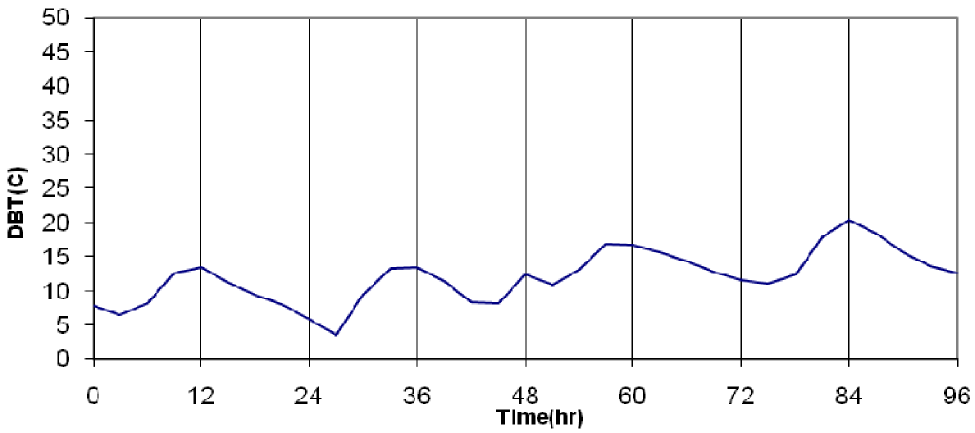


Figure 11 Variations of 3-hourly DBT 30Jan06-31Jan06 --- 01Feb98-02Feb98

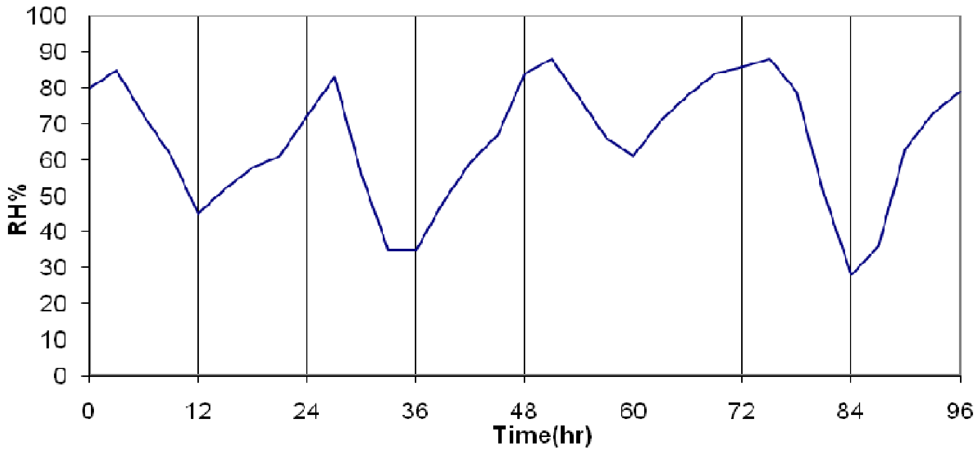


Figure 12 Variations of 3-hourly RH 30Jan06-31Jan06 --- 01Feb98-02Feb98

CHAPTER 4: SOLAR RADIATION MODELS

4.1 Introduction

Local solar irradiation data is vital for a number of applications, such as air conditioning and solar system design and analysis. Several empirical methods have been prepared to model solar irradiation using weather parameters including sunshine durations. This chapter explains the procedure of estimating hourly global and diffuse solar radiation from the number of sunshine hours occurring on a single day. The procedure is then applied to generate hourly solar radiation values for the selected TRY.

The extraterrestrial solar radiation is initially found and used in the calculation of daily global solar radiation. After that, the hourly global solar radiations from sunrise to sunset have been estimated followed by hourly diffuse solar radiation estimation. Hourly global and diffuse solar radiations are the two essential parameters for energy modelling software such as IES. The following diagram illustrates the procedure of calculating hourly global and diffuse solar radiation.

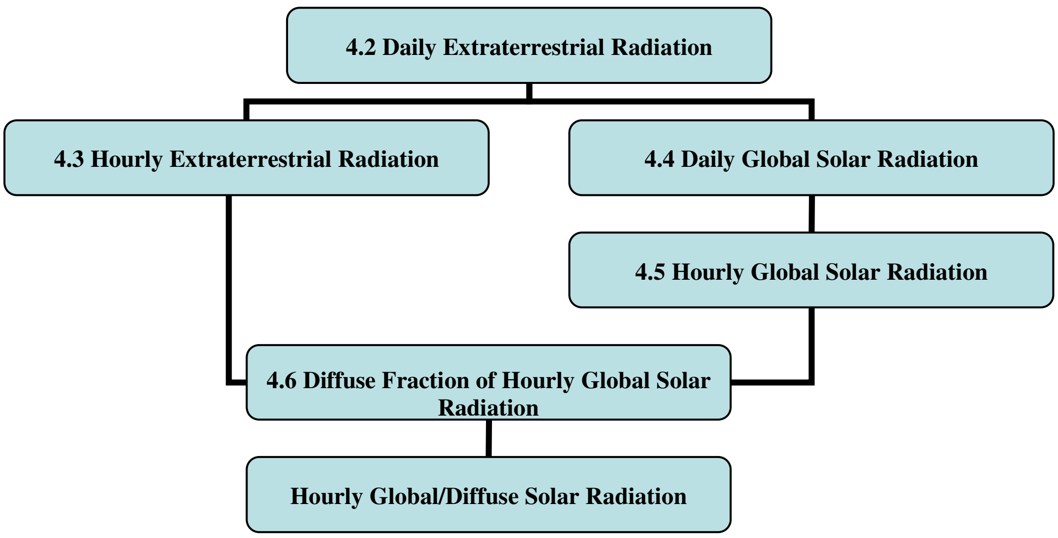


Figure 13 Hourly global/diffuse solar radiation calculation

4.2 Daily extraterrestrial radiation

The solar radiation received at the top of the earth's atmosphere on a horizontal surface is called extraterrestrial radiation. Extraterrestrial radiation is a function of latitude, date and time of day. The extraterrestrial radiation, Ra, for each day of the year and for different latitudes can be estimated using solar constant, the solar declination and the time of the year by: [32]

$$R_a = \frac{24(60)}{\pi} G_{sc} d_r [\omega_s . Sin(\lambda). Sin(\delta) + Cos(\lambda). Cos(\delta). Sin(\omega_s)], \quad (4)$$

The latitude, λ, expressed in radians, is positive for the northern hemisphere and negative for the southern hemisphere. The conversion from decimal degrees to radians is given by:

$$(Radians) = \frac{\pi}{180} (Decimal Degrees). \quad (5)$$

Table 7 Latitude of Ahvaz (Iran) at 31° 19’ N in radians

Latitude	Ahvaz (Northern Hemisphere)
Degrees and minutes	31°19’N
Decimal degrees	31 + 19/60 = 31.31
Radians	(л/180) 31.31 = **+ *0.55***

The latitude of Ahvaz in radians is equal to 0.55. The inverse relative distance of the Earth-Sun, d_r, and the solar declination, δ, are given by: [32]

$$d_r = 1 + 0.033 Cos(\frac{2\pi}{365} i), \quad (6)$$

$$\delta = 0.409 Sin(\frac{2\pi}{365} i - 1.39), \quad (7)$$

Solar declination for the latitude of Ahvaz over a whole year of 365 days is plotted in the following chart.

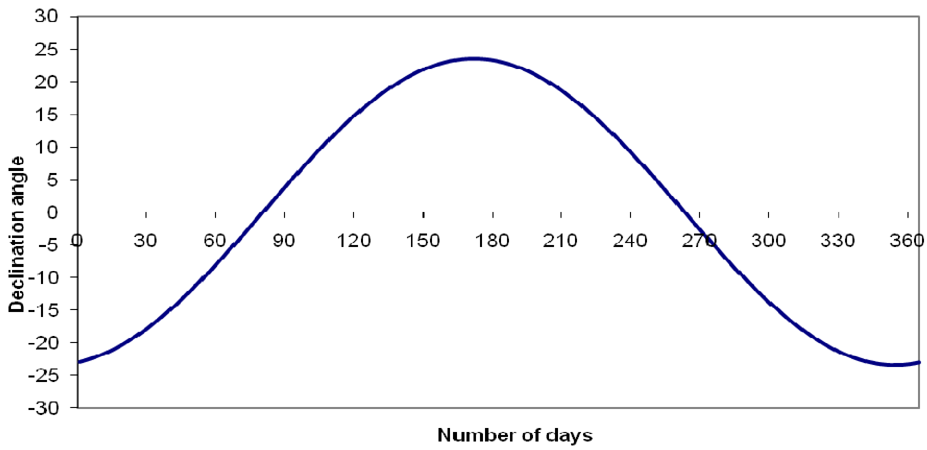


Figure 14 Solar declination for Ahvaz (Iran)

The sunset and sunrise hour angle, ω_s, and the daylight hours, N, are given by: [32]

$$\omega_s = Arc\cos[-\tan(\lambda).\tan(\delta)], \tag{8}$$

$$N = \frac{24}{\pi}\omega_s. \tag{9}$$

The following chart shows the annual variation of daylight hours (N) at 31.31° North.

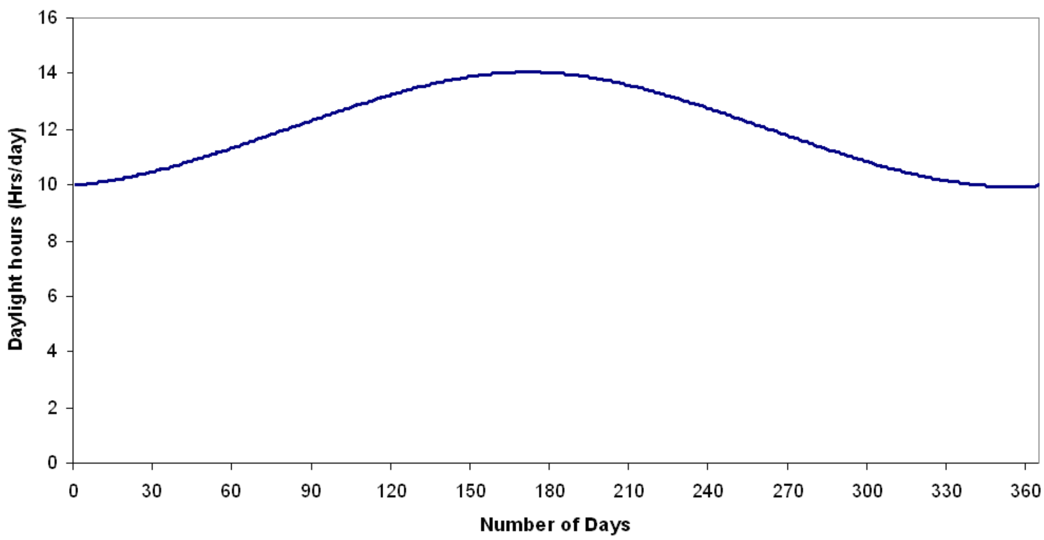


Figure 15 Annual variation of daylight hours (N) at 31.31° North

Extraterrestrial radiation for Ahvaz is found from equation (4) and is plotted in the following chart.

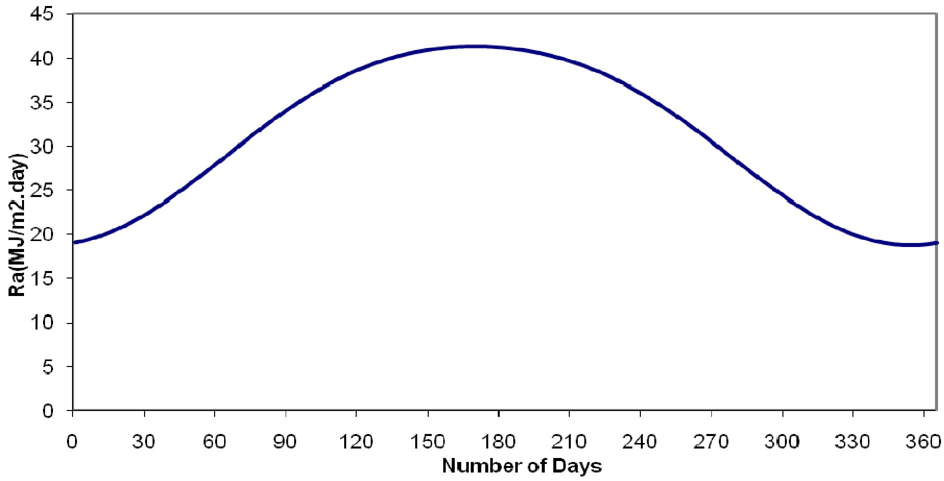


Figure 16 Daily extraterrestrial Radiation for Ahvaz

4.3 Hourly extraterrestrial radiation

The hourly extraterrestrial radiation, R_{ah}, can be found from the following equations [33]

$$R_{ah} = G_{sc}.\ d_r.\cos(\psi) \tag{10}$$

$$\psi = \text{Arccos}\ \{\sin(\lambda).\sin(\delta) + \cos(\lambda).\cos(\delta).\cos[tr_e.\ (h_r - hr_o)]\} \tag{11}$$

4.4 Daily global solar radiation from sunshine durations

For Ahvaz, there is no measured solar radiation data available apart from sunshine hours; therefore, these have been used to estimate the global solar radiation. Sunshine hours can easily be measured and this data is available for many other locations apart from Ahvaz. A number of models for estimating daily global solar radiation from daily sunshine duration have been described in the literature. [32]

A comparison by Almorox and Hontoria has been done between four regression models to calculate solar radiation for sixteen different stations in Spain. These models are linear, quadratic, third degree and logarithmic. Software (Statgraphics Plus) was used to do the comparison. The results illustrate that all models have similar outcomes with tiny differences. It is found that the third degree model has the best results while the linear model gave good and similar accuracy compared to others. This test was also done for two different groups of annual and seasonal calculation. It was found that annual results would be satisfactory. [34]

Ampratwum did a study on several main solar radiation models: original (linear) and modified (linear-logarithmic) Angstrom-Black type regression functions, a quadratic function, a power relationship, a power-trigonometric equation and one from a new Angstrom-Black type logarithmic model. The results show a good performance of all estimators of global solar-radiation from sunshine hours. However, the non-linear models were better than the basic linear models. The power-trigonometric model estimated the radiation values best. The quadratic and linear-logarithmic models were the preferred models when only the relative sunshine hours are used. [35]

Ertekin evaluated twenty six available models for computing the monthly average daily global radiation on a horizontal surface. The comparison was based on errors that occurred including the mean percentage error (MPE), root mean square error (RMSE) and the mean bias error (MBE). Empirical models of solar radiation using various parameters including extraterrestrial radiation, sunshine hours, relative humidity, temperature, soil temperature, number of rainy days, altitude, latitude, total precipitable water, albedo, cloudiness and evaporation. [36]

The Angstrom method uses a linear relationship between the ratio of daily global radiation to extraterrestrial global radiation and the ratio of daily sunshine hours to the maximum possible sunshine hours (i.e. the day length). [32]

$$R_s = (\alpha_s + b_s.n/N).\ R_a \tag{12}$$

In this research, it was decided to use the Angstrom model because it is simple and widely used by other researchers. Sunshine hours can easily be measured and this data is widely available. Sunshine hours may be used to estimate global solar radiation. Most of the models available are based on the use of sunshine ratios. As an example, the Angstrom method uses a linear relationship between the two ratios of average daily global radiation to the maximum global solar radiation on a clear day and the ratio of the average daily sunshine hours to the maximum possible sunshine hours or simply the day length. [34]

Estimated daily solar radiation from sunshine durations is illustrated in Fig.17.

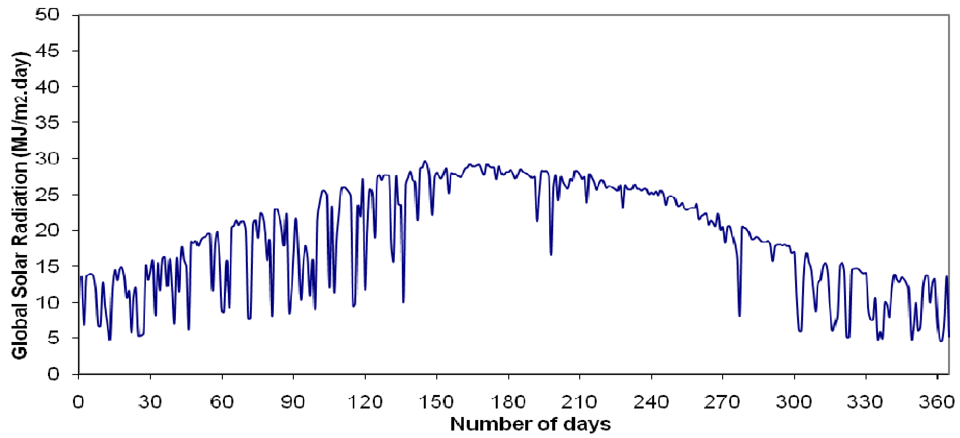


Figure 17 Daily values for Global Solar Radiation for Ahvaz over the TRY

Depending on atmospheric conditions (humidity, dust) and solar declination (latitude and month), the Angstrom values a_s and b_s will vary. [34] There is a comprehensive database of these coefficients available, *European Solar Radiation Atlas*, for most European sites [23]. In very clear climates the sum ($a + b$) can exceed 0.76. In very dirty or dusty climates the sum may fall below 0.68. There are many places in the world that have very different atmospheric conditions in different seasons of the year. Therefore, different coefficients can be presented for different months. [23]

Where no actual solar radiation data are available to enable calculation of actual a_s and b_s parameters for the site, the values $a_s = 0.25$ and $b_s = 0.50$ are recommended [32]. As there is no data for Ahvaz for this matter, these recommended values have been used in the calculation of TRY.

4.5 Generation of hourly global solar irradiation (HGSR)

This section concerns estimating hourly global solar radiation from daily values. For this purpose, Chaw's model has been used. [37]

$$R_{sh} = \frac{M}{2}\left(\cos\left[\frac{(t-12).2\pi}{(SS-SR)}\right]+1\right). \qquad (13)$$

$$M = 2MHGSR \qquad (14)$$

$$MHGSR = DGSR / N \qquad (15)$$

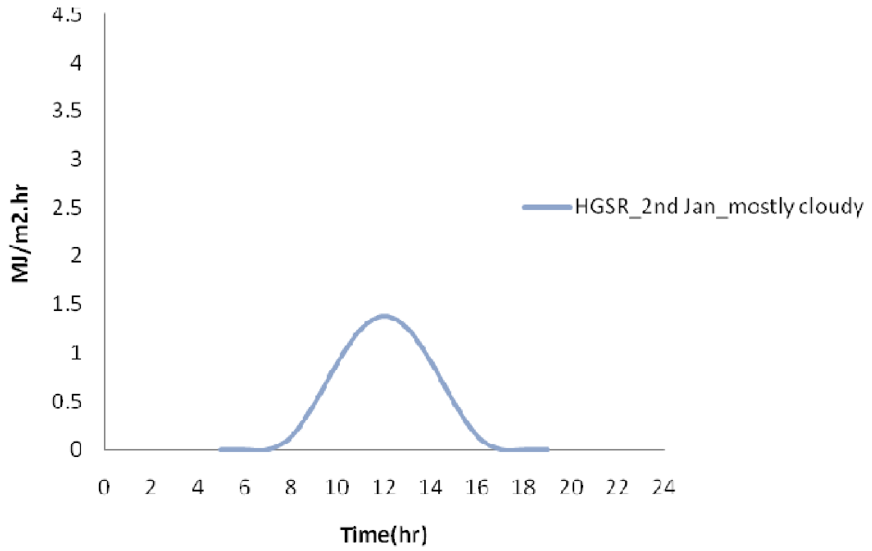


Figure 18 Hourly Solar Radiation for Ahvaz on January 2nd [MJ/m^2.hr]

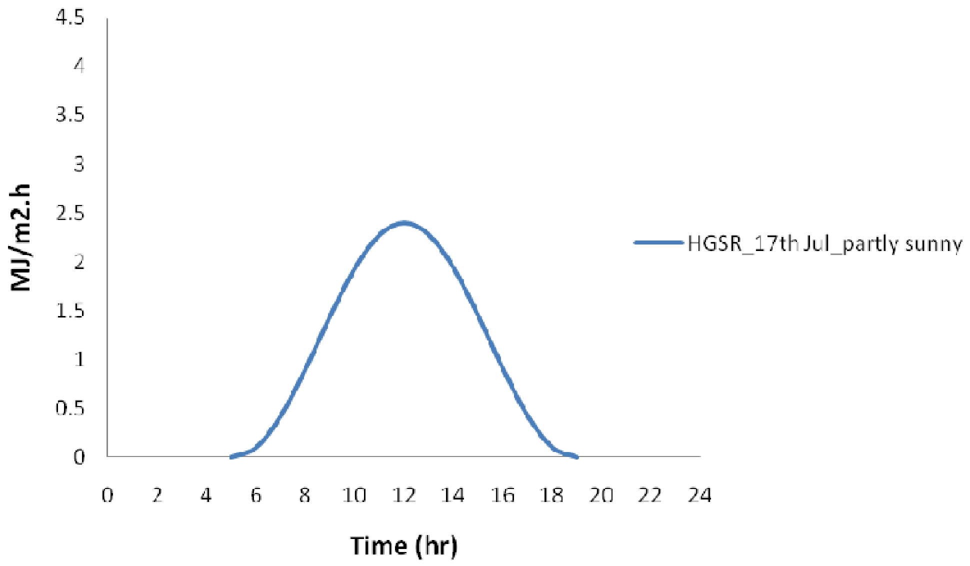


Figure 19 Hourly Solar Radiation for Ahvaz on Jul 17th [MJ/m^2.hr]

$MJ/m^2.hr$ may be converted to W/m^2 as follows:

$$MJ/m^2.hr * 24 * 11.6 \rightarrow W/m^2 \quad (16)$$

4.6 Estimating diffuse fraction of hourly global radiation

For many thermal analysis and software modeling, the global solar radiation is not the only necessary solar factor, but the diffuse fraction of the global radiation is also needed. It is found that the diffuse radiation is very much related to the clearness index K_T, that is a criterion for clearness of the atmosphere. There is a relationship between K_T and the ratio of the hourly diffuse radiation to the hourly global radiation. K_T is the ratio of hourly global to hourly extraterrestrial radiation, R_{sh}/R_{ah}. [38]

$$R_{dh} = R_{sh} (1-0.09K_T) \qquad \text{for } K_T \leq 0.22$$

$$R_{dh} = R_{sh} (0.09511-01604K_T+4.388 K_T^2-16.638K_T^3+12.336K_T^4 \qquad \text{for } 0.22 < K_T \leq 0.80 \quad (17)$$

$$R_{dh}= R_{sh} *0.165 \qquad \text{for } K_T > 0.80$$

The above figures show the estimated hourly global and diffuse radiation for a mainly cloudy day and a partly sunny day. The completed data for the Ahvaz TRY is included on CD as a text file and as on IES format file with this thesis.

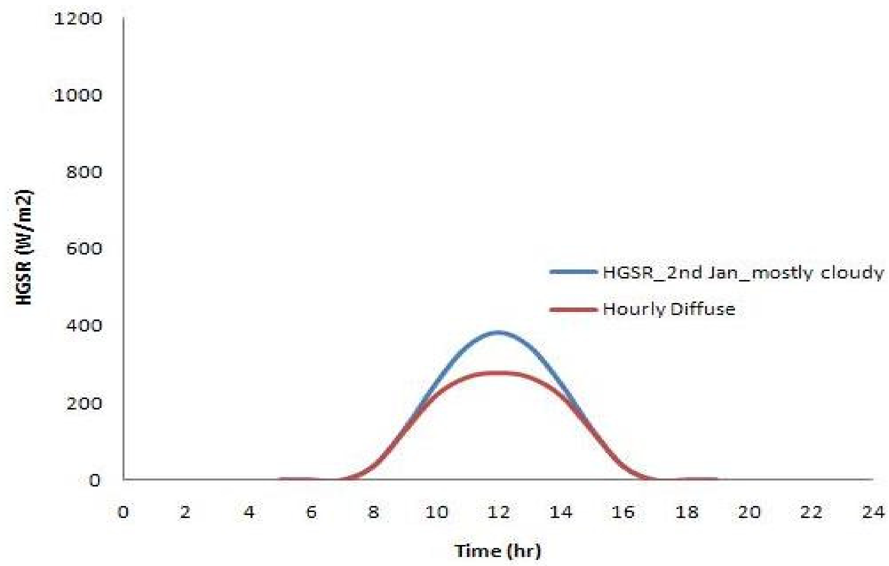


Figure 20 Hourly global and diffuse solar radiation for Ahvaz on January 2nd [W/m^2]

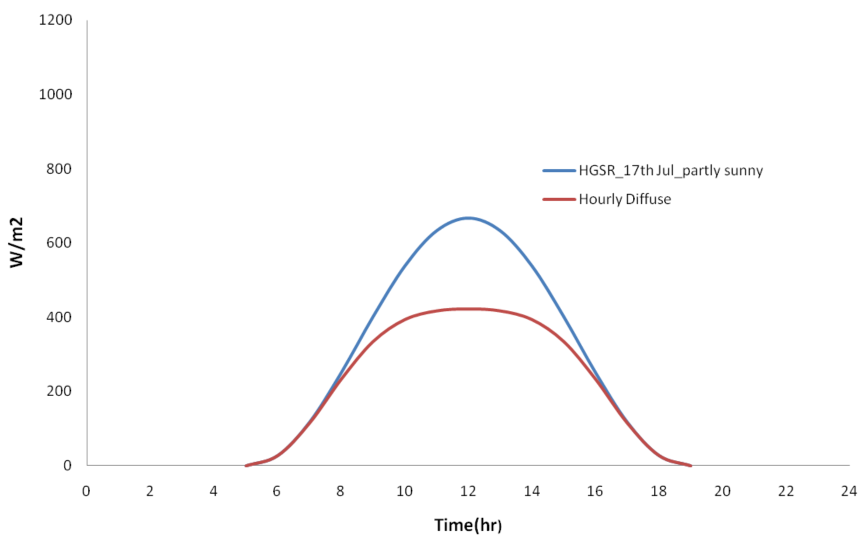


Figure 21 Hourly global and diffuse solar radiation for Ahvaz on Jul 17th [W/m^2]

CHAPTER 5: COMPARISON OF AHVAZ TRY WITH OTHER WEATHER DATA

5.1 Introduction

Computer simulation programs let the practitioners and researchers to observe and understand building problems more accurately. Also, different energy behaviour of buildings can be predicted and dealt by such software. Some of these behaviours include transient heat flows, casual gains and occupant influences on the thermal situation, the impact of solar gains through short wave radiation into the buildings and long wave re-radiations from and into the furniture within the buildings. In addition, computer simulations provide a better and smoother technology transfer to the real projects and remove the complexity of manual calculations. [39]

5.2 Overview and historical background

Thermal simulation tools have been used for cost and performance prediction in the design stages. Computational modelling can also produce alternative solutions and scenarios in order to have more cost effective and efficient projects. The first generations of simulation software were simple but not user-friendly. Nowadays, modelling tools have become available in both analytical and numerical forms which are more accessible and easy to use. [39]

Thermal simulation of buildings allows practitioners to calculate the demands for heating, cooling and lighting for any time durations and any specific place in the building. Thermal simulation tools allow practitioners to predict the use of new technologies such as transparent insulations. it is also able to find the best combination of different technologies to get the best and most efficient ones. Analytical abilities of these software also make it possible to investigate the potential problems and applying the required modifications. [39]

5.3 Simulation of a building in Ahvaz

5.3.1 Introduction

By performing comparative analysis, it is easier to check the feasibility of projects and make any necessary adjustments so that the right decisions can be made. Similarly, the construction industry in Iran suffers from a lack of accurate energy calculation techniques. One reason for this is that the right information has been unavailable. Raw weather data has always been available while a set of reliable typical weather data used for computer simulation have always been missed. The Test Reference Year for Ahvaz that was selected in this project could be used as a reference for simulation purposes in the south west of Iran.

5.3.2 Conversion of selected TRY into IES format

After selection of a test reference year for Ahvaz, the TRY was converted into IES format. There is an Excel program which accepts hourly data as input and exports an IES format weather data file together with a brief summary of what has been done. The generated weather file can be used in IES for energy simulations. A summary of the conversion results are shown in Appendix A.

5.3.3 Building simulation in Ahvaz

In this section a simple building is modelled using two sets of weather data, Ahvaz and Kuwait. Kuwait city is located almost 220 km from Ahvaz, on the north west side of the Persian Gulf; both have geographical and climate similarities as follows: Ahvaz with latitude of 31.31°N, longitude of 48.67°E, altitude of 22m and time zone of +3.5 compared to Kuwait with latitude of 29.22°N, longitude of 47.98°E, altitude of 55m and time zone of +3.

Two weather files for Kuwait are provided by the US Department of Energy, International Airport and KISR's coastal weather station. These two were originally made by the Kuwait Institute for Scientific Research (KISR) in spreadsheet format. This can be found in the IES weather archive by the name of Kuwait_KISR.fwt. There is also a typical weather year for Tehran Mehrabad Airport from weather data for 1992 through 2003, published by the Islamic Republic of Iran Meteorological Organisation (IRIMO). This was developed for standards development and energy simulation by Joe Huang, White Box Technologies that can be obtained from the US Department of energy. [40]

Figure 22 Ahvaz and Kuwait on the map

A two storey building shown below has been modelled. The area of each floor is 120 m^2 (12m*10m). The building represents a typical house in Ahvaz. Some of the characteristics include uninsulated tile roof, exposed ceiling, plaster/brick internal partitions, wooden door, brick/block cavity wall for external walls, low-e double glazing roof flight, occupied rooms, and auxiliary ventilation. Heating and cooling systems have been set on continually so that the conditions of all three cases remain constant in order to do the comparison. Details are given in appendices.

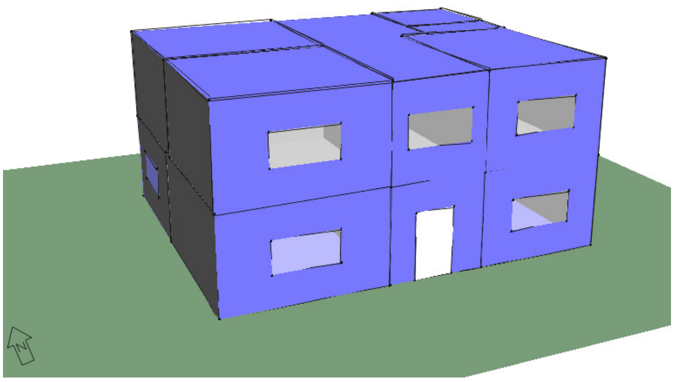


Figure 23 Perspective of a simple building modelled in IES

First of all, a 3D model was built using ModelIT, IES 6.0.6 programme that is able to make and import 3D models directly from CAD and gbXML files. This is a user friendly and easy option programme with good visual perspective. The simplest model that can be made by IES is a room with six surfaces. This is a limitation in IES in which details of layers of building elements cannot be analysed. However, the output and results of the calculation and simulation could be used as input data for other complementary software programmes for more analysis.

Solar shading analysis was done using the selected test reference year for Ahvaz. By using the Aplocate programme, the location and its geographical information, including latitude, longitude, altitude, time zone, daylight saving time (March-September), are applied. Profiles describe the time variation of input variables into the software. They are used for illustration of how variables such as casual gains, ventilation rates and set points vary during the days, weeks and the year. This can be done with the APpro programme.

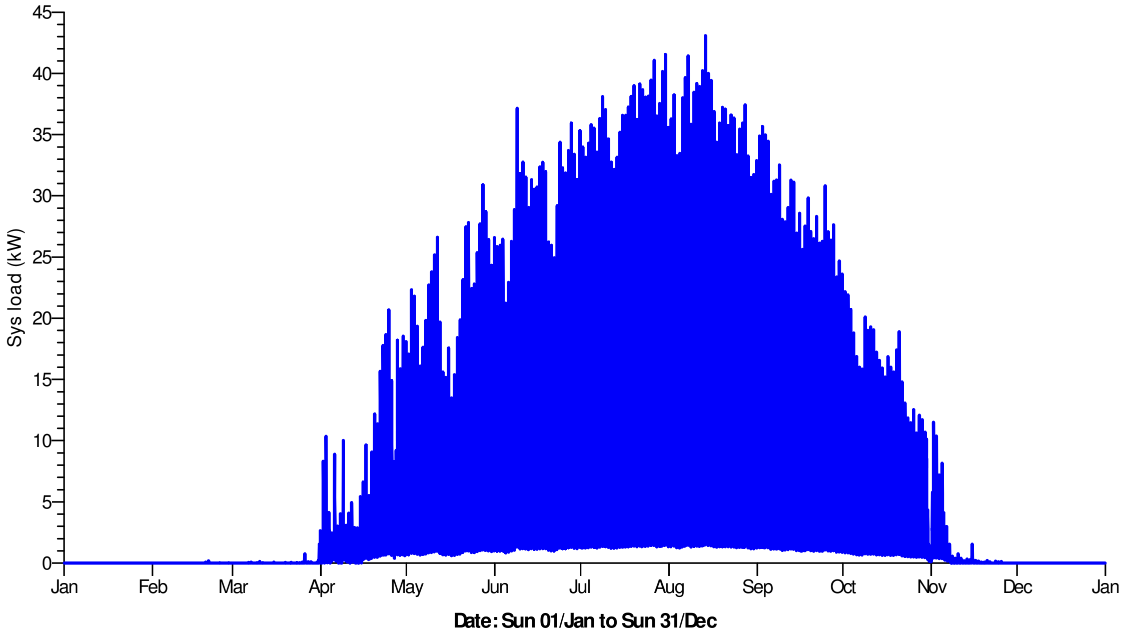


Figure 24 Cooling plant sensible load for Ahvaz

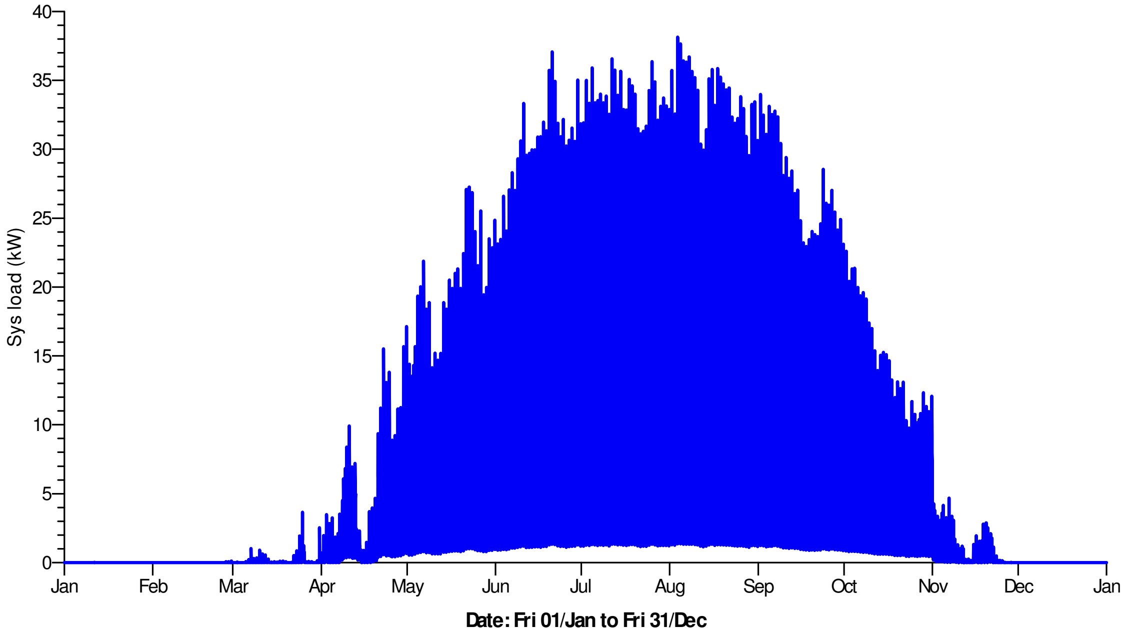


Figure 25 Cooling plant sensible load in Kuwait

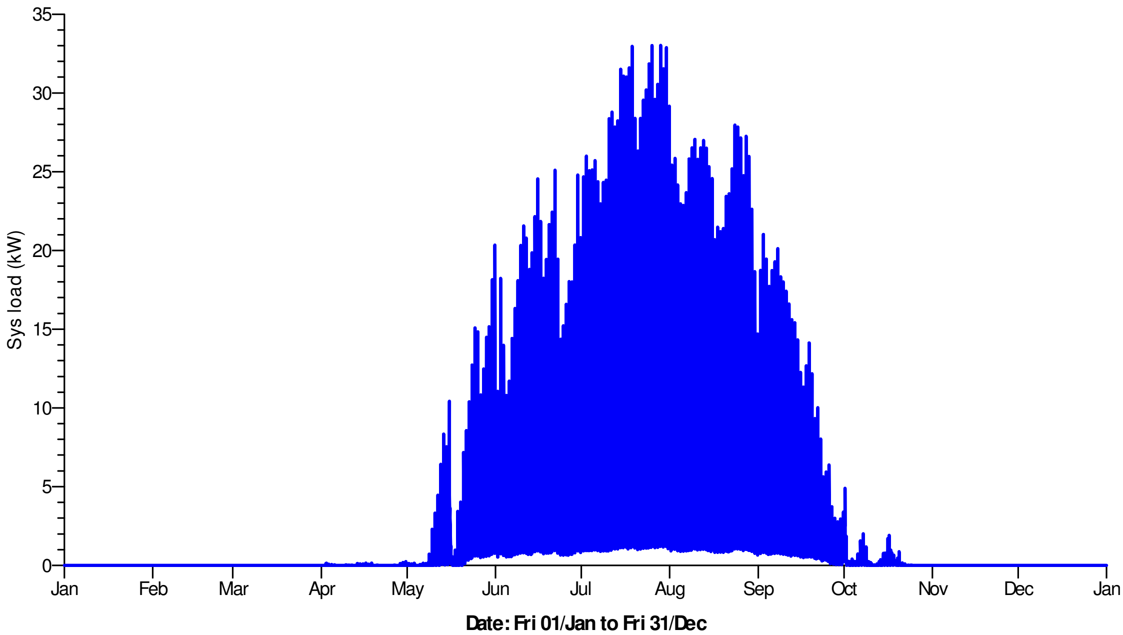


Figure 26 Cooling plant sensible load in Tehran

A simulation has been done for three weather data in three cities, Ahvaz, Kuwait and Tehran. This has been done to show the use of the selected TRY for Ahvaz and comparing some results with Kuwait and Tehran's weather data. Results for Ahvaz and Kuwait are close as these two cities are close to each other, around 220 km distance, and with close geographical and climate conditions. Tehran produces more different results as it is located in the north part of Iran. For cooling loads, the building in Ahvaz starts from April to mid-November while in Kuwait; load is needed from early March to late November. On the other hand, Tehran has a lower system load of maximum 32 kW and the period is shorter, from mid-March to early October.

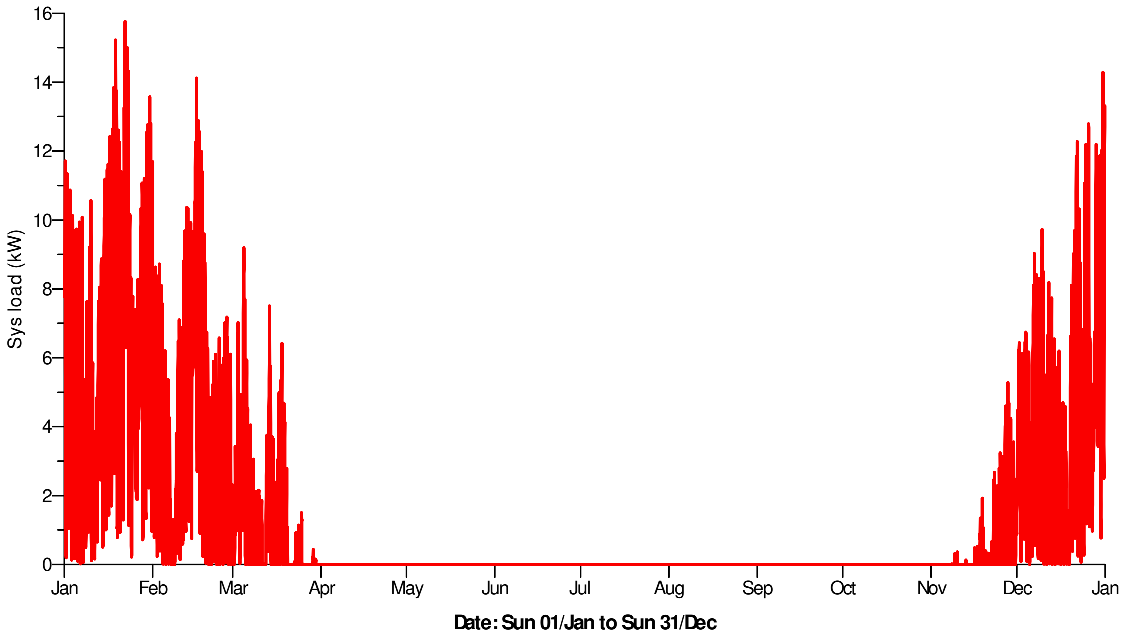


Figure 27 Heating plant sensible load for Ahvaz

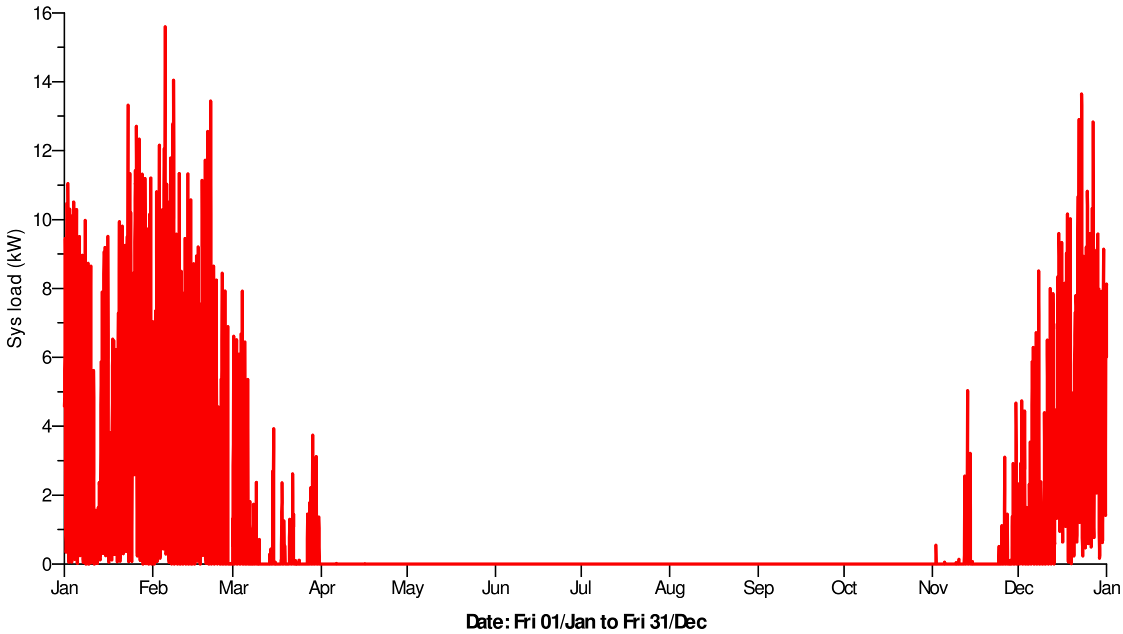


Figure 28 Heating plant sensible load for Kuwait

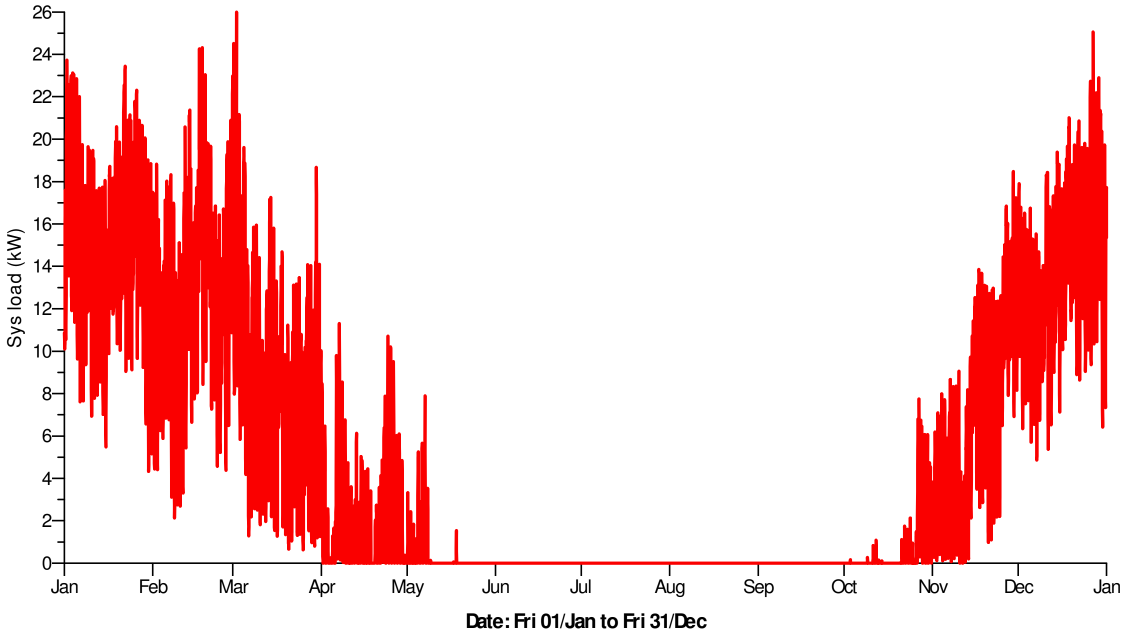


Figure 29 Heating plant sensible load for Tehran

Heating loads for Ahvaz and Kuwait are much lower than the one for Tehran as they are shown above. Tehran shows a longer level of healing load during the year, from late October to early May. Similarly, the following tables show the monthly and annual heating and cooling loads and the maximum and minimum heating and cooling loads for three cities. The overall view of the charts and tables suggests that though Ahvaz and Kuwait are both located close to each other and they have similarities in climate conditions, their typical weather data produces different results hence various design conditions would be needed. This demands that Ahvaz has its own typical weather data which is selected and suggested in this thesis.

Table 8 Monthly and annual heating and cooling loads for Ahvaz, Kuwait and Tehran

Loads Date	**Heating plant sens. load (MWh)**			**Cooling plant sens. load (MWh)**		
	Ahvaz	Kuwait	Tehran	Ahvaz	Kuwait	Tehran
Jan 01-31	4.4429	3.0318	11.0435	0.0000	0.0000	0.0000
Feb 01-28	2.5069	2.3778	8.5412	0.001	0.0009	0.0000
Mar 01-31	0.7868	0.4407	6.5449	0.0146	0.0411	0.0000
Apr 01-30	0.0000	0.0000	1.1720	1.7412	1.3873	0.0063
May 01-31	0.0000	0.0000	0.1753	5.6534	5.9587	1.1414
Jun 01-30	0.0000	0.0000	0.0000	7.7105	8.6930	3.7850
Jul 01-31	0.0000	0.0000	0.0000	9.9964	9.9095	7.0698
Aug 01-31	0.0000	0.0000	0.0000	9.9431	9.8347	6.0608
Sep 01-30	0.0000	0.0000	0.0000	7.1553	6.9892	2.6457
Oct 01-31	0.0000	0.0000	0.3967	4.342	4.1452	0.0964
Nov 01-30	0.2447	0.1099	4.9654	0.3643	0.2648	0.0000
Dec 01-31	3.1061	2.6586	10.2391	0.0000	0.0000	0.0000
Summed total	11.0873	8.6190	43.0782	46.9216	47.2244	20.8053

Table 9 Maximum and minimum heating and cooling load for Ahvaz, Kuwait and Tehran

Var. Name	Heating plant sens. load(kW)			Cooling plant sens. load(kW)		
	Ahvaz	Kuwait	Tehran	Ahvaz	Kuwait	Tehran
Min	0.000	0.000	0.000	0.000	0.000	0.000
Min. Time	13:30,05/02	13:30,08/01	15:30,01/04	00:30,01/01	00:30,01/01	00:30,01/01
Max	15.763	15.594	25.99579	43.083	38.1265	33.027
Max Time	06:30,22/01	06:30,05/02	06:30,02/03	19:30,13/08	19:30,03/08	19:30,28/07
Mean	1.266	0.984	4.91760	5.356	5.39091	2.375

5.4 Mean and Standard deviations

Statistical quantities mean and standard deviations have been used to make a comparison between the selected TRY for Ahvaz and a typical weather year for Kuwait and Tehran. The arithmetic means and standard deviations of each parameters, hourly dry bulb temperature, hourly relative humidity, hourly wind speed and hourly global solar irradiation for each selected month have been found and shown on the following charts. Mean and standard deviation was calculated in Matlab that is presented in appendix C.

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i \quad (18)$$

$$SD = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(X_i - \bar{X})^2} \quad (19)$$

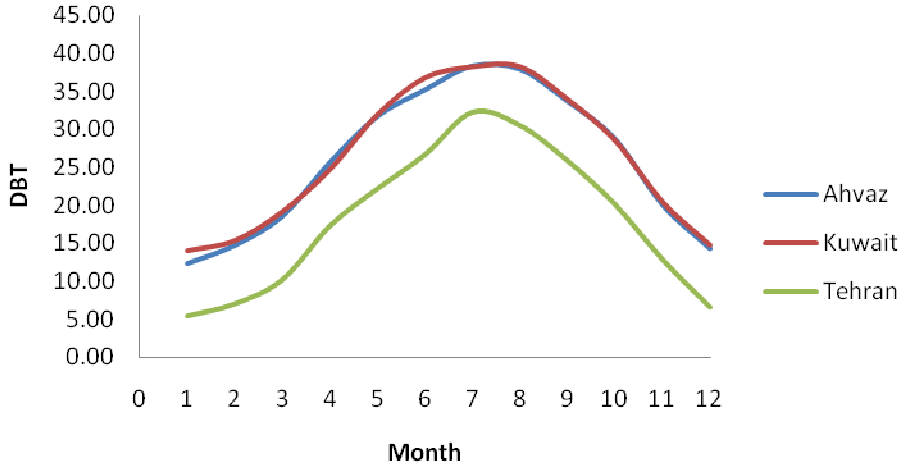


Figure 30 Monthly mean hourly DBT

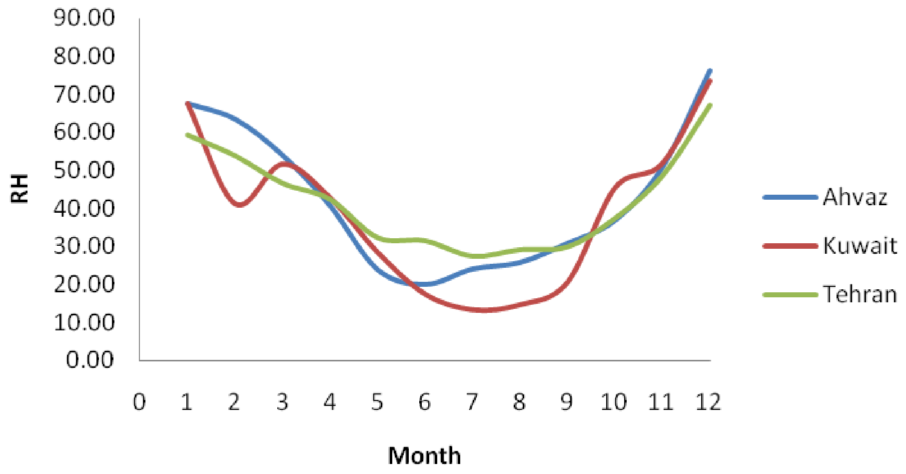


Figure 31 Monthly mean hourly RH

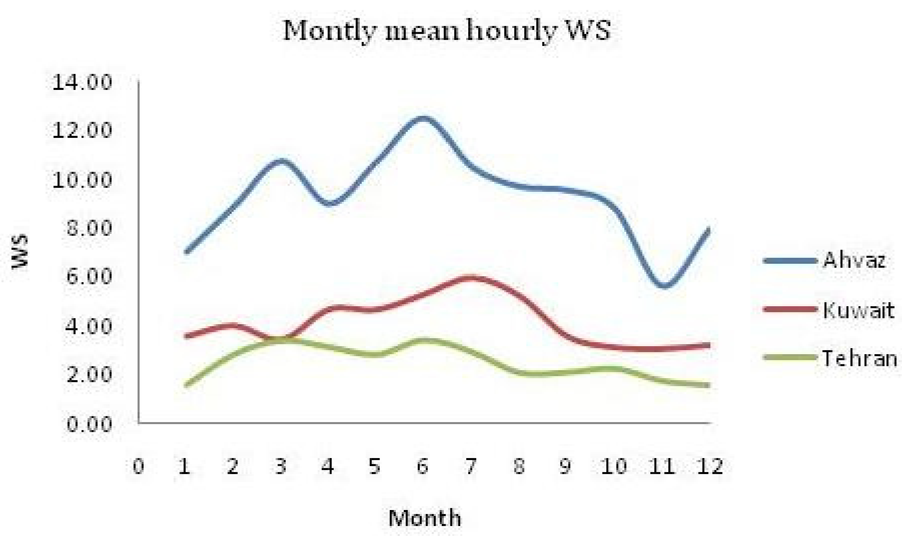


Figure 32 Monthly mean hourly WS

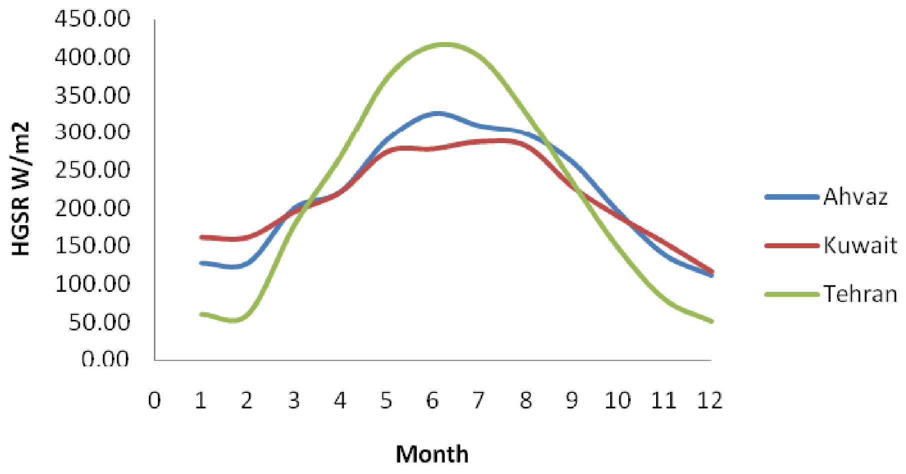


Figure 33 Monthly mean hourly GSR

Monthly mean hourly values for the main parameters for Ahvaz, Kuwait and Tehran show that Ahvaz and Kuwait have similarities in all areas while the differences are not small enough that Kuwait's typical weather year could be used for accurate building simualtions in Ahvaz.

Another area that needs be considered is the monthly mean hourly global solar irradiation for Tehran that does not look reasonable. As can be seen in the above chart, the amount of solar irradiaiton for Tehran starts with very low figures and rises to a peak that is much higher than Ahvaz and Kuwait, two cities located in the south with hot climates. This suggests a second review and consideration of the selection and calculations procedure of a Tehran weather year.

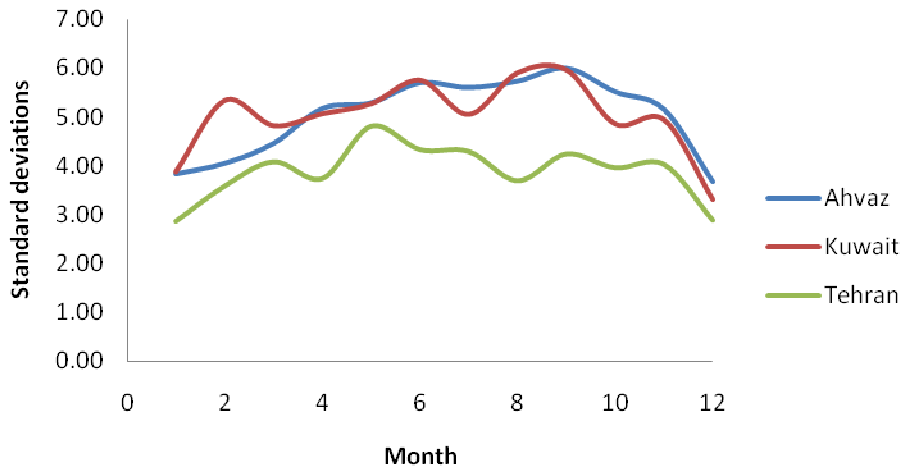


Figure 34 DBT Standard deviations

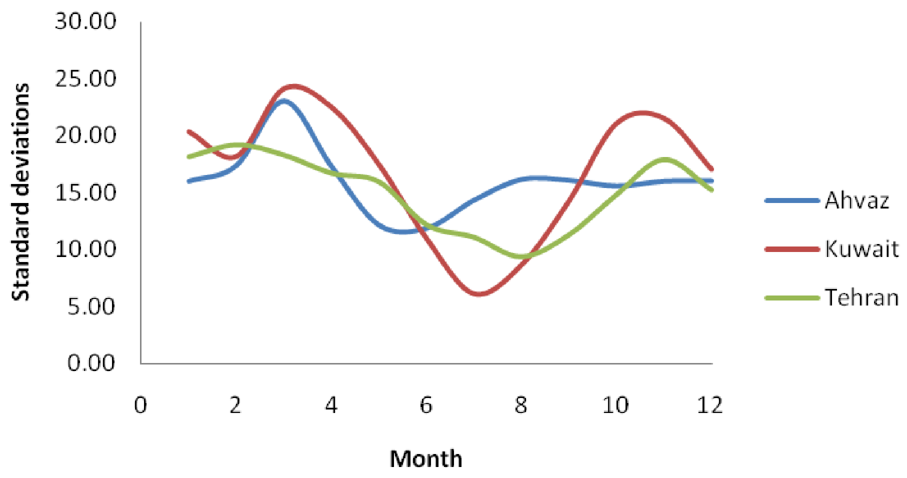


Figure 35 RH Standard deviations

Figure 36 WS Standards deviations

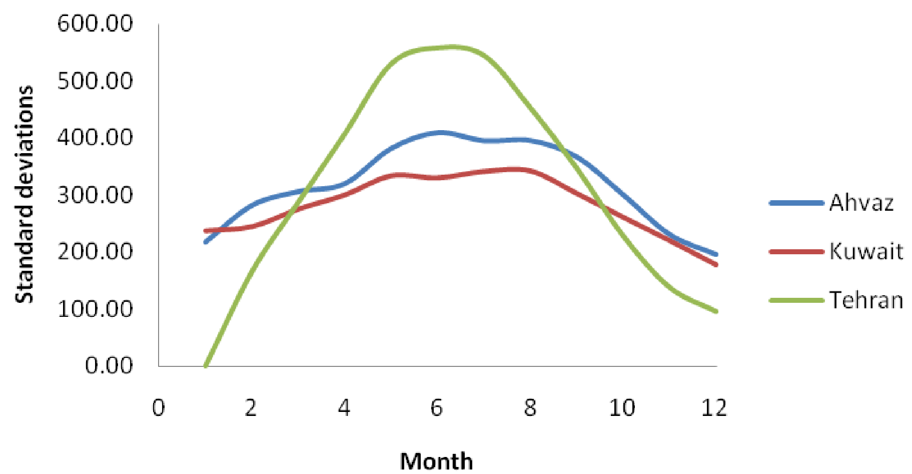


Figure 37 HGSR Standard deviations

From the monthly mean hourly wind speed and the standard deviations for this parameter, one can realise that there is an apparent disparity between the curve for Ahvaz and the other two. As mentioned before, in chapter 3, wind speed data is available in knot that is then converted into $m.s^{-1}$ for IES calculations, simulations and the comparisons. In author's opinion, wind speed raw data should be considered and quality checked to make sure the typical weather data works well.

CHAPTER 6: CONCLUSIONS

6.1 Introduction

This research demonstrates the procedure of selecting a new Test Reference Year for Ahvaz, Iran. Ahvaz is located in a hot and humid climate, in the south west of Iran. A shortage of typical weather data for building energy simulation for south west areas of Iran were the main focus of this study. The main parts of the project include raw weather data collection from Iran's Met Office and preparing and working with data to select a typical weather data for Ahvaz so that building energy simulation programmes could be used to analyse energy estimations in Ahvaz. Overall, the selection of a new weather year in a hot climate for three hourly historical data has been presented.

6.2 Raw weather data

There are a large number of raw weather data available for the majority of cities in Iran, especially for large cities. Among them, Ahvaz, the second largest city in the country after the capital Tehran, was selected for typical weather data selection. Most raw weather data, dry-bulb temperature, relative humidity and wind speed, are in three-hourly formats.

Solar radiation, another essential parameter which is needed for building energy modelling, was unavailable for Ahvaz except as daily sunshine hours. Therefore, daily sunshine durations were used to estimate global solar radiation.

6.3 TRY selection procedure

Test Reference Year (TRY) was selected as the methodology for generating a typical weather year for Ahvaz as this method is accepted and suggested by the British, European and International Standards (BS EN ISO 15927-4:2005) together with a large number of researchers and scientists use it in their typical weather selection procedures.

Test reference year selection is based on standard deviation and the cumulative distribution functions of daily mean values of all weather parameters that are used in the selection process. The general idea was to choose the best months representing the long-term set of weather data. The selected TRY is a combination of twelve individually selected months from different years of the dataset so that the selected year would have the closest frequency distribution to the calendar months of the long term data.

The Finkelstein-Schafer statistic was used to find the differences between cumulative distribution functions of each individual month and CDF for the whole dataset for each parameter. Each individual month from the long term raw dataset were analysed and ranked and the months with smallest FS values were selected to form the TRY. In some parts, there was missing data in the raw weather data. In order to make the calculation and results more realistic, those months with missing data were removed.

In some circumstances, there could be large transitions between two joined months from different years. This could be overcome by smoothing the transitions between each two months of the selected TRY. As the variation between selected months is far less than the one between days in TRY, smoothing transition was found to be unnecessary. At the same time, smoothing can be applied by future researchers if required.

6.4 Generation of hourly data from three-hourly data

After selecting TRY, three parameters of DBT, RH and WS were interpolated to generate hourly values, making it possible to convert it into IES format. This should be done as modelling software needs only hourly values. The fourth parameter, solar radiation, was in the form of daily values which were processed differently.

6.5 Solar radiation models

Solar radiation is one of the input parameters used by simulation software for building energy simulations and load calculations. Meanwhile, this parameter is usually unavailable due to the high cost and complication of measurement instruments. Solar radiation has therefore been estimated from sunshine durations using the Angstrom equation.

Daily global solar radiation that was found with the Angstrom method was then used to generate hourly global solar radiation from Hadley models presented in Chow's PhD thesis. Building simulation usually needs two segments of solar radiation including global and diffuse radiations. Therefore, diffuse fraction of global solar radiation for hourly values from sunrise to sunset were found.

6.6 Weather file comparison

The Ahvaz TRY was compared with Kuwait and Tehran's typical weather data by a comparison between the mean and standard deviations of all major parameters, hourly dry bulb temperature, hourly relative humidity, hourly wind speed and hourly global solar radiation in each month of the selected TRY. It was found that Ahvaz and Kuwait have similarities while the differences are not small enough that Kuwait's typical weather year could be used for accurate building simualtions in Ahvaz.

6.7 Using the selected TRY

The new test reference year for Ahvaz was converted into IES format by a simple Excel program made by the IES Company. And used for simulating a simple building. This was done for the three cities of Ahvaz, Kuwait and Tehran. The simulation is mainly done to show that the selected and converted weather data for Ahvaz has been practically used by simulation software. The results of the simulation gives reasonable feeling that the weather data works, however, few recommendations has been offered to future researchers to make the selected TRY more accurate.

6.8 Future research

6.8.1 Raw weather data quality control

Within this study, some of the typical reference months that were selected from the long term raw weather data were not really the best ones as some of the selected months had to be removed because of the missing parts they experienced. Therefore, one area that could raise the quality of this research is to work with the raw data to fill the gaps.

6.8.2 Wind speed raw data quality check

Wind speed was one of the four parameters used in the selection process. In section 5.4 one can realise that the amounts of Ahvaz's wind speed illustrated on chars are much higher than the one for Kuwait and Tehran. This issue should be taken into consideration and the accuracy of wind speeds should be quality checked.

6.8.3 Tehran's typical weather year evaluation

Through the comparison of weather parameters of the studied cities, Ahvaz, Kuwait and Tehran, the hourly global solar radiation for Tehran was found to be much higher than that of Ahvaz and Kuwait, which are both located in a southern and hotter climate area than Tehran. Tehran's typical weather year was collected from the US Department of Energy. It is suggested that the global solar radiation data for Tehran be checked and quality controlled.

REFERENCES

1. World Energy Council (2007), *Energy and climate change, Executive summary*, Elsevier
2. World Energy Council (2007), *Survey of energy resources, executive summary* Elsevier
3. World Energy Council (2008), *Energy Efficiency Policies around the World: Review and Evaluation.* Elsevier,
4. World Energy Council (2004), *Survey of energy resources.* Elsevier,
5. World Bank (2008), Climate Change, Available at http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20432982~menuPK:34480~pagePK:64257043~piPK:437376~theSitePK:4607,00.html
6. Eurisol Mineral Wool Insulation (2010), The UK Mineral Wool Association, accessed on Apr 2010, Available at http://www.eurisol.com/pages/what_is_mw.htm
7. Bradshaw. V (2006), *The building environment: active and passive control systems* 3rd ed., New Jersey, USA: Wiley.
8. British Petroleum (2008), *BP Statistical Review of World Energy.*
9. CIA (2010), The World Factbook, Iran. 2010, Amercian Central Intellingent Agenecy, April 2010, availble at https://www.cia.gov/library/publications/the-world-factbook/geos/ir.html#Econ
10. World Bank (2010), Data, CO2 emissions (metric tons per capita), http://data.worldbank.org/indicator/EN.ATM.CO2E.PC/countries/IR-1w?display=graph.
11. British Broadcasting Corporation (2010), Iran: Energy overview. 2010, Available at http://news.bbc.co.uk/1/hi/world/middle_east/4688984.stm.

12. Hessari, F.A. (2005), *Sectoral energy consumption in Iran. Renewable and Sustainable Energy Reviews*, 9(2): p. 203-214.
13. Iran Fuel Conservation Organization (2010), Organization, I.F.C., Building and home appliances. 2010, Iranian fuel conservation organization, Accessed in April 2010 http://www.ifco.ir/building/building_index.asp#
14. Iran Fuel Cell Committee (2008), Fuel cell, available from http://www.fcc.gov.ir/b/index2.html, Iranian Fuel Cell Committee, Tehran, Iran: Tehran.
15. Ghobadian, B.N et al. (2007), *Future of renewable energies in Iran*. Renewable and Sustainable Energy Reviews, Tehran, Iran.
16. Karegar, H.K., et al. (2007), *Wind and solar energy developments in Iran*, The Australasian Universities Power Engineering Conference. Australia
17. Noorollahi, Y. and H. Yousefi (2003), *Preliminary environmental impact assessment of a geothermal project in Meshkinshahr, NW-Iran*. International Geothermal Conference. Reykjavík.
18. Roaf, S (2005), *Air-conditioning avoidance: lessons from the windcatchers of Iran,* International Conference "Passive and Low Energy Cooling for the Built Environment. Santorini, Greece.
19. Salamiran (2010), *Iran's geography and Climate*, Iranian Embassy in Ottawa, April 2010, available at http://www.salamiran.org/IranInfo/General/Geography/.
20. Federal Research Division (2008), *Country study of IRAN May 2008*, in Federal Research Division, Library of Congress, US Congress
21. Chow.D.H.C and Levermore.G.J. (2003), *Building Simulation for comfort analysis in a climate change senarios.* Climate change, energy awareness, energy efficeincy. Gyor, Hungary.

22. McMullan, R (2002), *Environmental Science in Building*., New York: Ashford Colour Press Ltd.

23. CIBSE (2002), Guide J, Weather, solar and illuminance data, London p. 5-16

24. Hitchin.E.R, (1983), *The CIBSE example weathe year BSERT*, 4(3).

25. Hitchin, E.R., et al. (1983), *The CIBS example weather year*. Building Service Engineering, 4(3): p. 119-124.

26. Chan, A.L.S., et al. (2006), *Generation of a typical meteorological year for Hong Kong*. Energy Conversion and Management, 2006. 47(1): p. 87-96.

27. Kalogirou, S.A. (2003) *Generation of typical meteorological year (TMY-2) for Nicosia, Cyprus.* Renewable Energy, 28(15): p. 2317-2334.

28. British Standard Institution (2005), *hydrothermal performance of buildings- Calculation and presentation of climatic data, Part4*: Hourly data for assessing the annual use for heating and cooling. BS EN ISO 15927-4:2005.

29. Rahman, I.A. and J. Dewsbury, (2007), *Selection of typical weather data (test reference years) for Subang, Malaysia*. Building and Environment, 42(10): p. 3636-3641.

30. Chow, D.H.C. and G.J. Levermore (2007), *new algorithm for generating hourly temperature values using daily maximum, minimum and average values from climate models.* Building Service Engineering, 2007. 28(3): p. 237-248.

31. Levermore, G.J. and J.B. Parkinson (2006), *Analyses and algorithms for new Test Reference Years and Design Summer Years for the UK.* Building Service Engineering, 27(4): p. 311-325.

32. Allen, R., et al. (1998), *Crop evapotranspiration: Guidelines for computing crop water requirements*. Irrigation and Drainage Paper No. 56. Rome, Italy: FAO.

33. JRC-IPSC and CRA-CIN (2010), Extra-terrestrial solar radiation, , The Institute for the Protection and Security of the Citizen (IPSC) of the European Commission's

Joint Research Centre (JRC). [cited 10 April 2010].
http://www.apesimulator.it/help/models/solarradiation/Calculating_extra-terrestrial_solar_radiation.html

34. Almorox, J. and C. Hontoria (2004), *Global solar radiation estimation using sunshine duration in Spain*. Energy Conversion and Management, 45(9-10): p. 1529-1535.
35. Ampratwum, D.B. and A.S.S. Dorvlo (1999), *Estimation of solar radiation from the number of sunshine hours*. Applied Energy, 63(3): p. 161-167.
36. Ertekin, C. and O. Yaldiz (2000), *Comparison of some existing models for estimating global solar radiation for Antalya (Turkey)*. Energy Conversion and Management, 41(4): p. 311-330.
37. CHOW, D.H.C. (2005), *The Effects of Future Climate Change and Near-Extreme Weather on Office Buildings in the UK*, in School of Mechanical, Aerospace and Civil Engineering, The University of Manchester: Manchester.
38. Erbs, D.G., S.A. Klein, and J.A. Duffie (1982), *Estimation of the diffuse radiation fraction for hourly, daily and monthly-average global radiation.* Solar Energy, 28(4): p. 293-302.
39. Clarke, J.A (2001), *Energy simulation in building design*, 2nd Edition, ISBN 0 7506 5082 6. 2nd ed. 2001, Oxford, UK.
40. US Department of Energy (2010), Weather Data Sources, ,http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_sources.cfm#ITMY.

APPENDICES

APPENDIX A: IES SIMULATION WEATHER CONVERTOR

A.1 Simulation weather data worksheet

IES
Simulation weather data worksheet

Key:	
Mandatory field	Include one field from set
Include field where possible	Include one field from set
Discretionary field (normally omitted)	

HEADER DATA	Simulation weather file name (up to 24 characters including extension .fwt)	Brief description (up to 16 characters)	Full description (3 lines of up to 32 characters each)	Year of last record	Site latitude (deg N)	Site longitude (deg E)	Time zone (hours ahead of GMT)	Solar radiation convention (1 = hour-centred, 2 = half-hour-centre
		BDESC	FDESC	YEAR	LAT	LON	TZ	SRC
Values:	Ahvaz2.fwt	Ahvaz.Iran2	Simualtion weather dara for Ahvaz by Vahid Alipour	2006	31.32	49.00	3.50	1

	Hour	Day of month	Month	Dry-bulb temp. (°C)	Wet-bulb temp. (°C)	Relative humidity (%)	Humidity ratio (kg/kg)	Dew-point temp. (°C)	Wind speed (m/s)	Wind direction (° E of N)	Direct normal solar irrad (W/m²)	Direct horizontal solar irrad (W/m²)	Global horizontal solar irrad (W/m²)	Diffuse horizontal solar irrad. (W/m²)	Solar altitude (°)	Solar azimuth (° E of N)	Cloud cover (fraction)	Atmosph. pressure (Pa)
HOURLY DATA	H	DM	M	T	TW	RH	G	TDEW	WS	WD	IDIRN	IDIRH	IGLOB	IDIFF	ALT	AZ	CLD	PAT
Multiplier:	-	-	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Offset:	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Values:				7.2		74			0				0	0				
				7		74.5			0				0	0				
				6.8		75			0				0	0				
				6.4		76			0				0	0				
				7.25		70.5			0				0	0				
				8.1		65			0				0	0				
				9.8		54			0				5.19E-03	8.57E-04				
				11.3		48.75			0				71.1548	68.8209				
				12.8		43.5			0				259.669	158.69				
				15.8		33			0				493.31	98.8015				
				16.4		33.5			0				682.546	112.62				
				17		34			0				754.862	124.552				
				18.2		35			0				682.546	112.62				
				17.05		39.75			0				493.31	98.8015				
				15.9		44.5			0				259.669	158.69				
				13.6		54			0				71.1548	68.8209				
				12.9		57.5			0				5.19E-03	8.57E-04				
				12.2		61			0				0	0				
				10.8		68			0				0	0				
				10.45		67.5			0				0	0				
				10.1		67			0				0	0				
				9.4		66			0				0	0				
				8.8		70			0				0	0				
				8.2		74			0				0	0				

Row	Dry-bulb temp.	Relative humidity	Wind speed	Global horizontal solar irrad	Diffuse horizontal solar irrad.
8758	7.9	91.75	7.76	0	0
8759	7.6	91.5	7.76	0	0
8760	7	91	7.76	0	0
8761	6.7	93.25	8.73	0	0
8762	6.4	95.5	9.7	0	0
8763	5.8	100	11.64	2.01E-03	3.31E-04
8764	7.05	95.5	8.73	27.4985	27.24219
8765	8.3	91	5.82	100.3519	98.52286
8766	10.8	82	0	190.6449	182.7851
8767	11.45	79.75	0	263.7771	242.0974
8768	12.1	77.5	0	291.7242	262.0393
8769	13.4	73	0	263.7771	242.0974
8770	13.1	76.25	0	190.6449	182.7851
8771	12.8	79.5	0	100.3519	98.52286
8772	12.2	86	0	27.4985	27.24219
8773	11.55	89.5	0	2.01E-03	3.31E-04
8774	10.9	93	0	0	0
8775	9.6	100	0	0	0
8776	9.05	100	0	0	0
8777	8.5	100	0	0	0
8778	7.4	100	0	0	0
8779	7.55	97.5	0	0	0
8780	7.7	95	0	0	0

A.2 Simulation weather file summary

IES

Simulation weather file summary

Simulation weather file

Description	Year of last record	Site latitude (deg N)	Site longitude (deg E)	Time zone (hrs ahead of GMT)	Solar radiation convention 1=hour-centred, 2=half-hour-centred
Ahvaz.Iran2 Simualtion weather dara for Ahvaz by Vahid Alipour	2006	31.32	49.00	3.50	1

Period & statistic		Dry-bulb temp. (˚C)	Wet-bulb temp. (˚C)	Relative humidity (%)	Wind speed (m/s)	Wind direction (˚ E of N)	Direct normal sol. irrad. (W/m^2)	Global horiz. sol. irrad. (W/m^2)	Diffuse horiz. sol. irrad. (W/m^2)	Cloud cover (fraction)
Jan	Max.	22.00	16.42	100.0	44.6	0.0	1104	833	289	1.000
Jan	Min.	2.80	1.89	30.0	0.0	0.0	0	0	0	0.078
Jan	Mean	12.41	9.27	67.7	7.0	0.0	138	128	54	0.763
Feb	Max.	25.60	19.02	98.0	36.9	0.0	1096	979	321	1.000
Feb	Min.	5.00	2.68	22.0	0.0	0.0	0	0	0	0.088
Feb	Mean	14.81	10.88	63.6	8.9	0.0	185	179	63	0.733
Mar	Max.	33.40	20.41	98.0	40.7	0.0	1082	1057	410	1.000
Mar	Min.	9.20	5.66	16.0	0.0	0.0	0	0	0	0.101
Mar	Mean	18.66	12.77	54.0	10.7	0.0	166	200	80	0.755
Apr	Max.	39.60	22.31	87.0	56.3	0.0	1010	1131	429	1.000
Apr	Min.	15.00	10.14	11.0	0.0	0.0	0	0	0	0.115
Apr	Mean	25.71	16.44	40.8	9.0	0.0	149	222	99	0.780
May	Max.	44.00	21.19	64.0	48.5	0.0	1015	1194	431	1.000
May	Min.	21.40	12.77	5.0	0.0	0.0	0	0	0	0.117
May	Mean	31.77	17.38	23.9	10.7	0.0	227	291	98	0.690
Jun	Max.	46.00	31.82	96.0	44.6	0.0	977	1157	263	0.956
Jun	Min.	23.60	12.46	3.0	0.0	0.0	0	0	0	0.117
Jun	Mean	35.25	18.48	19.9	12.5	0.0	276	327	91	0.624
Jul	Max.	49.00	30.33	83.0	33.0	0.0	988	1153	423	1.000
Jul	Min.	27.00	16.35	5.0	0.0	0.0	0	0	0	0.117
Jul	Mean	38.38	21.67	24.0	10.5	0.0	255	310	93	0.657
Aug	Max.	49.20	29.86	83.0	31.0	0.0	1006	1145	264	1.000
Aug	Min.	26.40	14.84	5.0	0.0	0.0	0	0	0	0.115
Aug	Mean	37.95	21.77	25.8	9.7	0.0	262	299	83	0.664
Sep	Max.	46.40	26.58	93.0	36.9	0.0	1033	1125	245	1.000
Sep	Min.	22.00	13.66	7.0	0.0	0.0	0	0	0	0.111
Sep	Mean	33.74	20.23	30.8	9.5	0.0	246	261	72	0.660
Oct	Max.	42.20	26.91	89.0	48.5	0.0	1043	990	351	1.000
Oct	Min.	14.00	7.22	10.0	0.0	0.0	0	0	0	0.103
Oct	Mean	28.76	18.11	36.8	8.8	0.0	195	195	63	0.747
Nov	Max.	33.80	22.96	95.0	36.9	0.0	1085	877	309	1.000
Nov	Min.	8.60	5.49	13.0	0.0	0.0	0	0	0	0.087
Nov	Mean	20.13	13.78	50.9	5.6	0.0	143	139	56	0.744
Dec	Max.	23.00	18.50	100.0	31.0	0.0	1117	770	277	1.000
Dec	Min.	5.40	3.85	27.0	0.0	0.0	0	0	0	0.073
Dec	Mean	14.38	11.90	76.4	7.9	0.0	117	112	52	0.774
Year	Max.	49.20	31.82	100.0	56.3	0.0	1117	1194	431	1.000
Year	Date	Aug 13	Jun 29	Jan 10	Apr 4	Jan 1	Dec 21	May 25	May 12	Jan 2
Year	Min.	2.80	1.89	3.0	0.0	0.0	0	0	0	0.073
Year	Date	Jan 19	Jan 18	Jun 25	Jan 1	Jan 1	Jan 1	Jan 1	Jan 1	Dec 21
Year	Mean	26.06	16.09	42.8	9.2	0.0	197	222	75	0.716

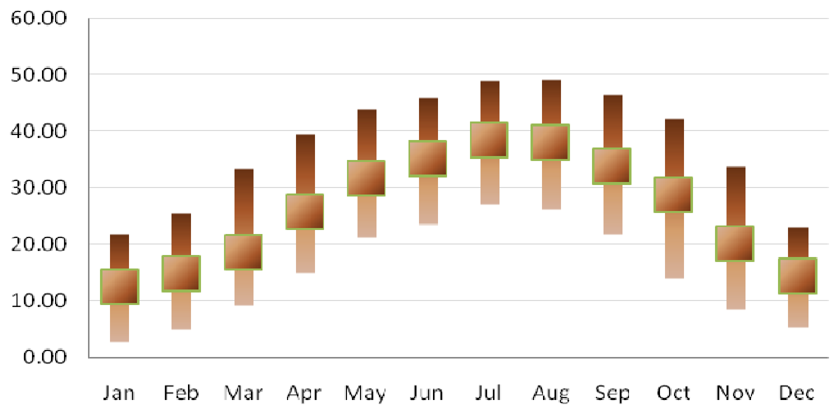


Figure 38 DBT variations over TRY from IES weather convertor

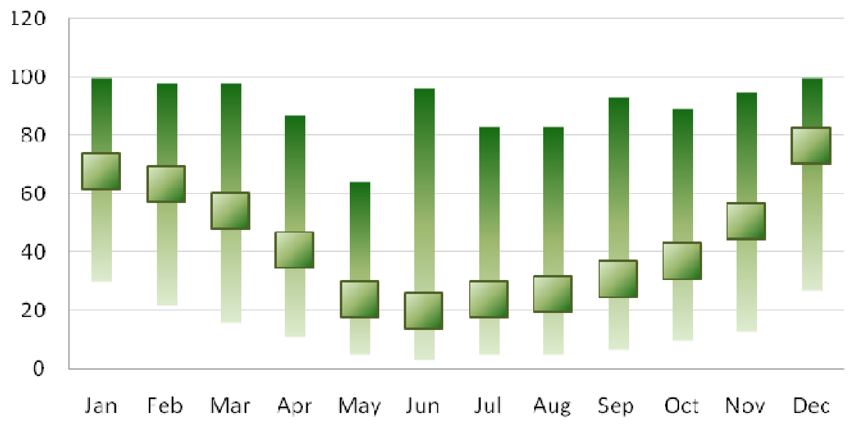


Figure 39 RH variations over selected TRY from IES weather convertor

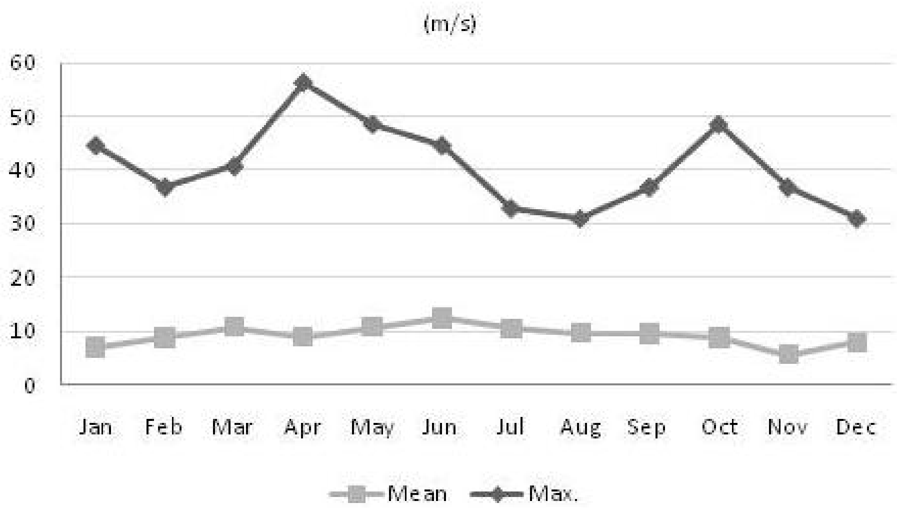


Figure 40 WS variations over selected TRY from IES weather convertor

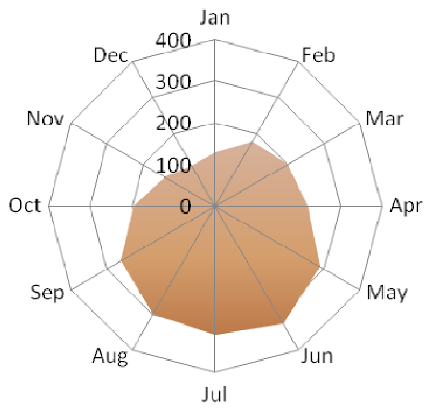


Figure 41 Global HSR (W/m2) variations over TRY from IES weather convertor

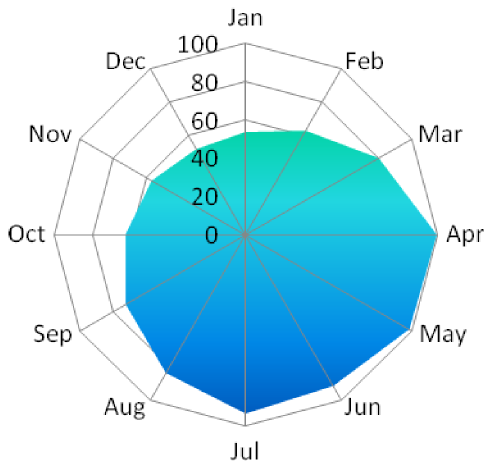


Figure 42 Diffuse HSR (W/m2) variations over TRY from IES weather convertor

APPENDIX B: CUMULITIVE DISTRIBUTION FUNCTIONS FOR BEST, WORST AND THE LONG TERM DATA

B.1 Best, worst and long term CDF% of DBT, RH and WS (kts)

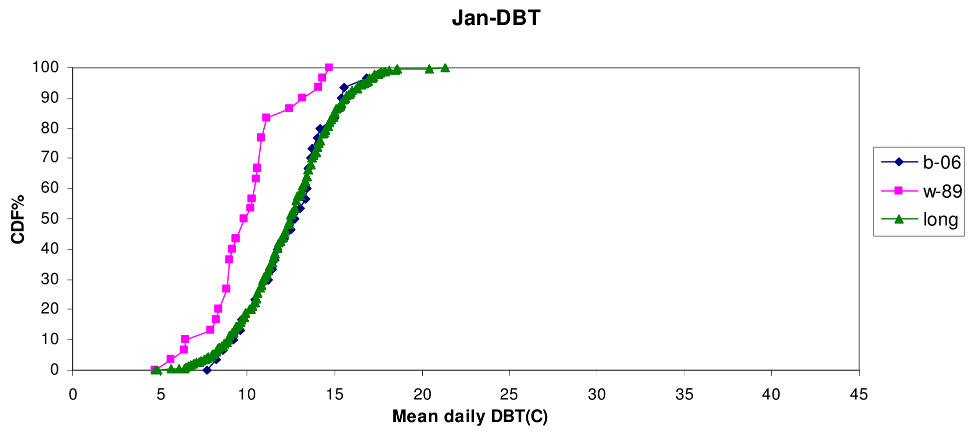


Figure 43 Best, worst and long term CDF% of DBT for January

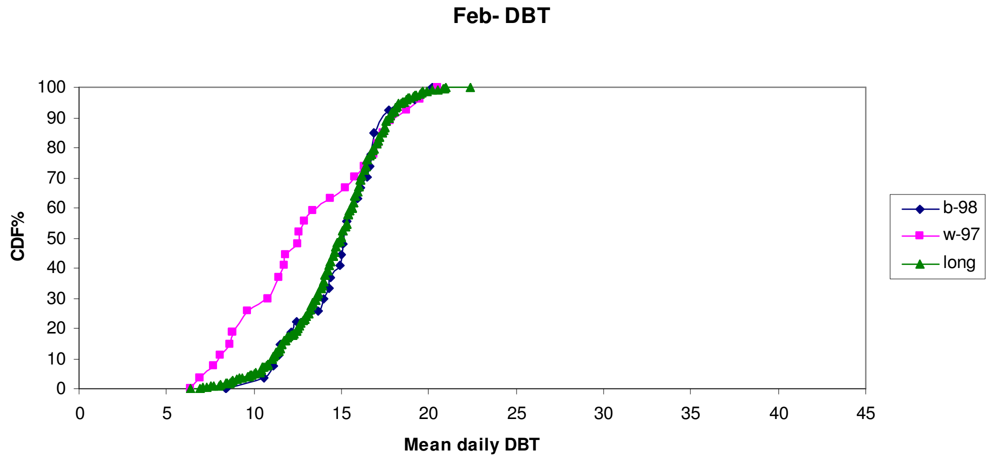


Figure 44 Best, worst and long term CDF% of DBT for February

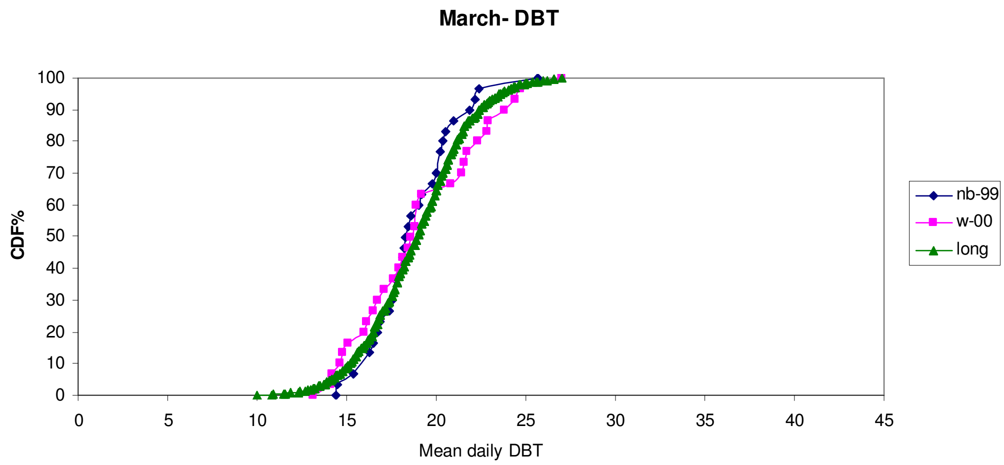


Figure 45 Best, worst and long term CDF% of DBT for March

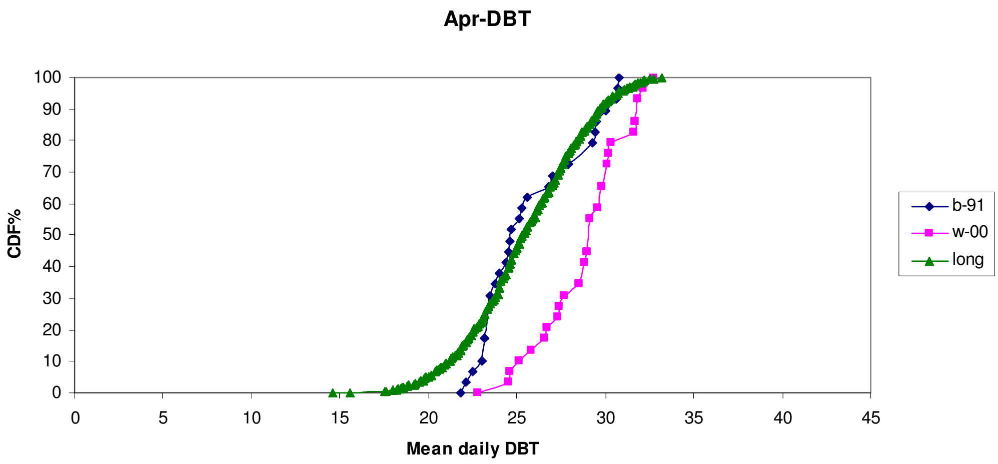


Figure 46 Best, worst and long term CDF% of DBT for April

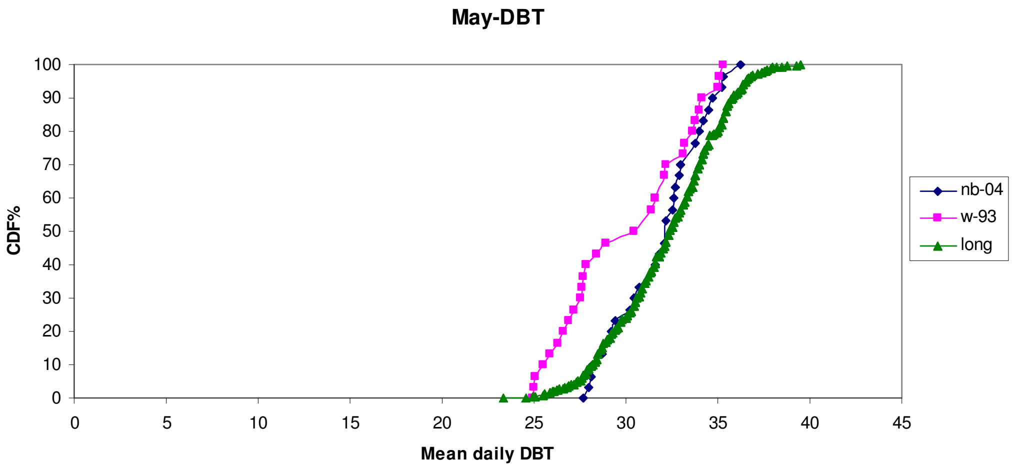


Figure 47 Best, worst and long term CDF% of DBT for May

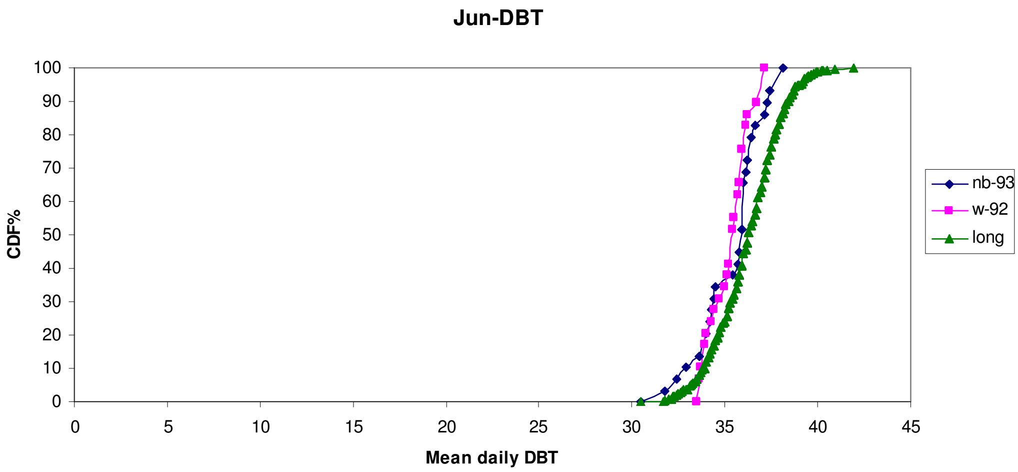


Figure 48 Best, worst and long term CDF% of DBT for Jun

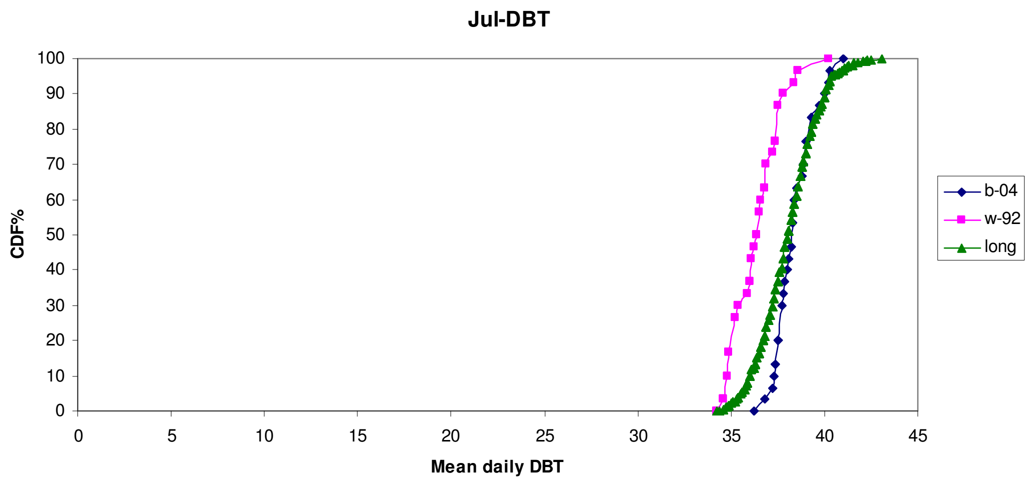


Figure 49 Best, worst and long term CDF% of DBT for Jul

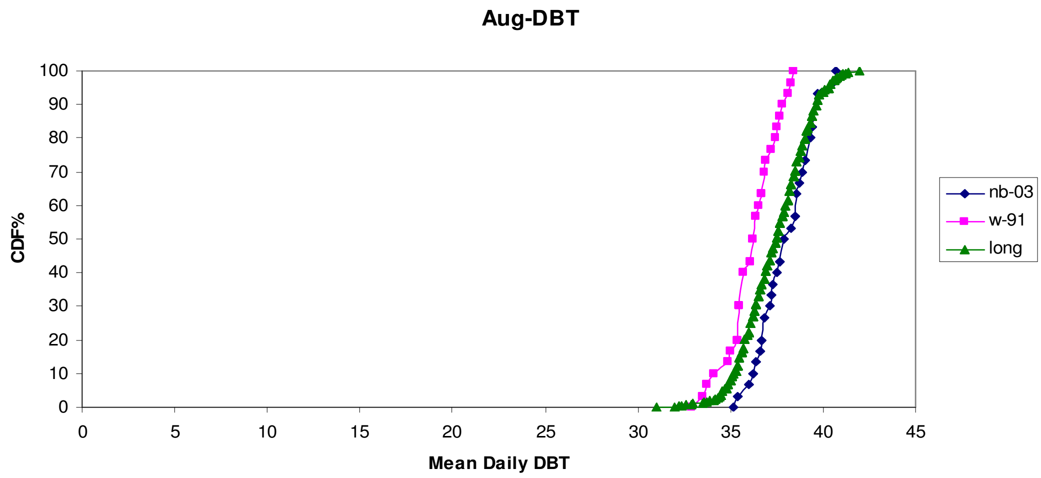


Figure 50 Best, worst and long term CDF% of DBT for Aug

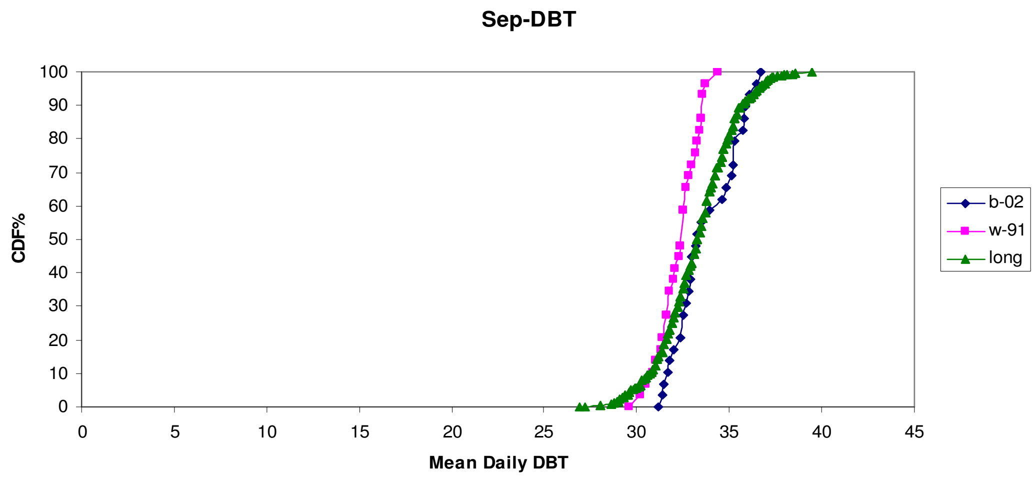


Figure 51 Best, worst and long term CDF% of DBT for Sep

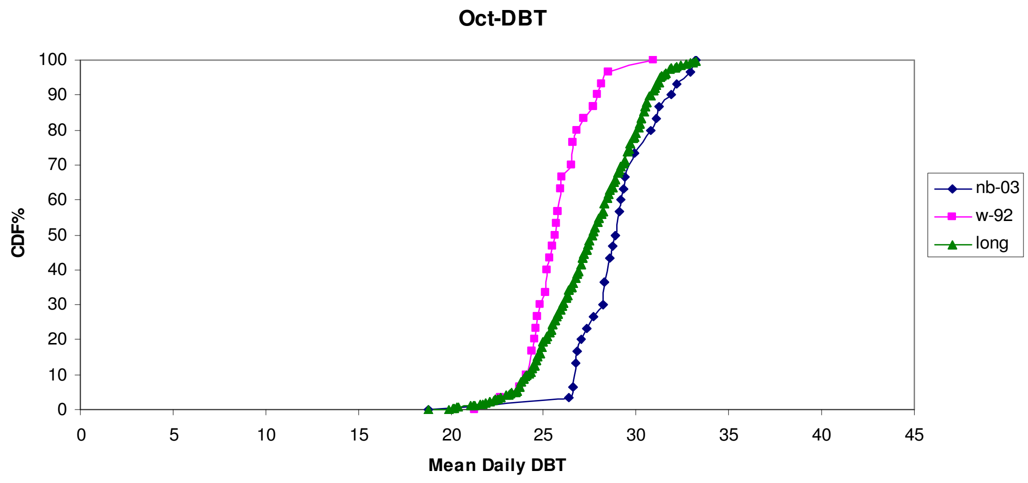


Figure 52 Best, worst and long term CDF% of DBT for Oct

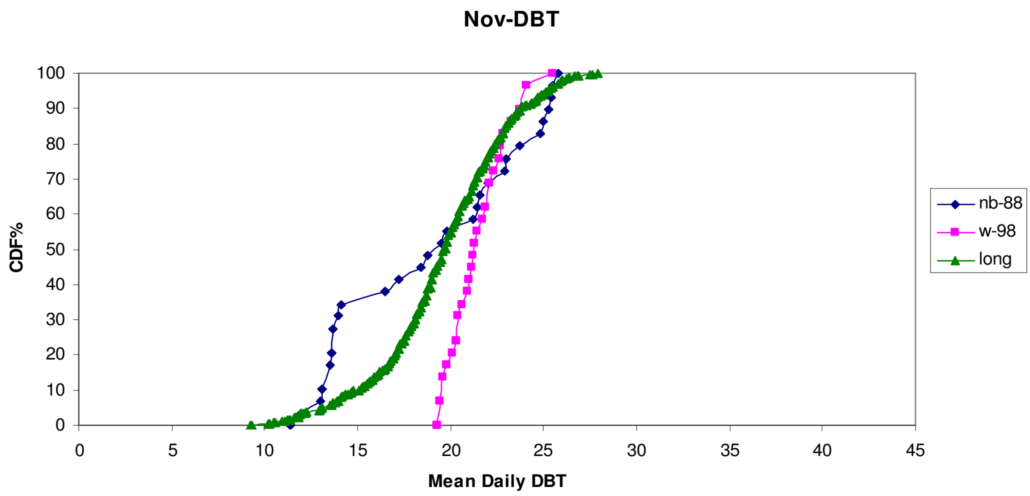


Figure 53 Best, worst and long term CDF% of DBT for Nov

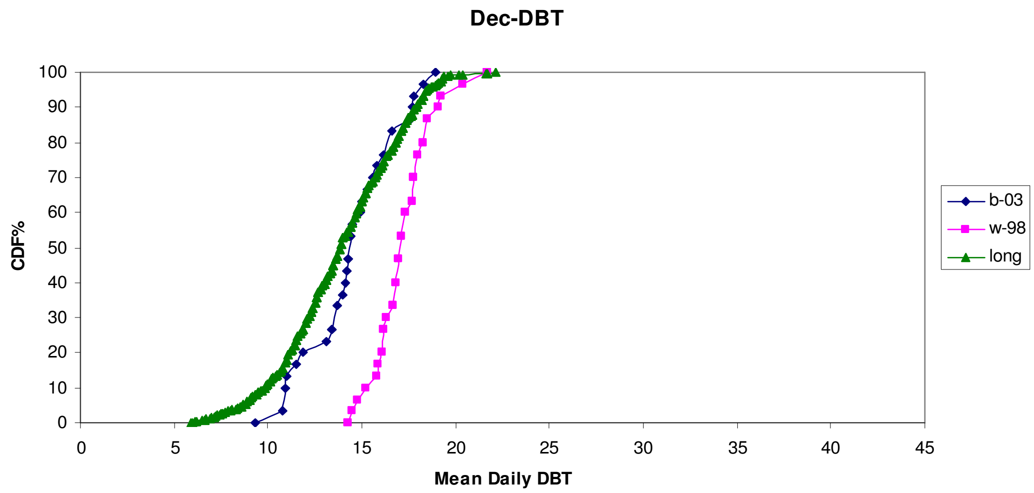


Figure 54 Best, worst and long term CDF% of DBT for Dec

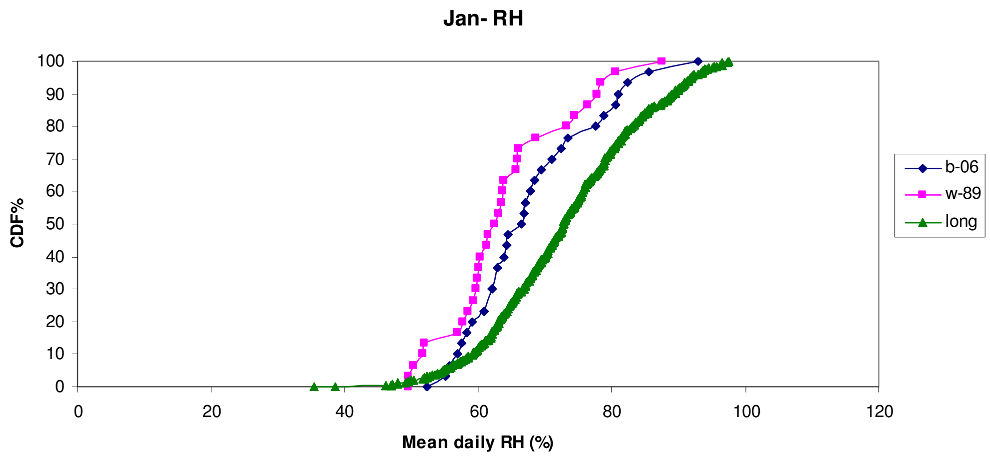


Figure 55 Best, worst and long term CDF% of RH for Jan

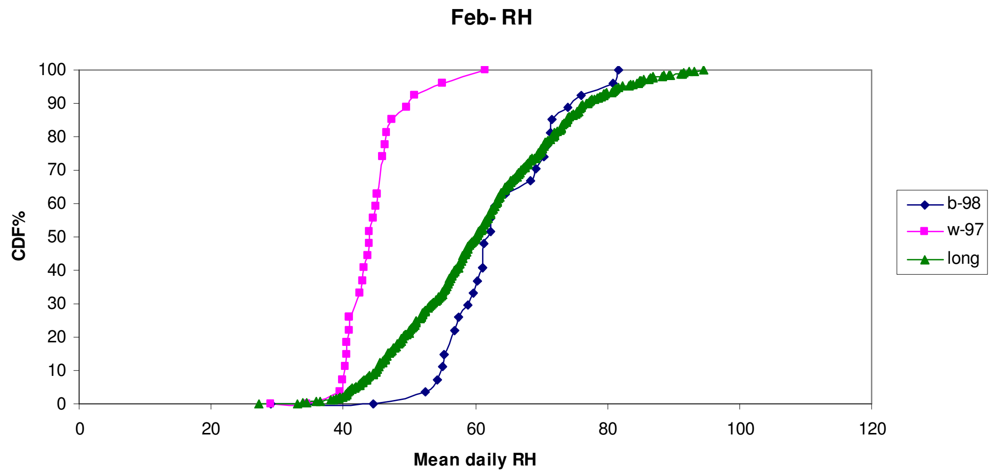


Figure 56 Best, worst and long term CDF% of RH for Feb

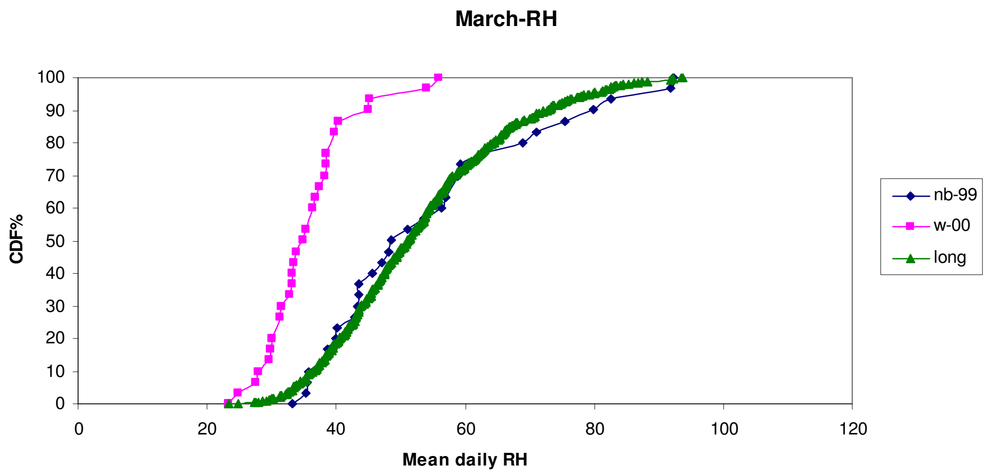


Figure 57 Best, worst and long term CDF% of RH for March

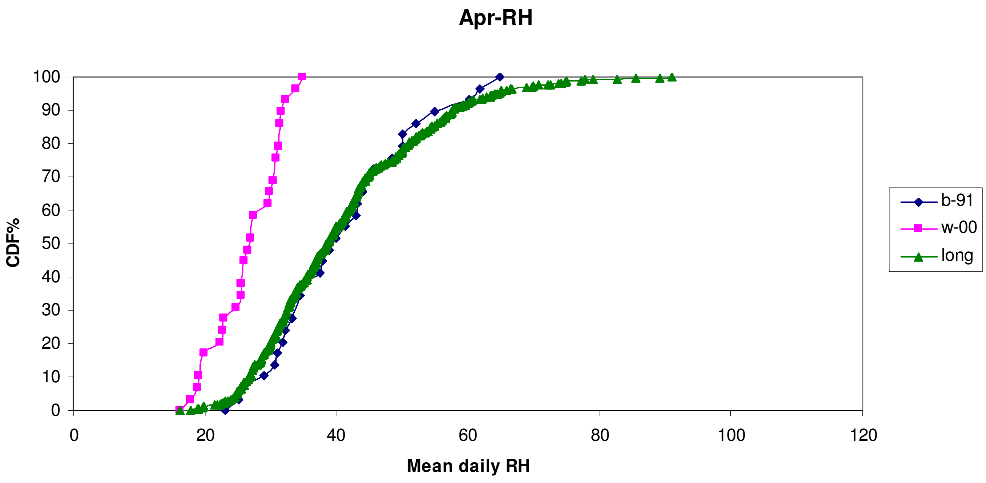


Figure 58 Best, worst and long term CDF% of RH for Apr

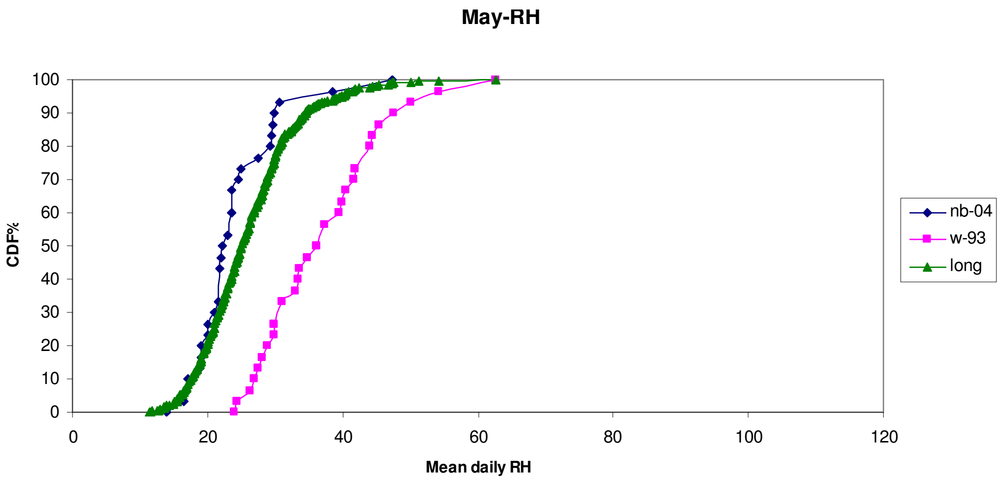


Figure 59 Best, worst and long term CDF% of RH for May

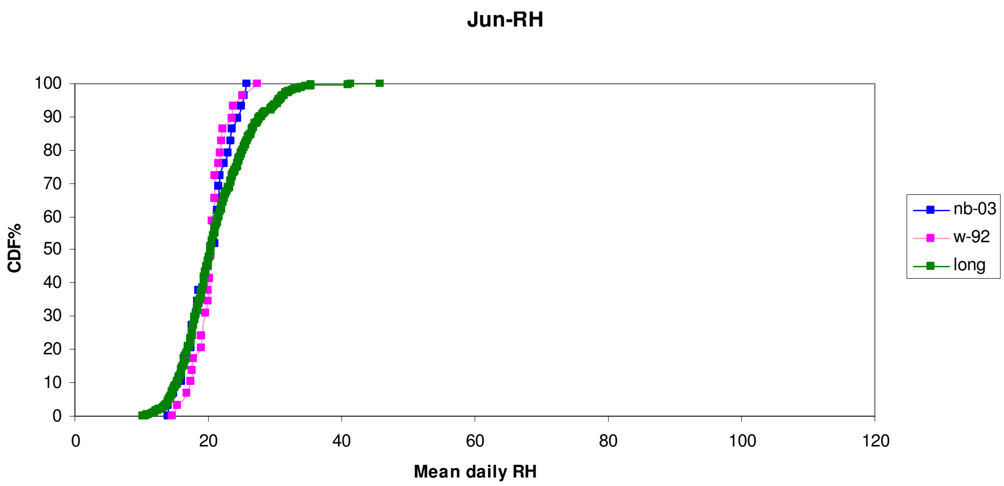


Figure 60 Best, worst and long term CDF% of RH for Jun

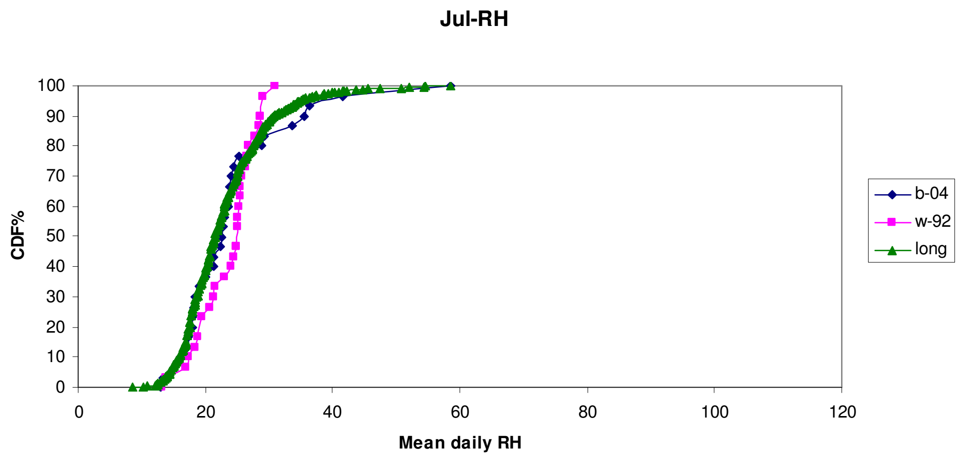


Figure 61 Best, worst and long term CDF% of RH for Jul

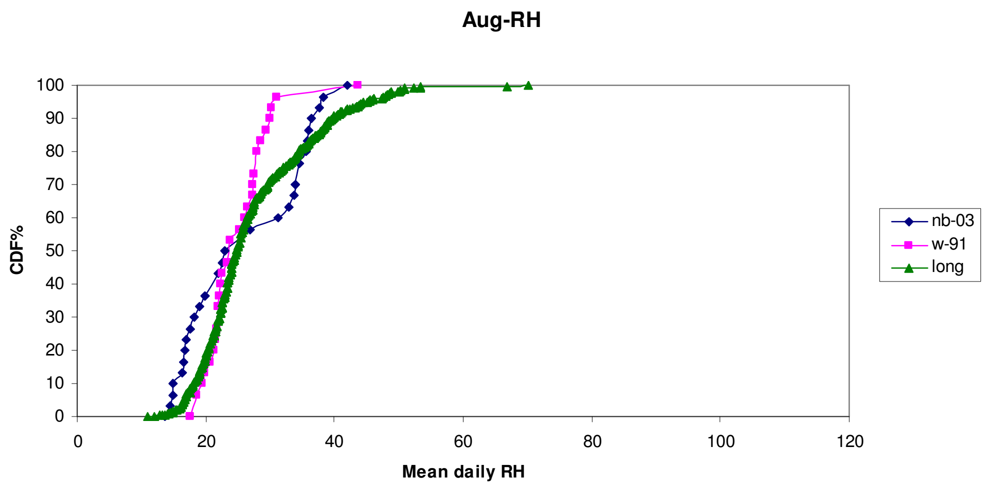


Figure 62 Best, worst and long term CDF% of RH for Aug

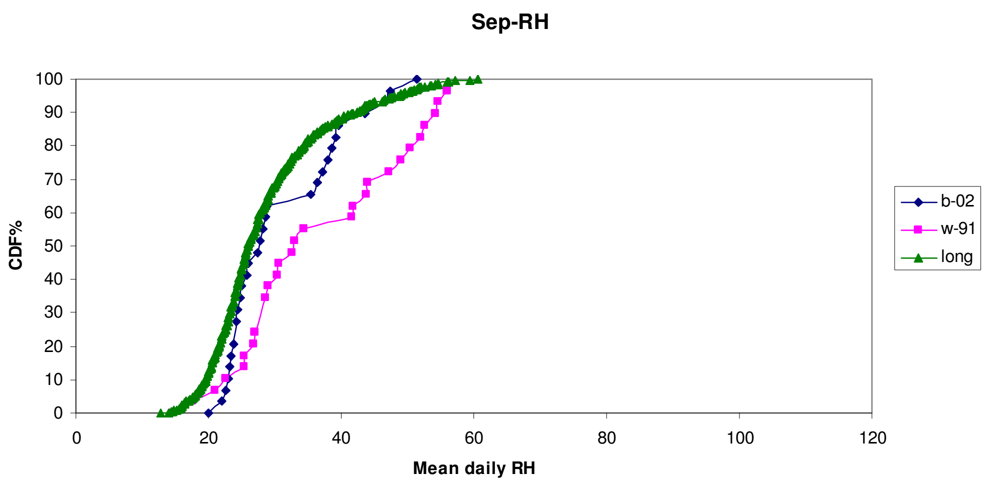


Figure 63 Best, worst and long term CDF% of RH for Sep

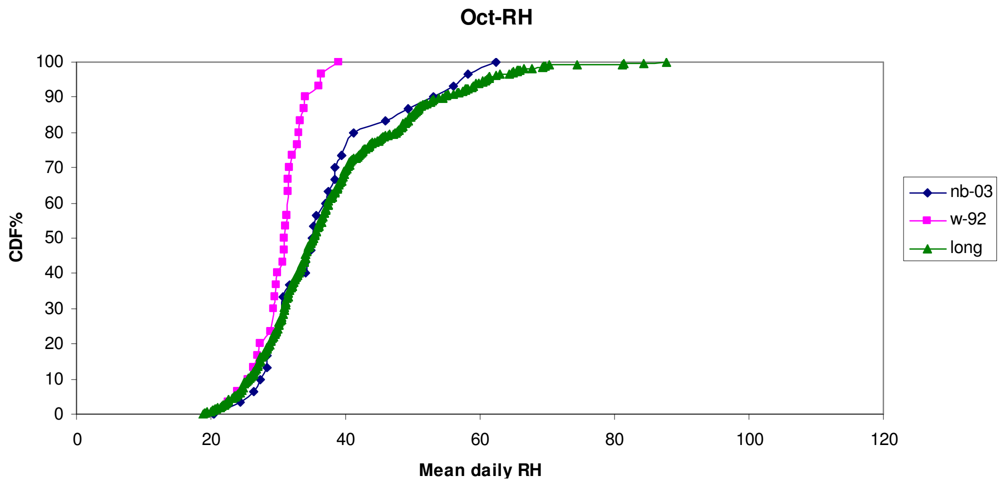


Figure 64 Best, worst and long term CDF% of RH for Oct

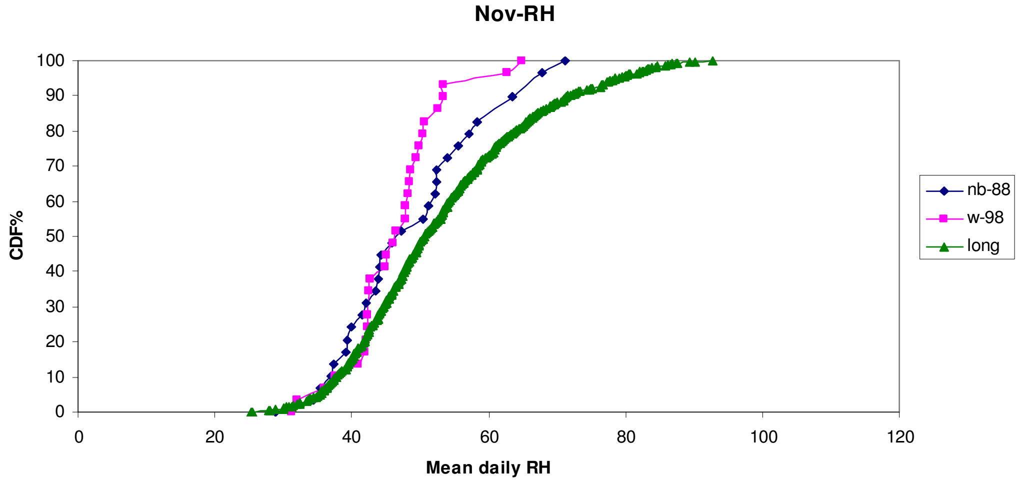


Figure 65 Best, worst and long term CDF% of RH for Nov

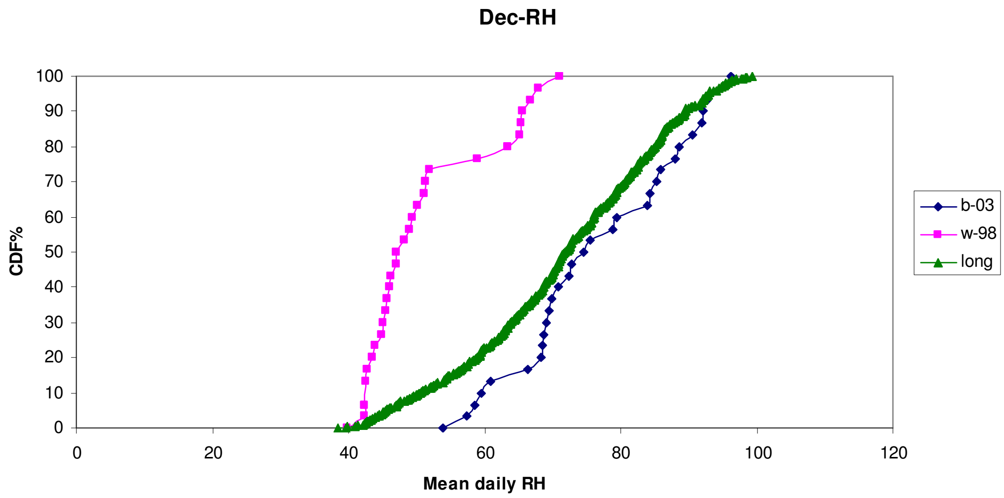


Figure 66 Best, worst and long term CDF% of RH for Dec

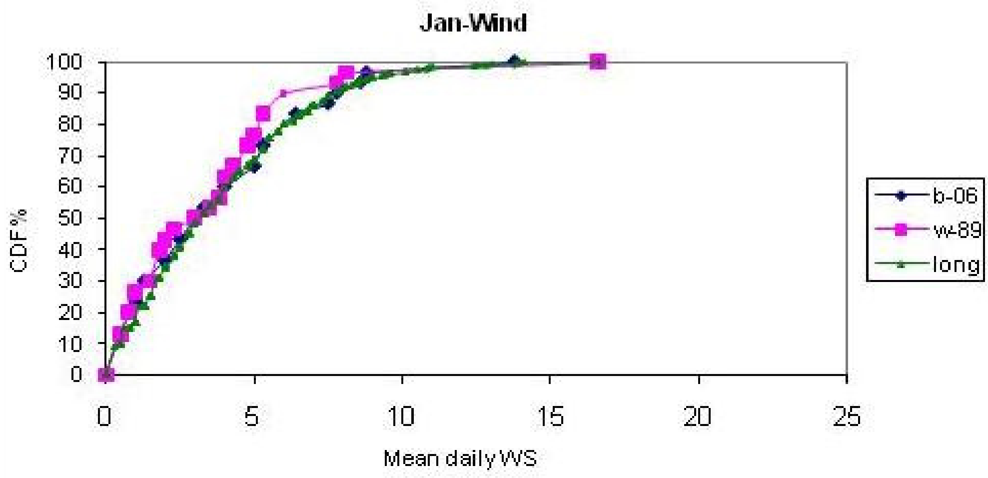


Figure 67 Best, worst and long term CDF% of WS for Jan

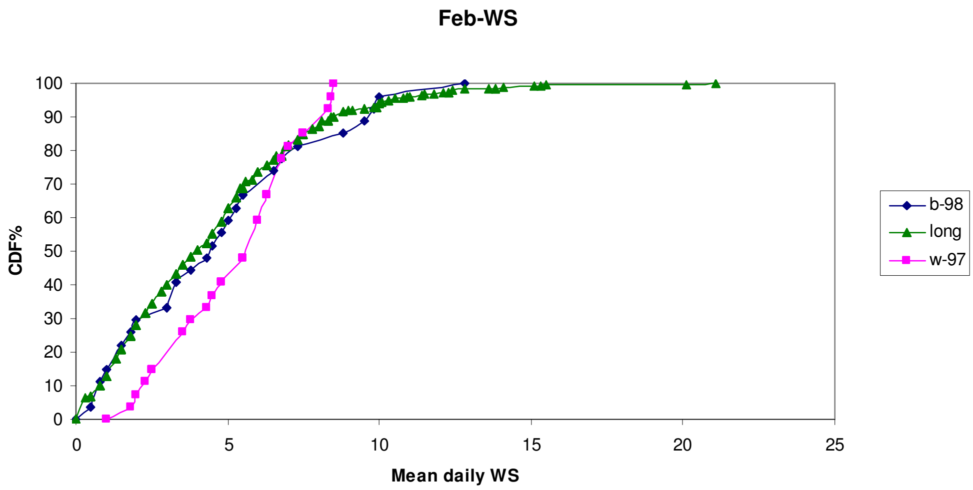


Figure 68 Best, worst and long term CDF% of WS for Feb

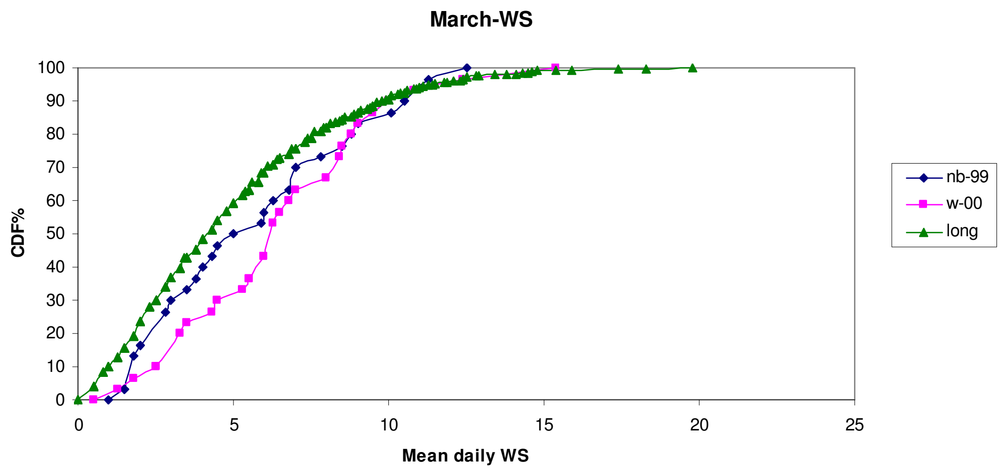


Figure 69 Best, worst and long term CDF% of WS for Mar

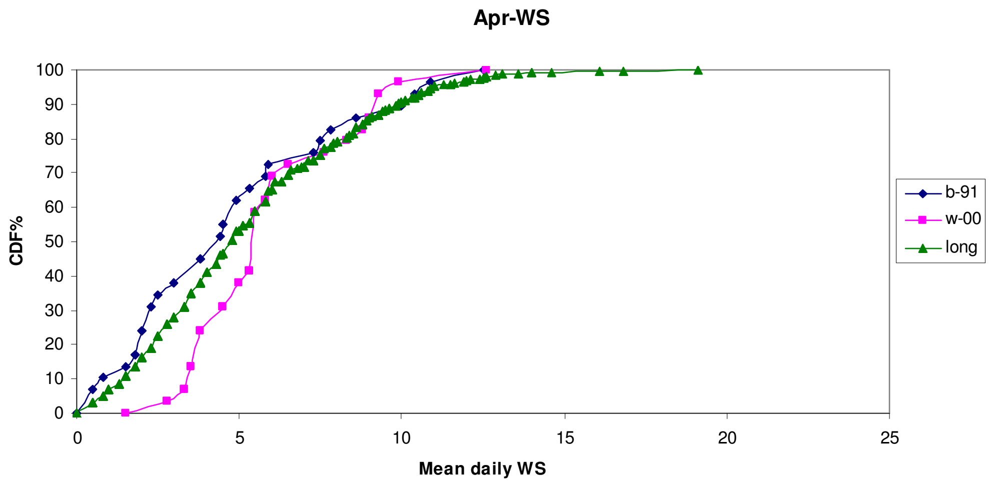


Figure 70 Best, worst and long term CDF% of WS for Apr

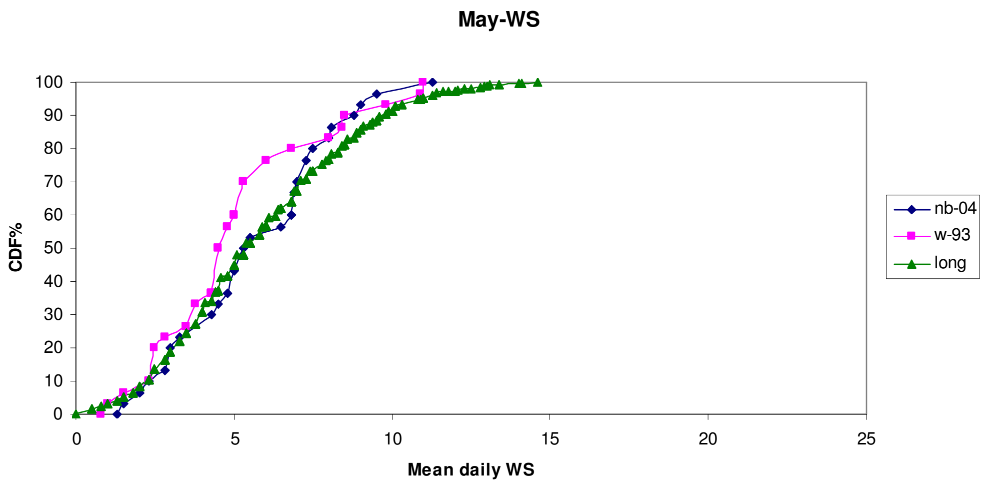


Figure 71 Best, worst and long term CDF% of WS for May

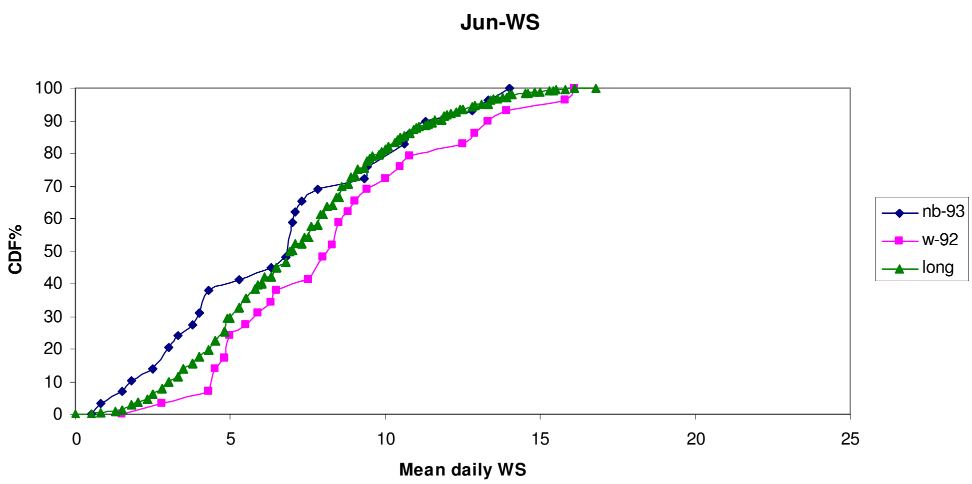


Figure 72 Best, worst and long term CDF% of WS for Jun

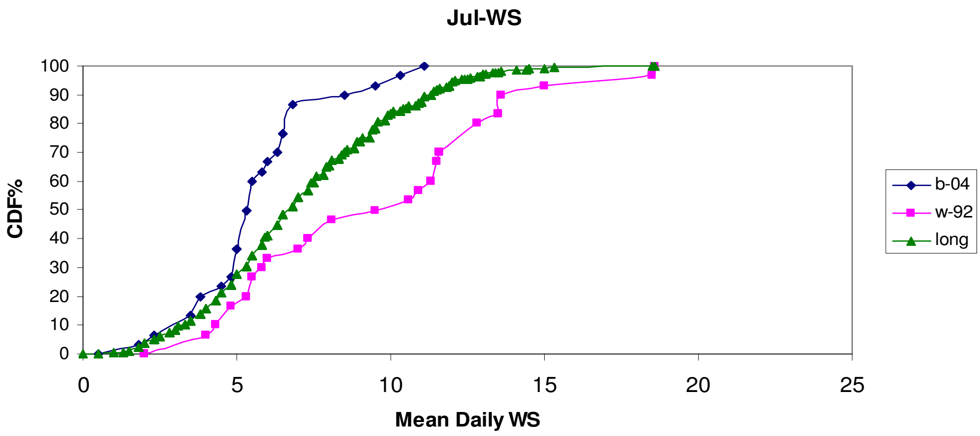


Figure 73 Best, worst and long term CDF% of WS for Jul

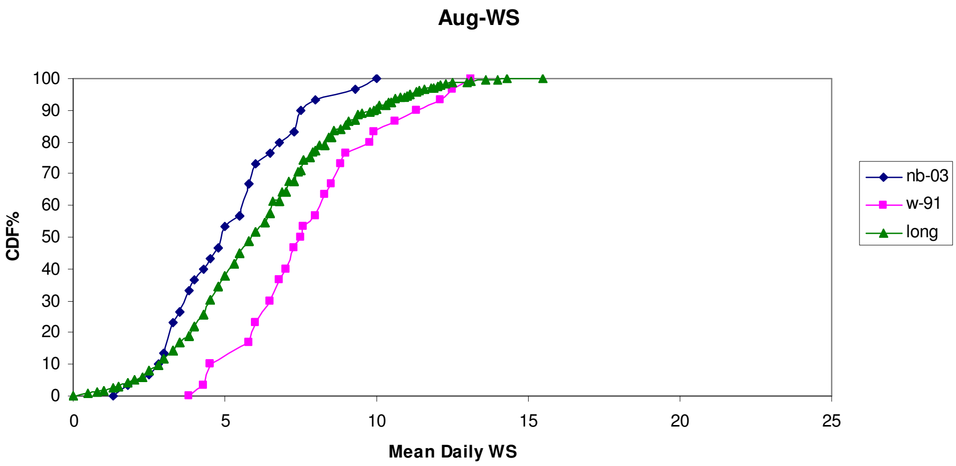


Figure 74 Best, worst and long term CDF% of WS for Aug

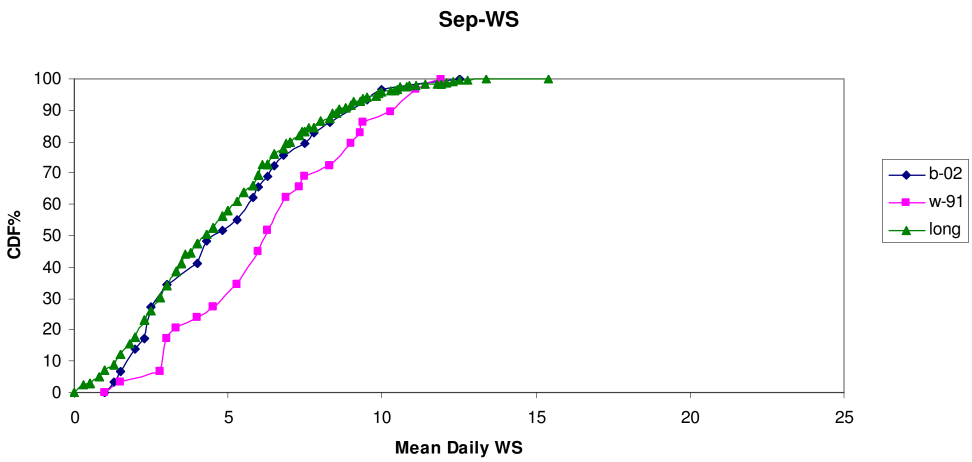


Figure 75 Best, worst and long term CDF% of WS for Sep

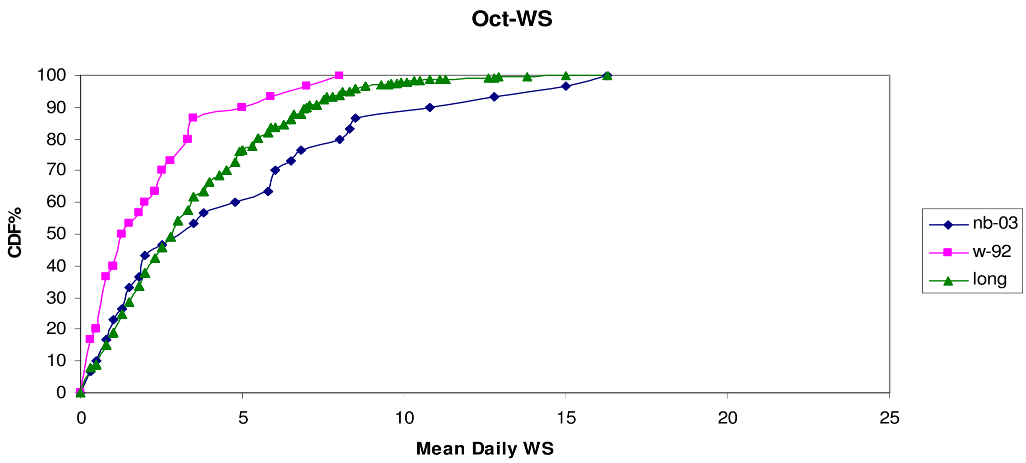


Figure 76 Best, worst and long term CDF% of WS for Oct

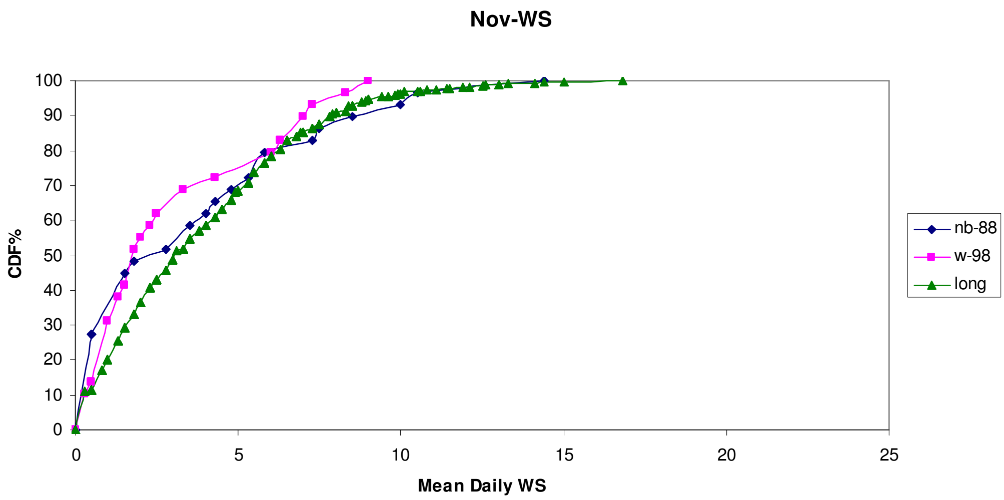


Figure 77 Best, worst and long term CDF% of WS for Nov

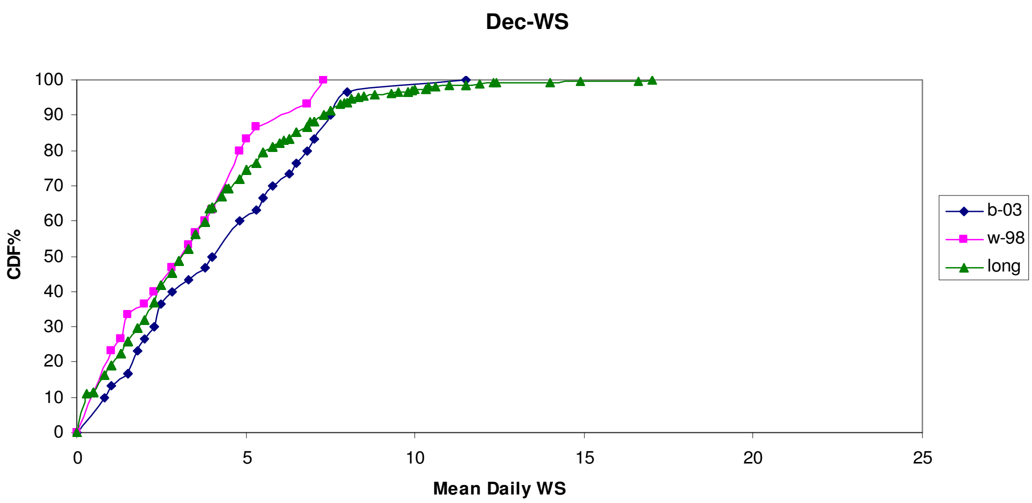


Figure 78 Best, worst and long term CDF% of WS for Dec

B.2 Variations between month for DBT, WS and RH

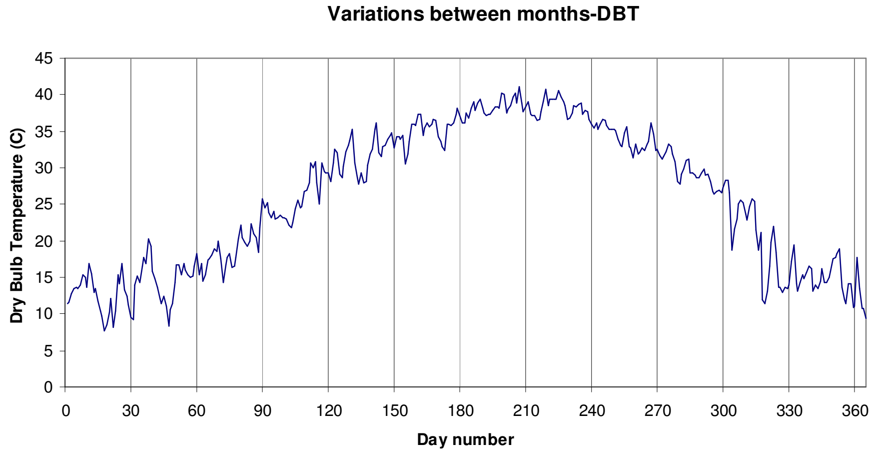


Figure 79 Variations of DBT of selected months over a whole year (TRY)

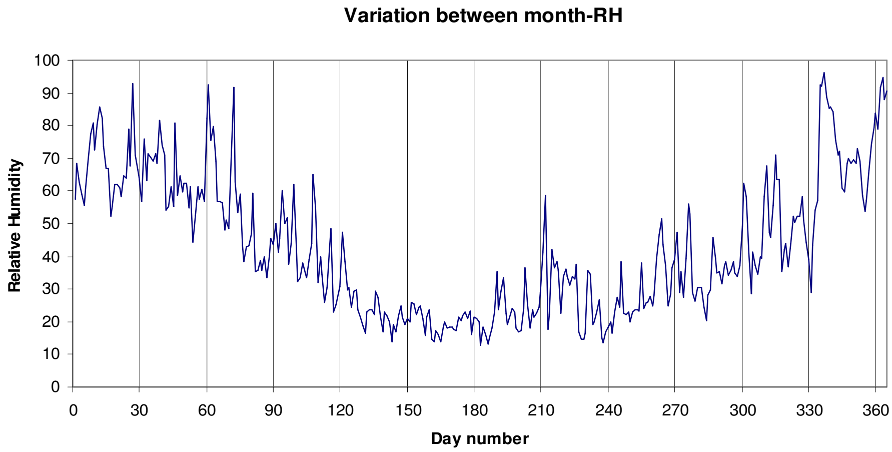


Figure 80 Variations of RH of selected months over a whole year (TRY)

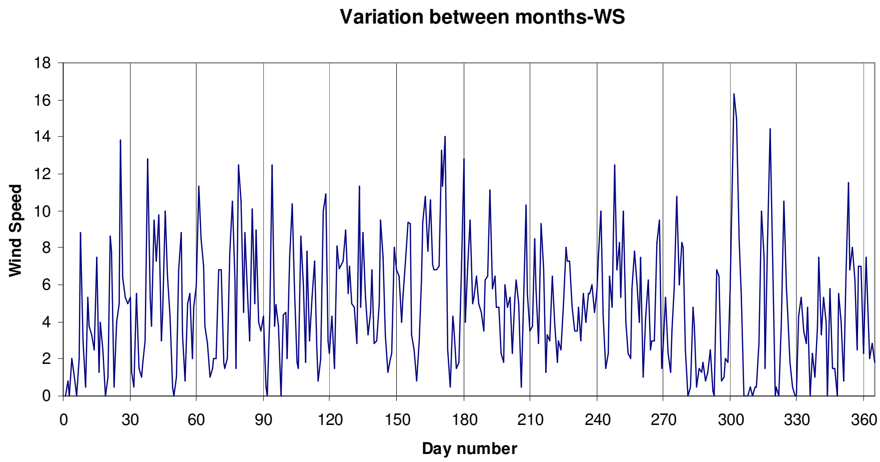


Figure 81 Variations of WS (kts) of selected months over a whole year (TRY)

B.3 Variations between every two joints in TRY

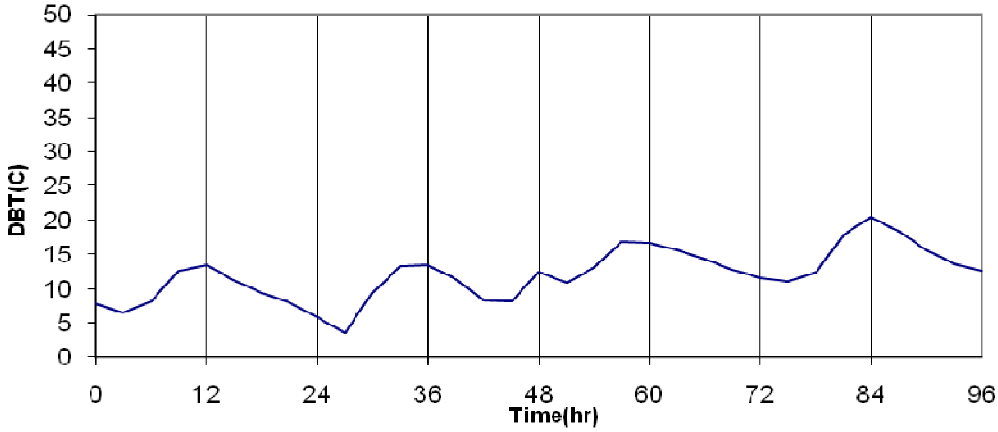


Figure 82 Variation of Temperature between 30Jan06-31Jan06 --- 01Feb98-02Feb98

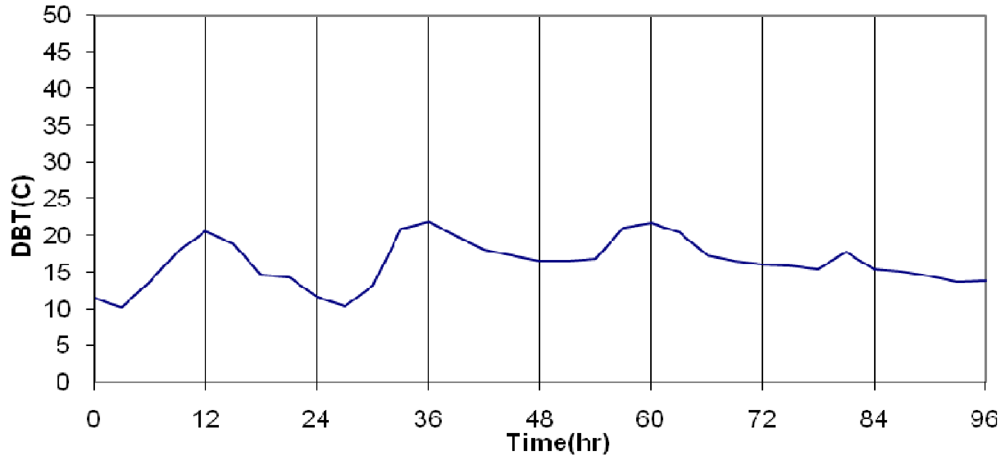


Figure 83 Variation of Temperature between 27Feb98-28Feb98 --- 01Mar99-02Mar99

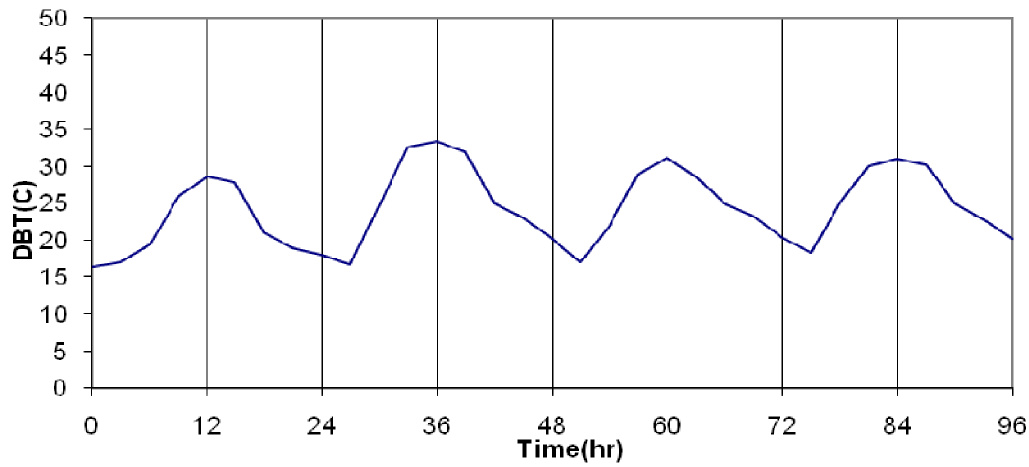


Figure 84 Variation of Temperature between 30Mar99-31Mar99 --- 01Apr91-02Apr91

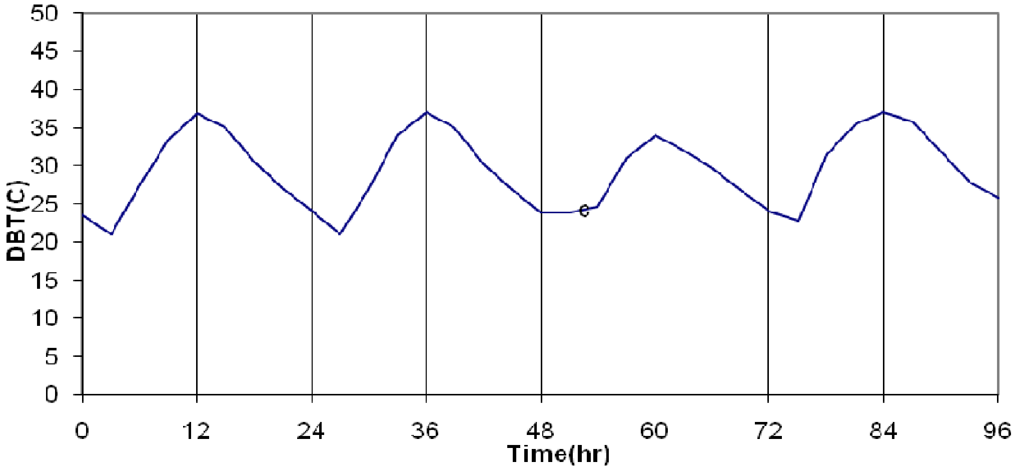


Figure 85 Variation of Temperature between 29Apr91-30Apr91--- 01May04-02May04

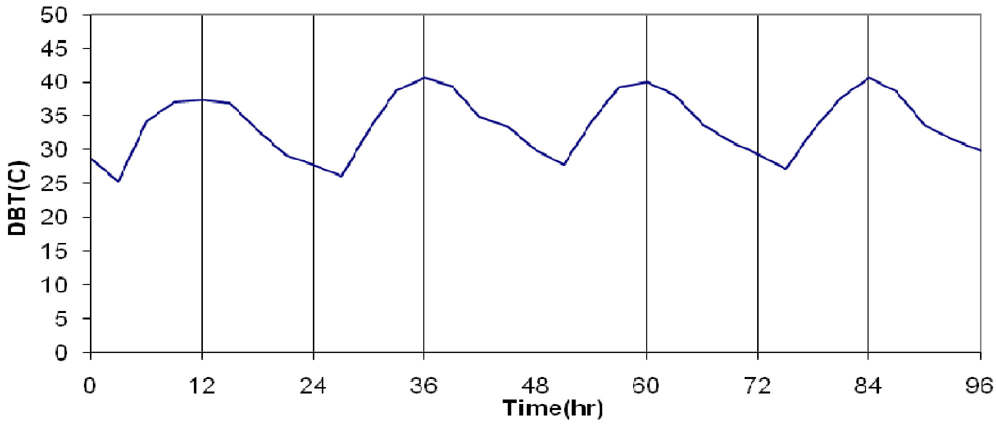


Figure 86 Variation of Temperature between 30May04-31May04 --- 01Jun93-02Jun93

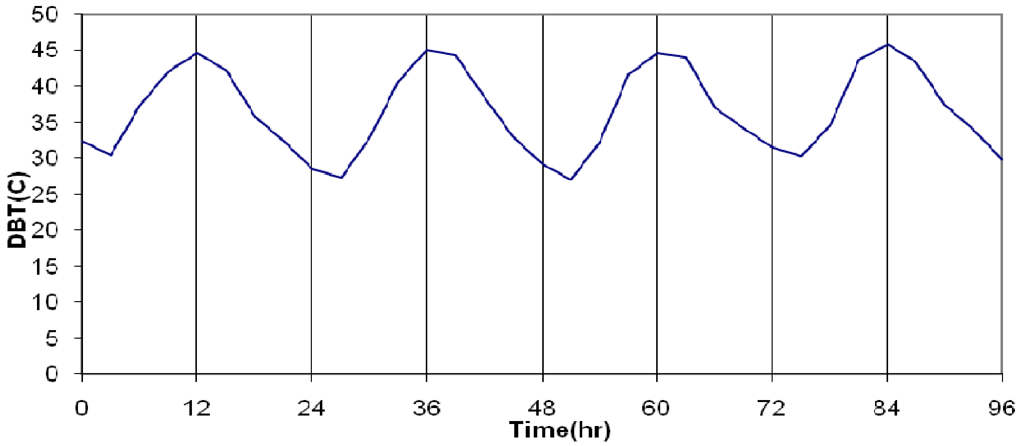


Figure 87 Variation of Temperature between 29Jun93-30Jun93 --- 01Jul04-02Jul04

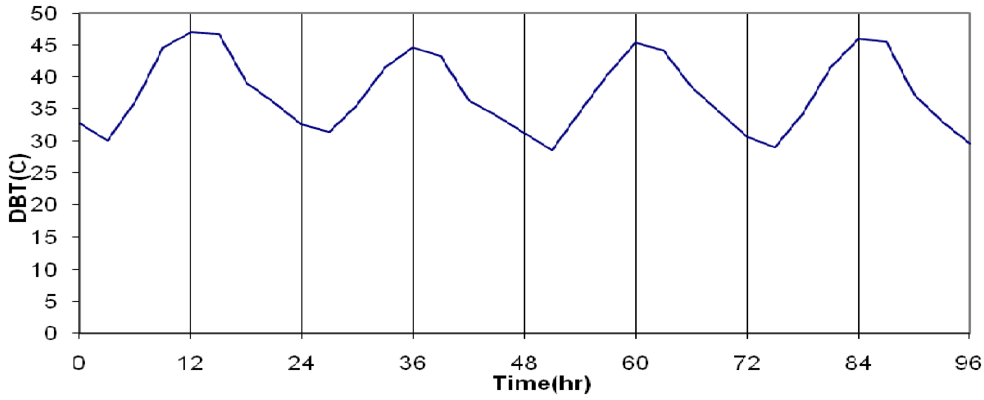


Figure 88 Variation of Temperature between 30Jul04-31Jul04 --- 01Aug03-02Aug03

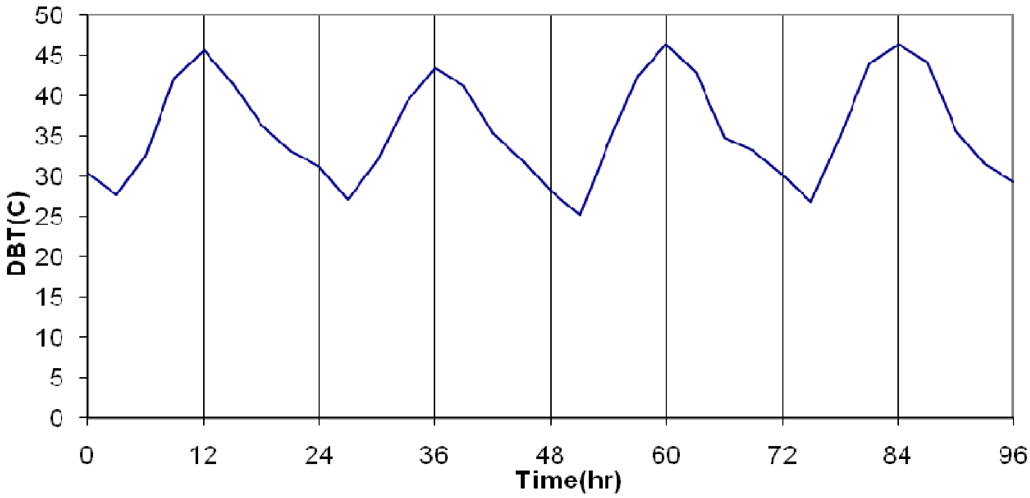


Figure 89 Variation of Temperature between 30Aug03-31Aug03 --- 01Sep02-02Sep02

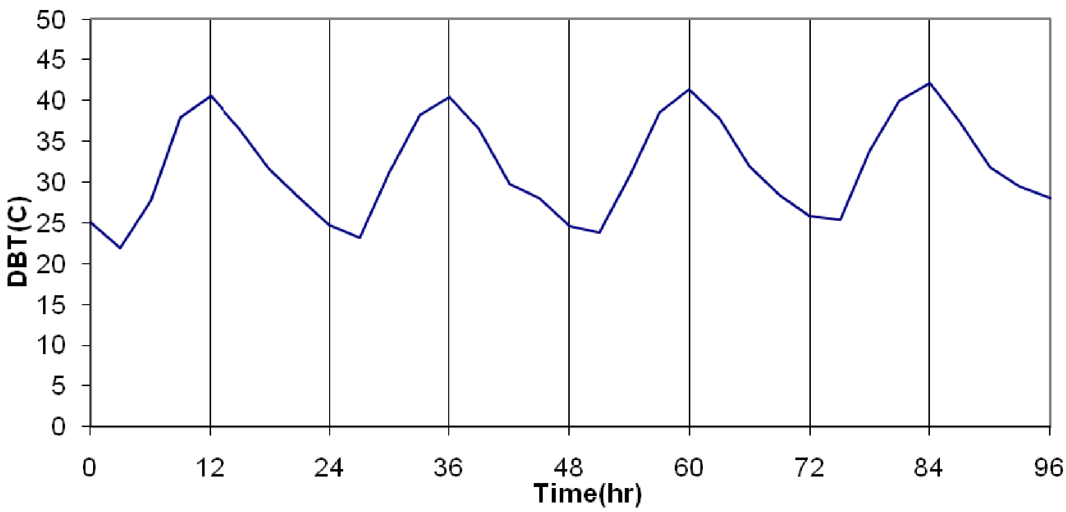


Figure 90 Variation of Temperature between 29Sep02-30Sep02 --- 01Oct03-02Oct03

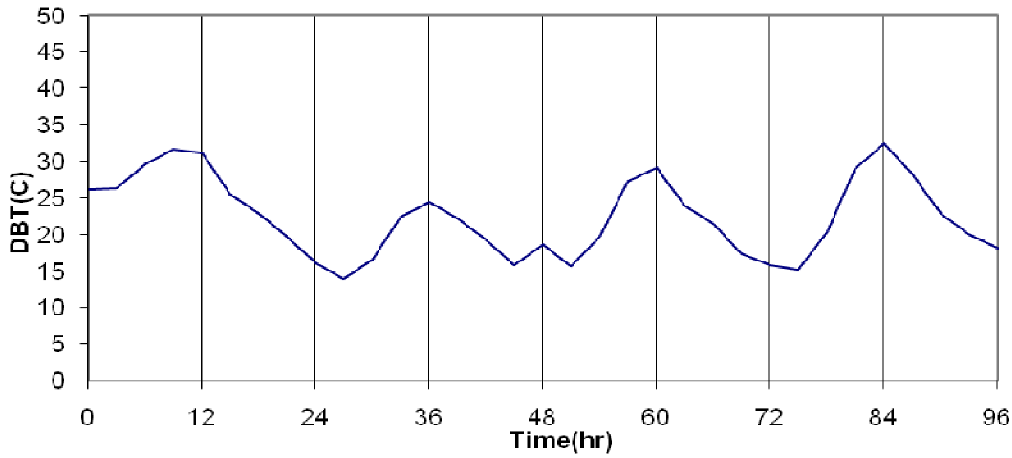


Figure 91 Variation of Temperature between 30Oct03-31Oct03 --- 01Nov88-02Nov88

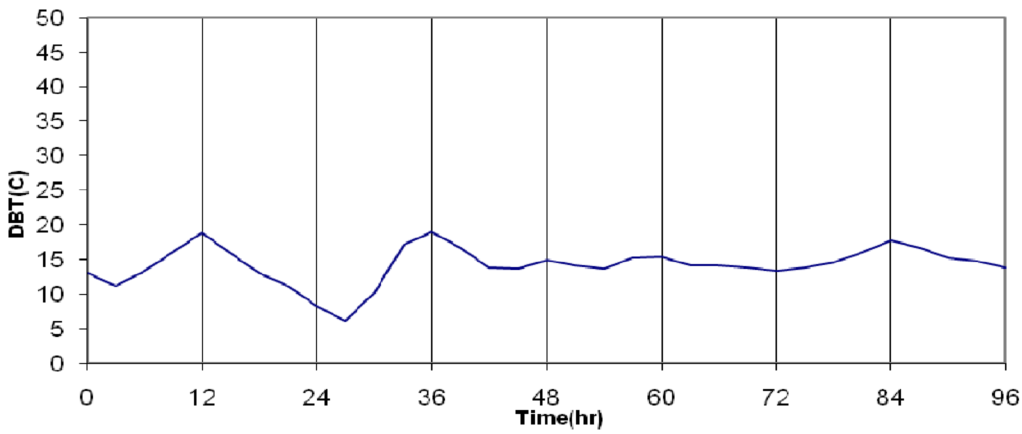


Figure 92 Variation of Temperature between 29Nov88-30Nov88 --- 01Dec03-02Dec03

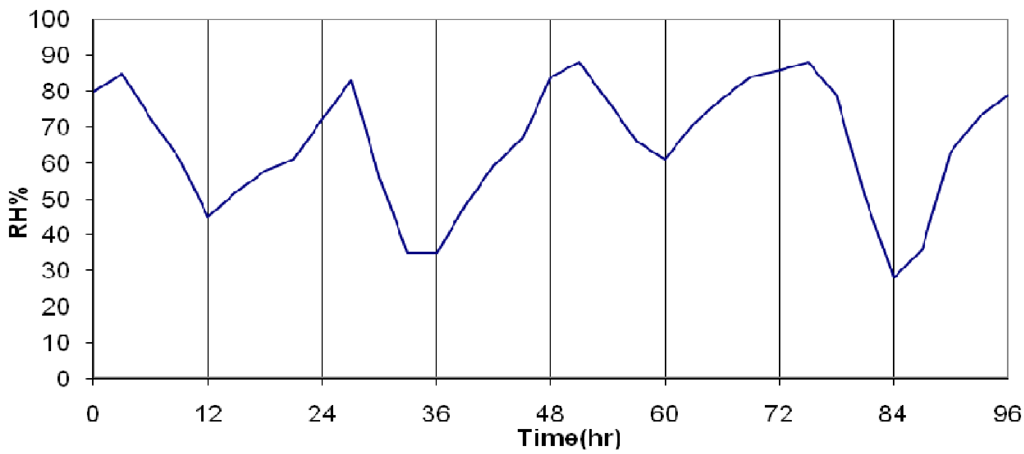


Figure 93 Variation of Relative Humidity between 30Jan06-31Jan06 --- 01Feb98-02Feb98

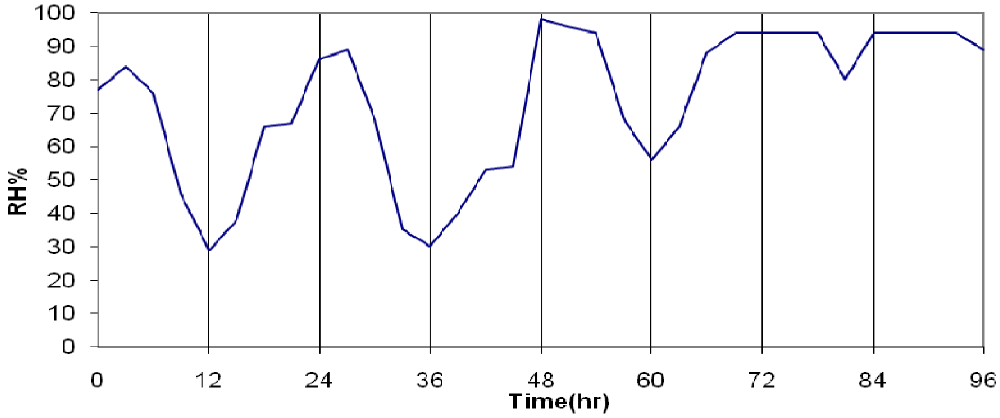


Figure 94 Variation of Relative Humidity between 27Feb98-28Feb98 --- 01Mar99-02Mar99

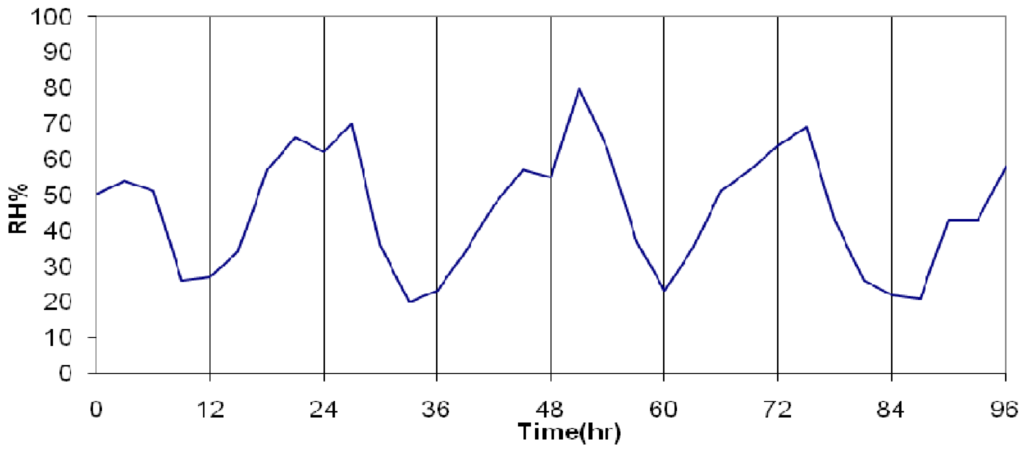


Figure 95 Variation of Relative Humidity between 30Mar99-31Mar99 --- 01Apr91-02Apr91

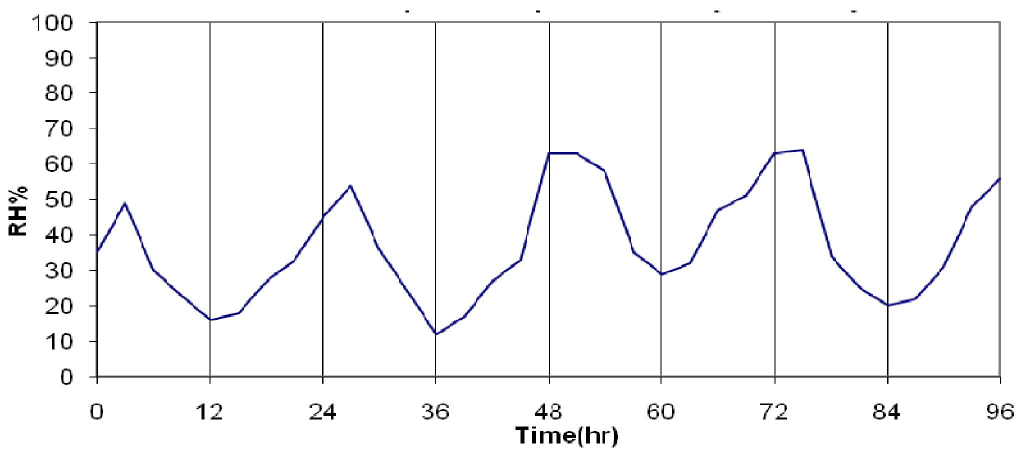


Figure 96 Variation of Relative Humidity between 29Apr91-30Apr91--- 01May04-02May04

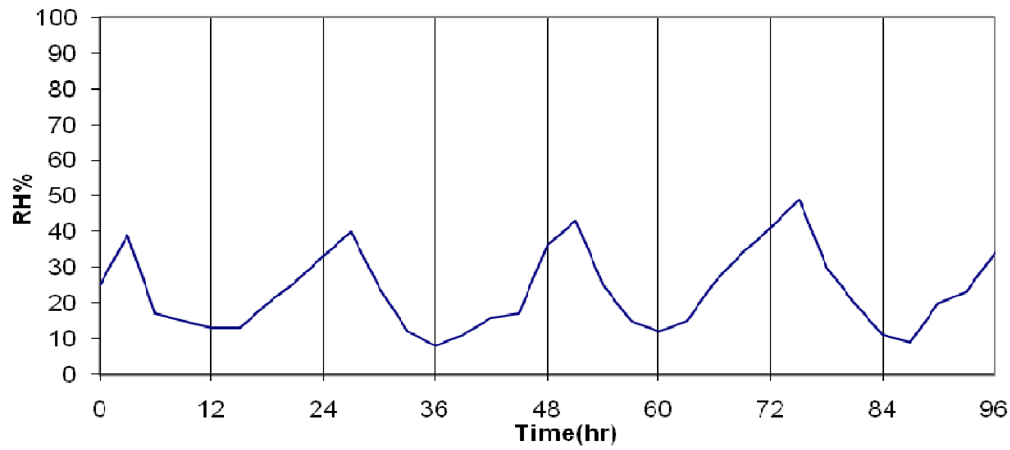


Figure 97 Variation of Relative Humidity between 30May04-31May04 --- 01Jun93-02Jun93

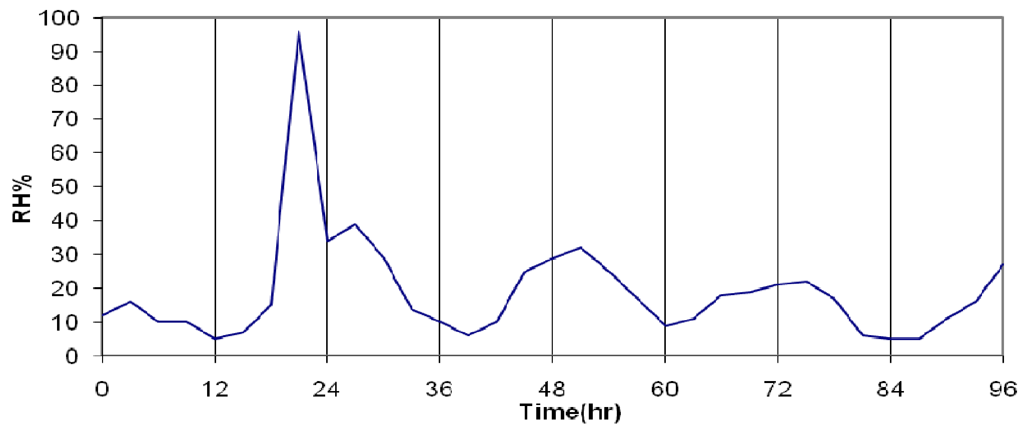


Figure 98 Variation of Relative Humidity between 29Jun93-30Jun93 --- 01Jul04-02Jul04

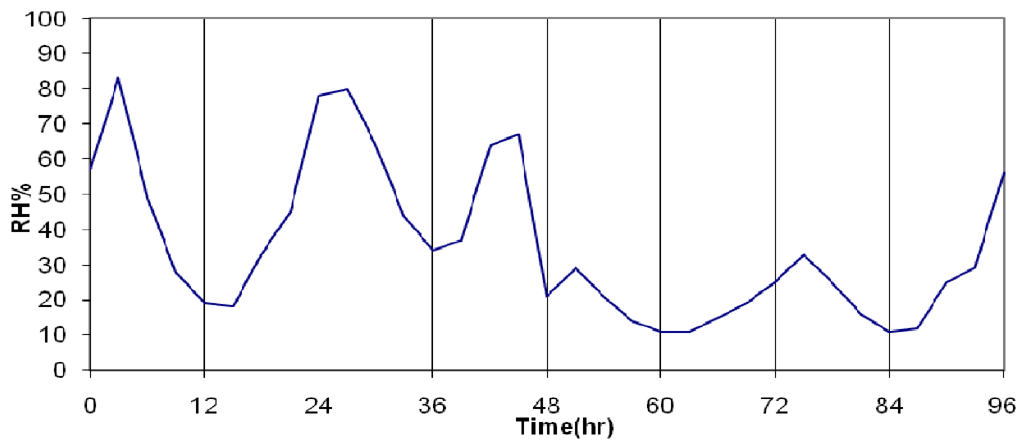


Figure 99 Variation of Relative Humidity between 30Jul04-31Jul04 --- 01Aug03-02Aug03

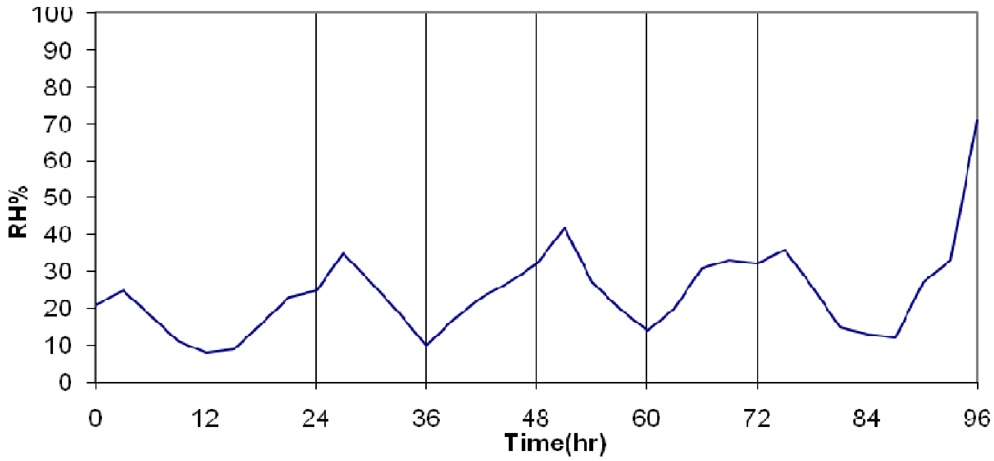


Figure 100 Variation of Relative Humidity between 30Aug03-31Aug03 --- 01Sep02-02Sep02

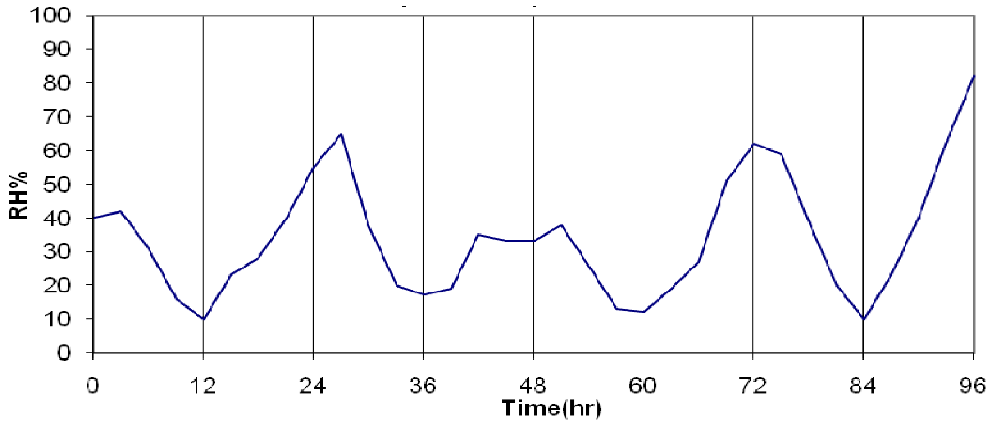


Figure 101 Variation of Relative Humidity between 29Sep02-30Sep02 --- 01Oct03-02Oct03

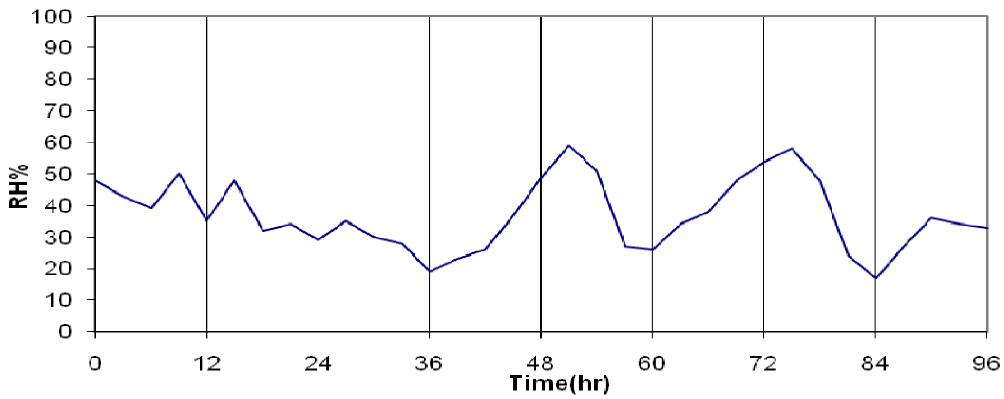


Figure 102 Variation of Relative Humidity between 30Oct03-31Oct03 --- 01Nov88-02Nov88

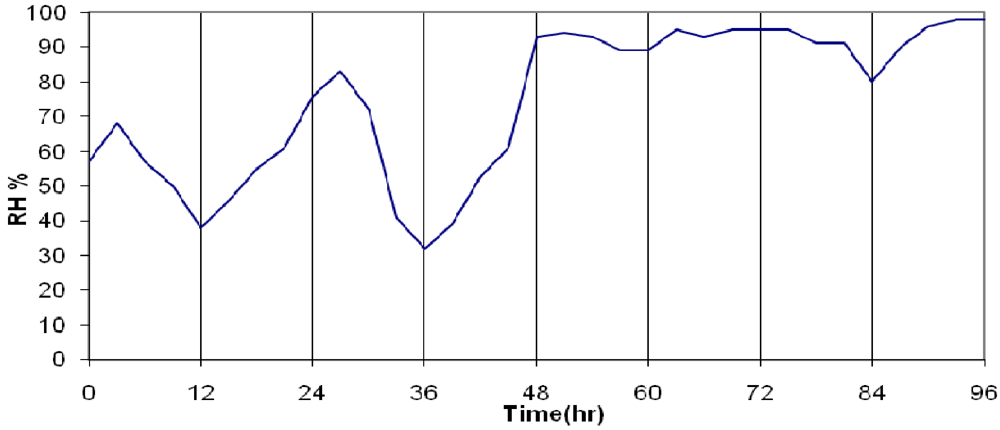


Figure 103 Variation of Relative Humidity between 29Nov88-30Nov88 --- 01Dec03-02Dec03

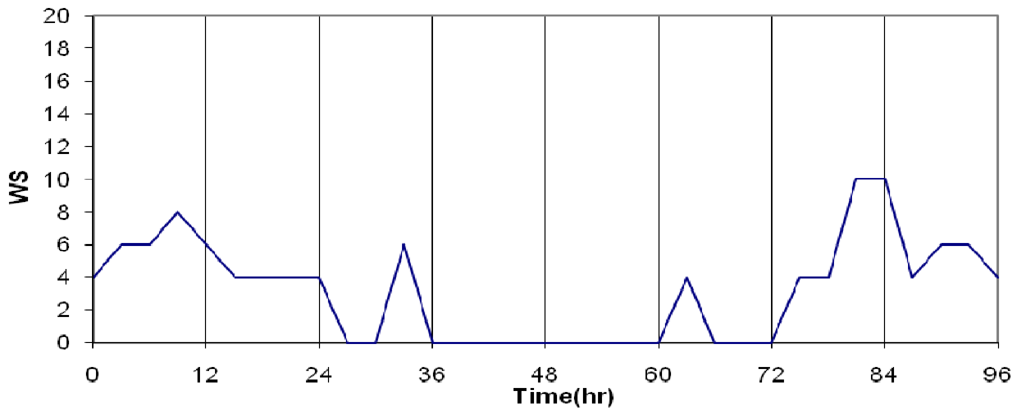


Figure 104 Variation of Wind Speed (kts) between 30Jan06-31Jan06 --- 01Feb98-02Feb98

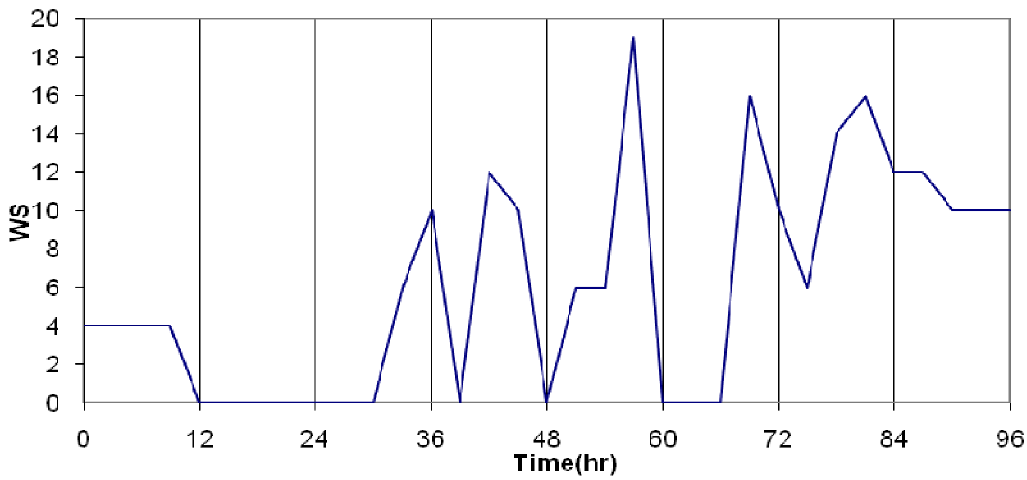


Figure 105 Variation of Wind Speed (kts) between 27Feb98-28Feb98 --- 01Mar99-02Mar99

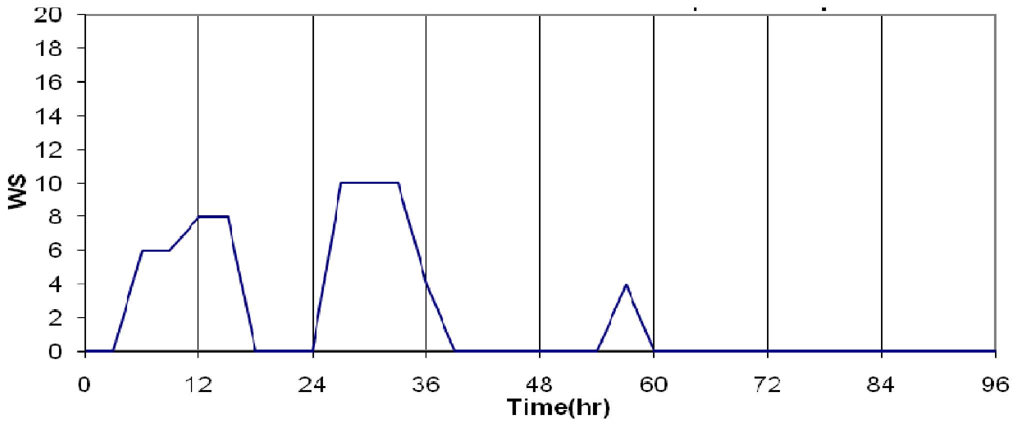


Figure 106 Variation of Wind Speed (kts) between 30Mar99-31Mar99 --- 01Apr91-02Apr91

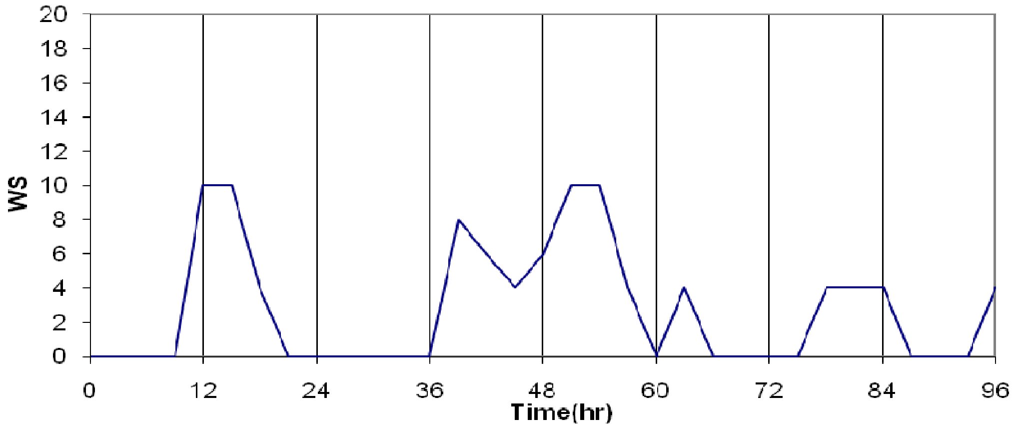


Figure 107 Variation of Wind Speed (kts) between 29Apr91-30Apr91--- 01May04-02May04

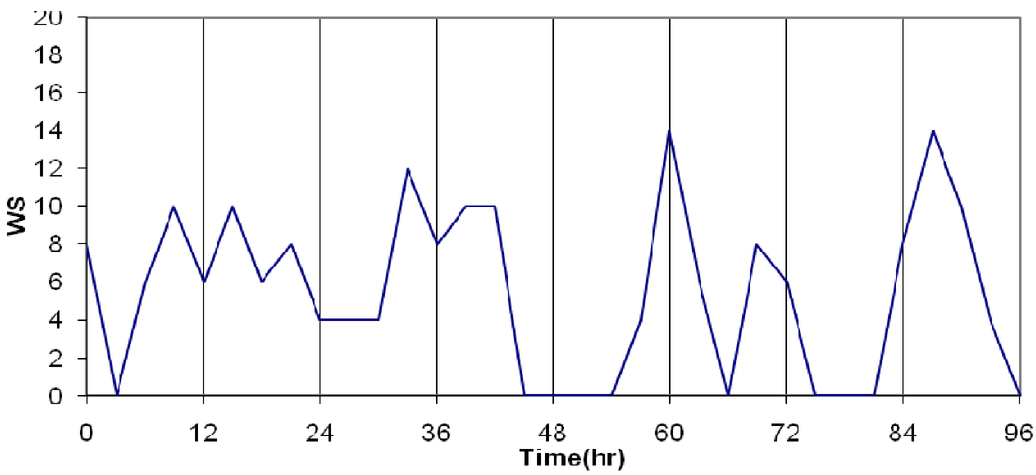


Figure 108 Variation of Wind Speed (kts) between 30May04-31May04 --- 01Jun93-02Jun93

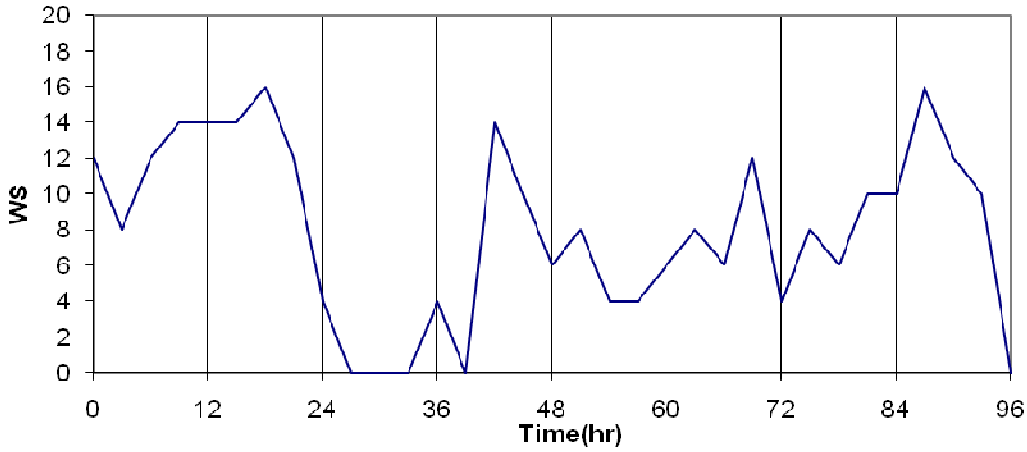


Figure 109 Variation of Wind Speed (kts) between 29Jun93-30Jun93 --- 01Jul04-02Jul04

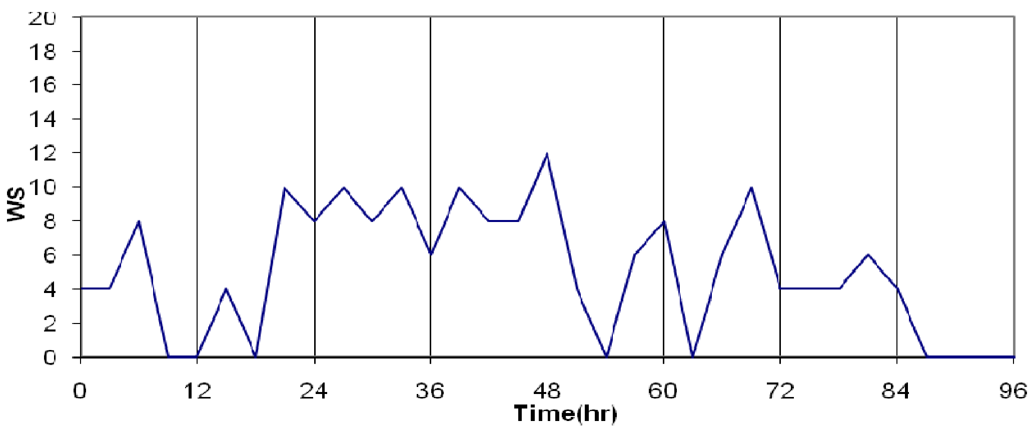


Figure 110 Variation of Wind Speed (kts) between 30Jul04-31Jul04 --- 01Aug03-02Aug03

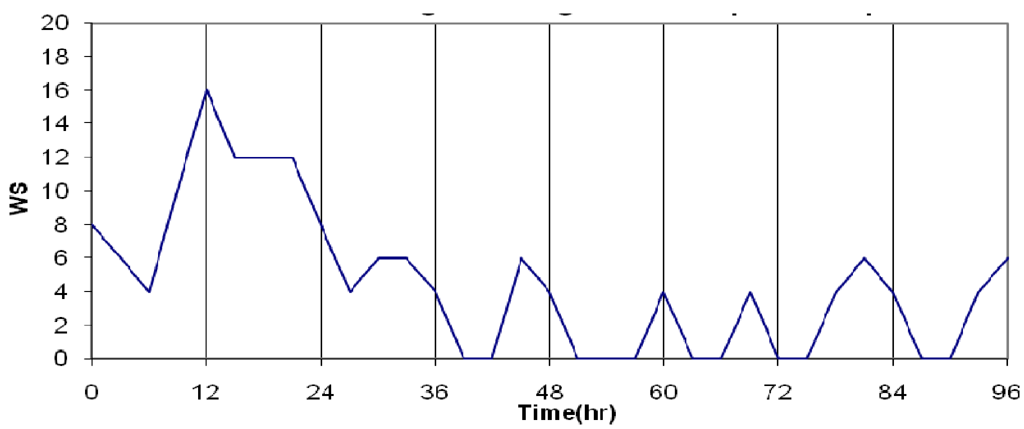


Figure 111 Variation of Wind Speed (kts) between 30Aug03-31Aug03 --- 01Sep02-02Sep02

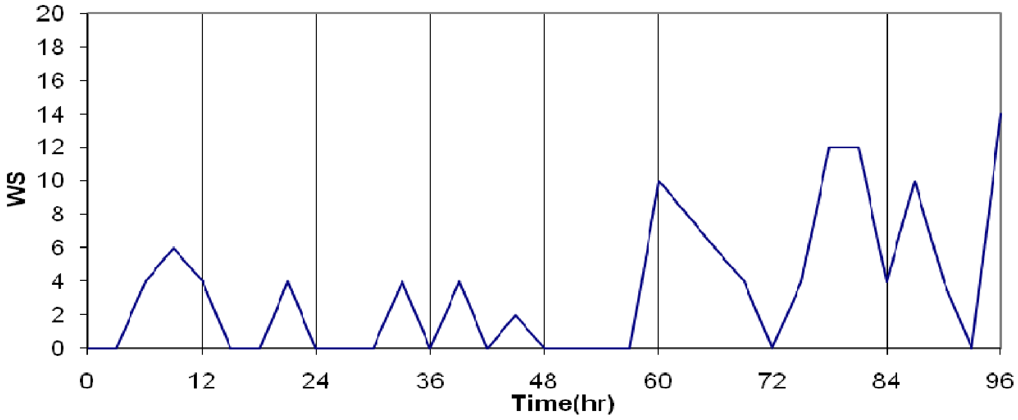


Figure 112 Variation of Wind Speed (kts) between 29Sep02-30Sep02 --- 01Oct03-02Oct03

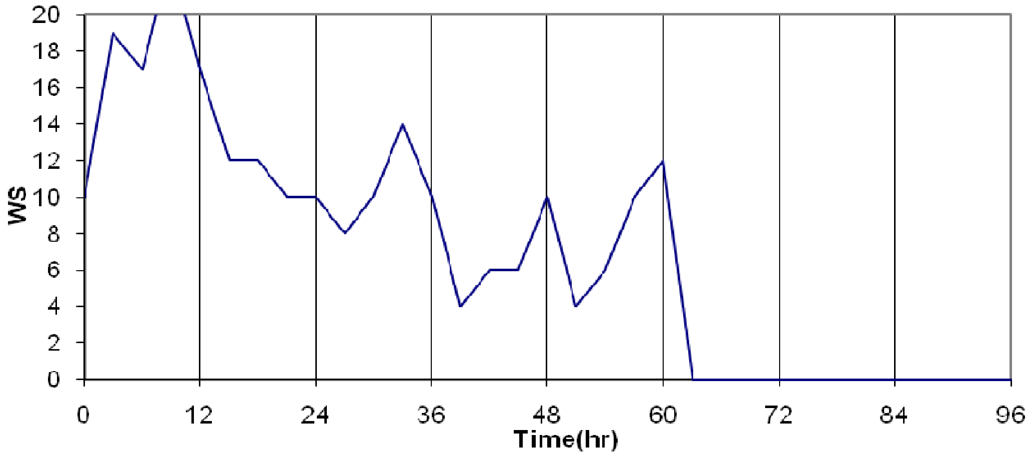


Figure 113 Variation of Wind Speed (kts) between 30Oct03-31Oct03 --- 01Nov88-02Nov88

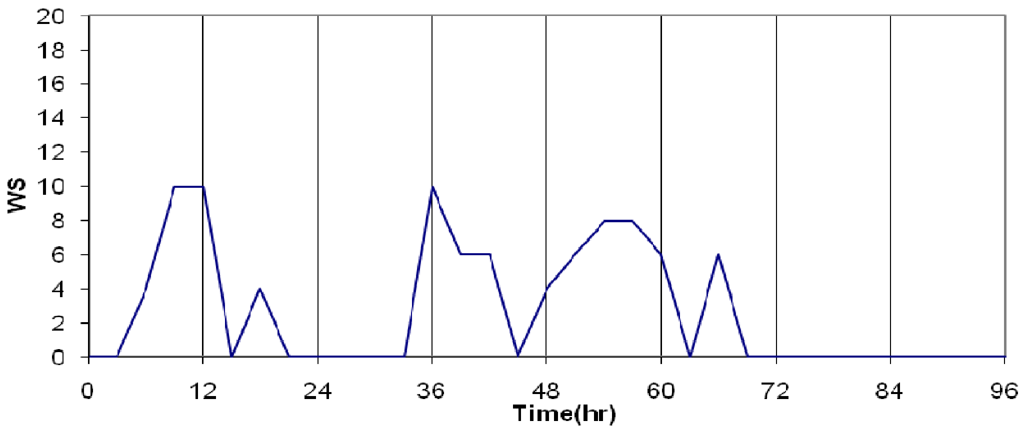


Figure 114 Variation of Wind Speed (kts) between 29Nov88-30Nov88 --- 01Dec03-02Dec03

APPENDIX C: MATLAB PROGRAMMING

C. 1 Mean and Standard deviations programming in Matlab for all parameters for each selected month of TRY for three cities of Ahvaz, Kuwait and Tehran

```
clc;
clear all;
open('C:\Documents and Settings\mbgngva2\Desktop\Comp.xlsx');
Fu=data;
[m n]=size(Fu);
A=mean(Fu(1:744,1));B=mean(Fu(1:744,5));C=mean(Fu(1:744,9));D=[A      B
C];D=D';
As=std(Fu(1:744,1));Bs=std(Fu(1:744,5));Cs=std(Fu(1:744,9));Ds=[As   Bs
Cs];Ds=Ds';


A2=mean(Fu(745:1416,1));B2=mean(Fu(745:1416,5));C2=mean(Fu(745:1416,9)
);D2=[A2 B2 C2];D2=D2';
As2=std(Fu(745:1416,1));Bs2=std(Fu(745:1416,5));Cs2=std(Fu(745:1416,9)
);Ds2=[As2 Bs2 Cs2];Ds2=Ds2';


A3=mean(Fu(1417:2160,1));B3=mean(Fu(1417:2160,5));C3=mean(Fu(1417:2160
,9));D3=[A3 B3 C3];D3=D3';
As3=std(Fu(1417:2160,1));Bs3=std(Fu(1417:2160,5));Cs3=std(Fu(1417:2160
,9));Ds3=[As3 Bs3 Cs3];Ds3=Ds3';



A4=mean(Fu(2161:2880,1));B4=mean(Fu(2161:2880,5));C4=mean(Fu(2161:2880
,9));D4=[A4 B4 C4];D4=D4';
As4=std(Fu(2161:2880,1));Bs4=std(Fu(2161:2880,5));Cs4=std(Fu(2161:2880
,9));Ds4=[As4 Bs4 Cs4];Ds4=Ds4';



A5=mean(Fu(2881:3624,1));B5=mean(Fu(2881:3624,5));C5=mean(Fu(2881:3624
,9));D5=[A5 B5 C5];D5=D5';
As5=std(Fu(2881:3624,1));Bs5=std(Fu(2881:3624,5));Cs5=std(Fu(2881:3624
,9));Ds5=[As5 Bs5 Cs5];Ds5=Ds5';



A6=mean(Fu(3625:4344,1));B6=mean(Fu(3625:4344,5));C6=mean(Fu(3625:4344
,9));D6=[A6 B6 C6];D6=D6';
As6=std(Fu(3625:4344,1));Bs6=std(Fu(3625:4344,5));Cs6=std(Fu(3625:4344
,9));Ds6=[As6 Bs6 Cs6];Ds6=Ds6';
```

```
A7=mean(Fu(4345:5088,1));B7=mean(Fu(4345:5088,5));C7=mean(Fu(4345:5088
,9));D7=[A7 B7 C7];D7=D7';

As7=std(Fu(4345:5088,1));Bs7=std(Fu(4345:5088,5));Cs7=std(Fu(4345:5088
,9));Ds7=[As7 Bs7 Cs7];Ds7=Ds7';



A8=mean(Fu(5089:5832,1));B8=mean(Fu(5089:5832,5));C8=mean(Fu(5089:5832
,9));D8=[A8 B8 C8];D8=D8';

As8=std(Fu(5089:5832,1));Bs8=std(Fu(5089:5832,5));Cs8=std(Fu(5089:5832
,9));Ds8=[As8 Bs8 Cs8];Ds8=Ds8';



A9=mean(Fu(5833:6552,1));B9=mean(Fu(5833:6552,5));C9=mean(Fu(5833:6552
,9));D9=[A9 B9 C9];D9=D9';

As9=std(Fu(5833:6552,1));Bs9=std(Fu(5833:6552,5));Cs9=std(Fu(5833:6552
,9));Ds9=[As9 Bs9 Cs9];Ds9=Ds9';



A10=mean(Fu(6553:7296,1));B10=mean(Fu(6553:7296,5));C10=mean(Fu(6553:7
296,9));D10=[A10 B10 C10];D10=D10';

As10=std(Fu(6553:7296,1));Bs10=std(Fu(6553:7296,5));Cs10=std(Fu(6553:7
296,9));Ds10=[As10 Bs10 Cs10];Ds10=Ds10';



A11=mean(Fu(7297:8016,1));B11=mean(Fu(7297:8016,5));C11=mean(Fu(7297:8
016,9));D11=[A11 B11 C11];D11=D11';

As11=std(Fu(7297:8016,1));Bs11=std(Fu(7297:8016,5));Cs11=std(Fu(7297:8
016,9));Ds11=[As11 Bs11 Cs11];Ds11=Ds11';



A12=mean(Fu(8017:8760,1));B12=mean(Fu(8017:8760,5));C12=mean(Fu(8017:8
760,9));D12=[A12 B12 C12];D12=D12';

As12=std(Fu(8017:8760,1));Bs12=std(Fu(8017:8760,5));Cs12=std(Fu(8017:8
760,9));Ds12=[As12 Bs12 Cs12];Ds12=Ds12';



A=mean(Fu(1:744,2));B=mean(Fu(1:744,6));C=mean(Fu(1:744,10));D=[A     B
C];D=D';

As=std(Fu(1:744,2));Bs=std(Fu(1:744,6));Cs=std(Fu(1:744,10));Ds=[As  Bs
Cs];Ds=Ds';


A2=mean(Fu(745:1416,2));B2=mean(Fu(745:1416,6));C2=mean(Fu(745:1416,10
));D2=[A2 B2 C2];D2=D2';

As2=std(Fu(745:1416,2));Bs2=std(Fu(745:1416,6));Cs2=std(Fu(745:1416,10
));Ds2=[As2 Bs2 Cs2];Ds2=Ds2';
```

```
A3=mean(Fu(1417:2160,2));B3=mean(Fu(1417:2160,6));C3=mean(Fu(1417:2160
,10));D3=[A3 B3 C3];D3=D3';
As3=std(Fu(1417:2160,2));Bs3=std(Fu(1417:2160,6));Cs3=std(Fu(1417:2160
,10));Ds3=[As3 Bs3 Cs3];Ds3=Ds3';

A4=mean(Fu(2161:2880,2));B4=mean(Fu(2161:2880,6));C4=mean(Fu(2161:2880
,10));D4=[A4 B4 C4];D4=D4';
As4=std(Fu(2161:2880,2));Bs4=std(Fu(2161:2880,6));Cs4=std(Fu(2161:2880
,10));Ds4=[As4 Bs4 Cs4];Ds4=Ds4';

A5=mean(Fu(2881:3624,2));B5=mean(Fu(2881:3624,6));C5=mean(Fu(2881:3624
,10));D5=[A5 B5 C5];D5=D5';
As5=std(Fu(2881:3624,2));Bs5=std(Fu(2881:3624,6));Cs5=std(Fu(2881:3624
,10));Ds5=[As5 Bs5 Cs5];Ds5=Ds5';

A6=mean(Fu(3625:4344,2));B6=mean(Fu(3625:4344,6));C6=mean(Fu(3625:4344
,10));D6=[A6 B6 C6];D6=D6';
As6=std(Fu(3625:4344,2));Bs6=std(Fu(3625:4344,6));Cs6=std(Fu(3625:4344
,10));Ds6=[As6 Bs6 Cs6];Ds6=Ds6';

A7=mean(Fu(4345:5088,2));B7=mean(Fu(4345:5088,6));C7=mean(Fu(4345:5088
,10));D7=[A7 B7 C7];D7=D7';
As7=std(Fu(4345:5088,2));Bs7=std(Fu(4345:5088,6));Cs7=std(Fu(4345:5088
,10));Ds7=[As7 Bs7 Cs7];Ds7=Ds7';

A8=mean(Fu(5089:5832,2));B8=mean(Fu(5089:5832,6));C8=mean(Fu(5089:5832
,10));D8=[A8 B8 C8];D8=D8';
As8=std(Fu(5089:5832,2));Bs8=std(Fu(5089:5832,6));Cs8=std(Fu(5089:5832
,10));Ds8=[As8 Bs8 Cs8];Ds8=Ds8';

A9=mean(Fu(5833:6552,2));B9=mean(Fu(5833:6552,6));C9=mean(Fu(5833:6552
,10));D9=[A9 B9 C9];D9=D9';
As9=std(Fu(5833:6552,2));Bs9=std(Fu(5833:6552,6));Cs9=std(Fu(5833:6552
,10));Ds9=[As9 Bs9 Cs9];Ds9=Ds9';

A10=mean(Fu(6553:7296,2));B10=mean(Fu(6553:7296,6));C10=mean(Fu(6553:7
296,10));D10=[A10 B10 C10];D10=D10';
As10=std(Fu(6553:7296,2));Bs10=std(Fu(6553:7296,6));Cs10=std(Fu(6553:7
296,10));Ds10=[As10 Bs10 Cs10];Ds10=Ds10';
```

```
A11=mean(Fu(7297:8016,2));B11=mean(Fu(7297:8016,6));C11=mean(Fu(7297:8016,10));D11=[A11 B11 C11];D11=D11';

As11=std(Fu(7297:8016,2));Bs11=std(Fu(7297:8016,6));Cs11=std(Fu(7297:8016,10));Ds11=[As11 Bs11 Cs11];Ds11=Ds11';



A12=mean(Fu(8017:8760,2));B12=mean(Fu(8017:8760,6));C12=mean(Fu(8017:8760,10));D12=[A12 B12 C12];D12=D12';

As12=std(Fu(8017:8760,2));Bs12=std(Fu(8017:8760,6));Cs12=std(Fu(8017:8760,10));Ds12=[As12 Bs12 Cs12];Ds12=Ds12';



A=mean(Fu(1:744,3));B=mean(Fu(1:744,7));C=mean(Fu(1:744,11));D=[A B C];D=D';

As=std(Fu(1:744,3));Bs=std(Fu(1:744,7));Cs=std(Fu(1:744,11));Ds=[As Bs Cs];Ds=Ds';


A2=mean(Fu(745:1416,3));B2=mean(Fu(745:1416,7));C2=mean(Fu(745:1416,11));D2=[A2 B2 C2];D2=D2';

As2=std(Fu(745:1416,3));Bs2=std(Fu(745:1416,7));Cs2=std(Fu(745:1416,11));Ds2=[As2 Bs2 Cs2];Ds2=Ds2';


A3=mean(Fu(1417:2160,3));B3=mean(Fu(1417:2160,7));C3=mean(Fu(1417:2160,11));D3=[A3 B3 C3];D3=D3';

As3=std(Fu(1417:2160,3));Bs3=std(Fu(1417:2160,7));Cs3=std(Fu(1417:2160,11));Ds3=[As3 Bs3 Cs3];Ds3=Ds3';



A4=mean(Fu(2161:2880,3));B4=mean(Fu(2161:2880,7));C4=mean(Fu(2161:2880,11));D4=[A4 B4 C4];D4=D4';

As4=std(Fu(2161:2880,3));Bs4=std(Fu(2161:2880,7));Cs4=std(Fu(2161:2880,11));Ds4=[As4 Bs4 Cs4];Ds4=Ds4';



A5=mean(Fu(2881:3624,3));B5=mean(Fu(2881:3624,7));C5=mean(Fu(2881:3624,11));D5=[A5 B5 C5];D5=D5';

As5=std(Fu(2881:3624,3));Bs5=std(Fu(2881:3624,7));Cs5=std(Fu(2881:3624,11));Ds5=[As5 Bs5 Cs5];Ds5=Ds5';



A6=mean(Fu(3625:4344,3));B6=mean(Fu(3625:4344,7));C6=mean(Fu(3625:4344,11));D6=[A6 B6 C6];D6=D6';

As6=std(Fu(3625:4344,3));Bs6=std(Fu(3625:4344,7));Cs6=std(Fu(3625:4344,11));Ds6=[As6 Bs6 Cs6];Ds6=Ds6';
```

```
A7=mean(Fu(4345:5088,3));B7=mean(Fu(4345:5088,7));C7=mean(Fu(4345:5088
,11));D7=[A7 B7 C7];D7=D7';

As7=std(Fu(4345:5088,3));Bs7=std(Fu(4345:5088,7));Cs7=std(Fu(4345:5088
,11));Ds7=[As7 Bs7 Cs7];Ds7=Ds7';


A8=mean(Fu(5089:5832,3));B8=mean(Fu(5089:5832,7));C8=mean(Fu(5089:5832
,11));D8=[A8 B8 C8];D8=D8';

As8=std(Fu(5089:5832,3));Bs8=std(Fu(5089:5832,7));Cs8=std(Fu(5089:5832
,11));Ds8=[As8 Bs8 Cs8];Ds8=Ds8';


A9=mean(Fu(5833:6552,3));B9=mean(Fu(5833:6552,7));C9=mean(Fu(5833:6552
,11));D9=[A9 B9 C9];D9=D9';

As9=std(Fu(5833:6552,3));Bs9=std(Fu(5833:6552,7));Cs9=std(Fu(5833:6552
,11));Ds9=[As9 Bs9 Cs9];Ds9=Ds9';


A10=mean(Fu(6553:7296,3));B10=mean(Fu(6553:7296,7));C10=mean(Fu(6553:7
296,11));D10=[A10 B10 C10];D10=D10';

As10=std(Fu(6553:7296,3));Bs10=std(Fu(6553:7296,7));Cs10=std(Fu(6553:7
296,11));Ds10=[As10 Bs10 Cs10];Ds10=Ds10';


A11=mean(Fu(7297:8016,3));B11=mean(Fu(7297:8016,7));C11=mean(Fu(7297:8
016,11));D11=[A11 B11 C11];D11=D11';

As11=std(Fu(7297:8016,3));Bs11=std(Fu(7297:8016,7));Cs11=std(Fu(7297:8
016,11));Ds11=[As11 Bs11 Cs11];Ds11=Ds11';


A12=mean(Fu(8017:8760,3));B12=mean(Fu(8017:8760,7));C12=mean(Fu(8017:8
760,11));D12=[A12 B12 C12];D12=D12';

As12=std(Fu(8017:8760,3));Bs12=std(Fu(8017:8760,7));Cs12=std(Fu(8017:8
760,11));Ds12=[As12 Bs12 Cs12];Ds12=Ds12';


A=mean(Fu(1:744,4));B=mean(Fu(1:744,8));C=mean(Fu(1:744,12));D=[A     B
C];D=D';

As=std(Fu(1:744,4));Bs=std(Fu(1:744,8));Cs=std(Fu(1:744,12));Ds=[As  Bs
Cs];Ds=Ds';


A2=mean(Fu(745:1416,4));B2=mean(Fu(745:1416,8));C2=mean(Fu(745:1416,12
));D2=[A2 B2 C2];D2=D2';

As2=std(Fu(745:1416,4));Bs2=std(Fu(745:1416,8));Cs2=std(Fu(745:1416,12
));Ds2=[As2 Bs2 Cs2];Ds2=Ds2';
```

```
A3=mean(Fu(1417:2160,4));B3=mean(Fu(1417:2160,8));C3=mean(Fu(1417:2160
,12));D3=[A3 B3 C3];D3=D3';

As3=std(Fu(1417:2160,4));Bs3=std(Fu(1417:2160,8));Cs3=std(Fu(1417:2160
,12));Ds3=[As3 Bs3 Cs3];Ds3=Ds3';


A4=mean(Fu(2161:2880,4));B4=mean(Fu(2161:2880,8));C4=mean(Fu(2161:2880
,12));D4=[A4 B4 C4];D4=D4';

As4=std(Fu(2161:2880,4));Bs4=std(Fu(2161:2880,8));Cs4=std(Fu(2161:2880
,12));Ds4=[As4 Bs4 Cs4];Ds4=Ds4';


A5=mean(Fu(2881:3624,4));B5=mean(Fu(2881:3624,8));C5=mean(Fu(2881:3624
,12));D5=[A5 B5 C5];D5=D5';

As5=std(Fu(2881:3624,4));Bs5=std(Fu(2881:3624,8));Cs5=std(Fu(2881:3624
,12));Ds5=[As5 Bs5 Cs5];Ds5=Ds5';


A6=mean(Fu(3625:4344,4));B6=mean(Fu(3625:4344,8));C6=mean(Fu(3625:4344
,12));D6=[A6 B6 C6];D6=D6';

As6=std(Fu(3625:4344,4));Bs6=std(Fu(3625:4344,8));Cs6=std(Fu(3625:4344
,12));Ds6=[As6 Bs6 Cs6];Ds6=Ds6';


A7=mean(Fu(4345:5088,4));B7=mean(Fu(4345:5088,8));C7=mean(Fu(4345:5088
,12));D7=[A7 B7 C7];D7=D7';

As7=std(Fu(4345:5088,4));Bs7=std(Fu(4345:5088,8));Cs7=std(Fu(4345:5088
,12));Ds7=[As7 Bs7 Cs7];Ds7=Ds7';


A8=mean(Fu(5089:5832,4));B8=mean(Fu(5089:5832,8));C8=mean(Fu(5089:5832
,12));D8=[A8 B8 C8];D8=D8';

As8=std(Fu(5089:5832,4));Bs8=std(Fu(5089:5832,8));Cs8=std(Fu(5089:5832
,12));Ds8=[As8 Bs8 Cs8];Ds8=Ds8';


A9=mean(Fu(5833:6552,4));B9=mean(Fu(5833:6552,8));C9=mean(Fu(5833:6552
,12));D9=[A9 B9 C9];D9=D9';

As9=std(Fu(5833:6552,4));Bs9=std(Fu(5833:6552,8));Cs9=std(Fu(5833:6552
,12));Ds9=[As9 Bs9 Cs9];Ds9=Ds9';


A10=mean(Fu(6553:7296,4));B10=mean(Fu(6553:7296,8));C10=mean(Fu(6553:7
296,12));D10=[A10 B10 C10];D10=D10';
```

```
As10=std(Fu(6553:7296,4));Bs10=std(Fu(6553:7296,8));Cs10=std(Fu(6553:7
296,12));Ds10=[As10 Bs10 Cs10];Ds10=Ds10';



A11=mean(Fu(7297:8016,4));B11=mean(Fu(7297:8016,8));C11=mean(Fu(7297:8
016,12));D11=[A11 B11 C11];D11=D11';

As11=std(Fu(7297:8016,4));Bs11=std(Fu(7297:8016,8));Cs11=std(Fu(7297:8
016,12));Ds11=[As11 Bs11 Cs11];Ds11=Ds11';



A12=mean(Fu(8017:8760,4));B12=mean(Fu(8017:8760,8));C12=mean(Fu(8017:8
760,12));D12=[A12 B12 C12];D12=D12';

As12=std(Fu(8017:8760,4));Bs12=std(Fu(8017:8760,8));Cs12=std(Fu(8017:8
760,12));Ds12=[As12 Bs12 Cs12];Ds12=Ds12';
```

C.2 Mean and Standard deviations of four main parameters in selecting TRY

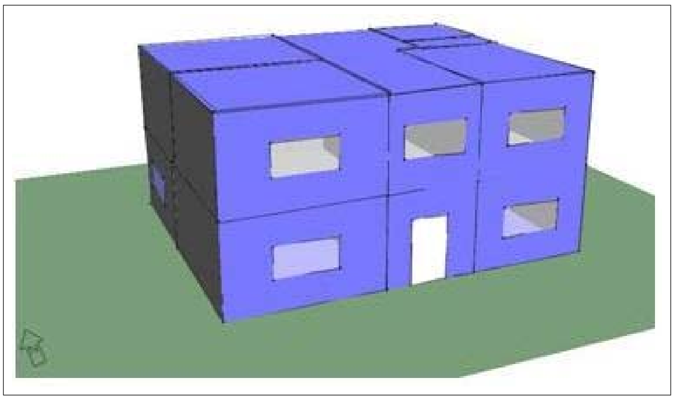
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	Ahvaz		Mean DB	12.41	14.81	18.66	25.70	31.76	35.25	38.38	37.95	33.75	28.76	20.13	14.38
3	Kuwait			14.08	15.42	19.23	24.78	32.01	36.87	38.33	38.33	34.03	28.59	20.50	14.82
4	Tehran			5.34	6.96	10.16	17.28	22.19	26.70	32.32	30.56	25.89	20.10	12.81	6.50
5															
6			SD DBT	3.84	4.06	4.46	5.18	5.30	5.70	5.61	5.74	6.00	5.52	5.16	3.68
7				3.88	5.34	4.82	5.07	5.27	5.75	5.05	5.90	5.96	4.86	4.94	3.31
8				2.86	3.58	4.08	3.74	4.80	4.32	4.29	3.69	4.23	3.95	4.02	2.88
9															
10															
11	Ahvaz		Mean RH	67.69	63.58	54.05	40.75	23.88	19.94	24.02	25.75	30.81	36.84	50.90	76.38
12	Kuwait			67.53	41.17	51.59	42.74	28.43	17.40	13.29	14.60	20.52	45.33	51.82	73.48
13	Tehran			59.17	53.75	46.53	42.34	32.29	31.48	27.44	29.13	29.88	37.34	48.50	66.97
14															
15			SD RH	16.00	17.38	22.99	17.30	12.18	11.90	14.35	16.16	16.08	15.58	16.01	16.03
16				20.32	18.15	24.10	22.48	17.44	10.94	6.09	8.62	14.25	21.06	21.50	17.02
17				18.16	19.22	18.32	16.72	15.96	12.16	11.06	9.35	11.29	14.83	17.92	15.24
18															
19															
20	Ahvaz		Mean WS	6.99	8.87	10.73	8.97	10.71	12.51	10.49	9.68	9.53	8.79	5.61	7.91
21	Kuwait			3.56	3.99	3.42	4.67	4.65	5.28	5.97	5.22	3.55	3.10	3.03	3.19
22	Tehran			1.61	2.84	3.39	3.13	2.83	3.41	2.93	2.09	2.11	2.27	1.77	1.59
23															
24			SD WS	8.12	8.69	9.41	10.65	8.26	10.86	6.94	7.52	7.96	10.00	7.65	7.38
25				2.59	2.69	2.88	2.57	2.75	2.87	2.64	2.95	2.27	2.57	2.28	2.46
26				2.24	2.50	3.16	2.91	2.55	2.59	1.77	1.62	1.77	2.27	2.03	1.91
27															
28															
29	Ahvaz		Mean GS	128.24	128.24	200.33	221.98	290.84	326.50	310.08	299.23	261.42	195.16	138.66	112.07
30	Kuwait			161.13	161.13	194.65	220.75	273.56	277.34	287.06	281.29	227.47	188.05	153.56	116.28
31	Tehran			60.09	60.09	177.36	268.19	372.78	415.52	400.99	326.26	234.20	146.40	79.34	50.82
32															
33			SD GSR	217.65	281.92	306.20	320.08	382.02	409.68	395.47	395.88	367.13	300.71	230.82	195.71
34				237.33	244.78	275.35	300.03	333.52	329.93	341.03	341.93	302.64	261.15	220.56	178.26
35					165.97	287.88	407.97	531.17	559.17	545.58	453.65	347.48	228.60	138.11	95.95

C.3 Diffuse fraction of global solar radiation programming

```
clc;
clear all;
open('C:\Documents and Settings\mbgngva2\Desktop\hextra.xlsx');
open('C:\Documents and Settings\mbgngva2\Desktop\global.xls');
V1=ex;
V2=data;
[m,n]=size(V1);KT=zeros(m,n);Id=zeros(m,n);
% Ki(i,j)=Id(i,j)/V2(i,j);

for j=1:n
    for i=1:m
        KT(i,j)=V2(i,j)/V1(i,j);
    end;end

for j=1:n
    for i=1:m
        if KT(i,j)<=0.22
            Id(i,j)=(1-0.09*KT(i,j))*V2(i,j);
        elseif KT(i,j)>0.22 & KT(i,j)<=0.8
            Id(i,j)=(0.9511-0.1604*KT(i,j)+4.388*KT(i,j)^2-
16.638*KT(i,j)^3+12.336*KT(i,j)^4)*V2(i,j);
        elseif KT(i,j)>0.80
            Id(i,j)=0.165*V2(i,j);
        end;end;end
```



Project contact details:
Vahid Alipour MPhil Civil Engineering
MACE University of Manchester
Project : A new Test Reference Year for Ahvaz, Iran
Email : vahid.alipour@postgrad.manchester.ac.uk

Location & Site Data

Location	Ahwaz
Region	Iran
Latitude	31.33 N
Longitude	48.67 E
Altitude	22.0m
Time zone **Hours ahead of GMT**	3.5 hours

Daylight Saving Time

Time adjustment	1.0 hours
From	April
Through	September
Adjustment for other months	0.0 hours

Site Data

Ground reflectance	0.2
Terrain type	City
Wind exposure **(CIBSE Heating Loads)**	Normal

Weather Simulation Data

ApacheSim File Ahvaz.fwt

Design Weather Data

Design Weather Data Source & Statistics

Source of Design Weather	ASHRAE design weather database
ASHRAE weather location	Ahwaz, Iran
Monthly percentile for Heating Loads design weather	99.6 %
Monthly percentile for Cooling Loads design weather	0.4 %

Heating Loads Weather Data

Outdoor Winter Design Temperature	4.9℃

Cooling Loads Weather Data

Max. Outside Dry-Bulb	49.0℃
Max. Outside Wet-Bulb	22.9℃

Weather model data

	Temperature		**Humidity**	**Solar Radiation**
	Dry bulb T Min (℃)	**Dry bulb T Max (℃)**	**Wet bulb T at Max dry bulb (℃)**	**Linke Turbidity Factor**
Jan	14.00	22.20	13.30	2.17
Feb	15.00	24.70	14.70	2.26
Mar	20.70	31.80	18.10	2.52
Apr	26.40	39.20	19.40	2.88
May	30.80	45.80	20.70	3.15
Jun	31.70	48.00	22.00	3.34
Jul	33.80	49.00	22.20	3.43
Aug	32.60	48.50	22.90	3.24
Sep	29.50	45.90	21.90	2.88
Oct	25.50	40.20	19.90	2.62
Nov	20.90	32.20	18.40	2.35
Dec	16.20	24.50	15.90	2.26

Thermal Template: Bedroom

Building Regulations	
Room Type	Heated or occupied room
External Ventilation	0 air changes per hour
NCM Building Type	Nursing/residential home or hostel
NCM Activity	NCM NursHome: Bedroom
Room Conditions	
Heating	
Profile	on continuously
Setpoint: Constant	20 °C
Hot Water consumption	0.00 l/(h·pers)
Cooling	
Profile	on continuously
Setpoint: Constant	25°C
Model Settings	
Solar Reflected Fraction	NaN
Furniture Mass Factor	1.00
Systems	
HVAC System	
Auxilliary vent. system	
DHW system	
Heating	
Radiant Fraction	0.30
Capacity	unlimited
Cooling	
Radiant Fraction	0.00
Capacity	unlimited
Humidity Control	
Min. % Saturation	0 %
Max. % Saturation	100 %
System outside air supply	
Min. Flow Rate	0.80 l/(s·m²)
Add. Free Cooling Capacity	0.00 AC/h
Variation Profile	on continuously
Internal Gains	
Miscellaneous : Bedroom	
Max Sensible Gain	3.00 W/m²
Max Latent Gain	0.00 W/m²
Max Power Consumption	3.00 W/m²
Radiant Fraction	0.50
Fuel	Electricity
Variation Profile	off continuously
People : Bedroom	
Max Sensible Gain	90.00 W/P
Max Latent Gain	60.00 W/P
Occupant Density	6.00 m²/person
Variation Profile	off continuously
Fluorescent Lighting : Fluorescent Lighting	
Max Sensible Gain	0.00 W/m²
Max Power Consumption	0.00 W/m²
Radiant Fraction	0.45
Fuel	Electricity
Variation Profile	off continuously
Dimming Profile	on continuously
Air Exchanges	
NCM NursHome_Bed Vnt	
Type	Auxiliary Ventilation
Variation Profile	NCM NursHome_Bed_Vnt_WK1[BRE estimates]
Adjacent Condition	External Air
Max A/C Rate	1.00 l/(s.m²)
Infiltration	
Type	Infiltration
Variation Profile	NCM NursHome_Bed_Cool_WK1[BRE estimates]
Adjacent Condition	Temperature from Profile
Temperature Profile	
Max A/C Rate	0.25 AC/h

Rooms using this template

Room ID	Name
[BED10000]	Bed1
[BED20000]	Bed2
[BED30000]	Bed3
[STDY0000]	Study room

Thermal Template: Hall/Living/Dining

Building Regulations	
Room Type	Heated or occupied room
External Ventilation	0 air changes per hour
NCM Building Type	Nursing/residential home or hostel
NCM Activity	NCM NursHome: Eating/drinking area
Room Conditions	
Heating	
Profile	on continuously
Setpoint: Constant	20℃
Hot Water consumption	0.00 l/(h·pers)
Cooling	
Profile	on continuously
Setpoint: Constant	25℃
Model Settings	
Solar Reflected Fraction	NaN
Furniture Mass Factor	1.00
Systems	
HVAC System	
Auxilliary vent. system	
DHW system	
Heating	
Radiant Fraction	0.30
Capacity	unlimited
Cooling	
Radiant Fraction	0.00
Capacity	unlimited
Humidity Control	
Min. % Saturation	0 %
Max. % Saturation	100 %
System outside air supply	
Min. Flow Rate	0.80 l/(s·m²)
Add. Free Cooling Capacity	0.00 AC/h
Variation Profile	on continuously
Internal Gains	
People : Living Room	
Max Sensible Gain	90.00 W/P
Max Latent Gain	60.00 W/P
Occupant Density	12.00 m²/person
Variation Profile	off continuously
Fluorescent Lighting : Fluorescent Lighting	
Max Sensible Gain	0.00 W/m²
Max Power Consumption	0.00 W/m²
Radiant Fraction	0.45
Fuel	Electricity
Variation Profile	off continuously
Dimming Profile	on continuously
Miscellaneous : Bedroom	
Max Sensible Gain	3.00 W/m²
Max Latent Gain	0.00 W/m²
Max Power Consumption	3.00 W/m²
Radiant Fraction	0.50
Fuel	Electricity
Variation Profile	off continuously
Air Exchanges	
NCM NursHome_OpenOff Vnt	
Type	Auxiliary Ventilation
Variation Profile	NCM NursHome_OpenOff_Vnt_WK1[BRE estimates]
Adjacent Condition	External Air
Max A/C Rate	1.10 l/(s·m²)
Infiltration	
Type	Infiltration
Variation Profile	NCM NursHome_Bed_Cool_WK1[BRE estimates]
Adjacent Condition	Temperature from Profile
Temperature Profile	
Max A/C Rate	0.25 AC/h

Rooms using this template

Room ID	Name
[DNNG0000]	Dining room
[HALL0000]	Hall
[HLL20000]	Hall2
[LVNG0000]	Living room

Thermal Template: Kitchen

Building Regulations	
Room Type	Heated or occupied room
External Ventilation	0 air changes per hour
NCM Building Type	Nursing/residential home or hostel
NCM Activity	NCM NursHome: Tea making
Room Conditions	
Heating	
Profile	on continuously
Setpoint: Constant	20 °C
Hot Water consumption	0.00 l/(hÄ·pers)
Cooling	
Profile	on continuously
Setpoint: Constant	25 °C
Model Settings	
Solar Reflected Fraction	0.05
Furniture Mass Factor	1.00
Systems	
HVAC System	
Auxilliary vent. system	
DHW system	
Heating	
Radiant Fraction	0.20
Capacity	unlimited
Cooling	
Radiant Fraction	0.00
Capacity	unlimited
Humidity Control	
Min. % Saturation	0 %
Max. % Saturation	100 %
System outside air supply	
Min. Flow Rate	0.80 l/(s·m^2)
Add. Free Cooling Capacity	0.00 AC/h
Variation Profile	on continuously
Internal Gains	
Fluorescent Lighting : Fluorescent Lighting	
Max Sensible Gain	0.00 W/m^2
Max Power Consumption	0.00 W/m^2
Radiant Fraction	0.45
Fuel	Electricity
Variation Profile	off continuously
Dimming Profile	on continuously
People : People	
Max Sensible Gain	90.00 W/P
Max Latent Gain	60.00 W/P
Occupant Density	10.00 mÄ^2/person
Variation Profile	off continuously
Cooking : Cooking	
Max Sensible Gain	0.00 W/m^2
Max Latent Gain	0.00 W/m^2
Max Power Consumption	0.00 W/m^2
Radiant Fraction	0.60
Fuel	Nat gas
Variation Profile	off continuously
Air Exchanges	
Infiltration	
Type	Infiltration
Variation Profile	NCM NursHome_Bed_Cool_WK1[BRE estimates]
Adjacent Condition	Temperature from Profile
Temperature Profile	
Max A/C Rate	0.25 AC/h
NCM NursHome_Reception Vnt	
Type	Auxiliary Ventilation
Variation Profile	NCM NursHome_Reception_Vnt_WK1[BRE estimates]
Adjacent Condition	External Air
Max A/C Rate	1.10 l/(s·m^2)

Rooms using this template

Room ID	Name
[KTCH0000]	Kitchen

Thermal Template: Circulation

Building Regulations	
Room Type	Internal void or warm roof
External Ventilation	0 air changes per hour
Room Conditions	
Heating	
Profile	on continuously
Setpoint: Constant	20 ℃
Hot Water consumption	0.00 l/(h·pers)
Cooling	
Profile	on continuously
Setpoint: Constant	25 ℃
Model Settings	
Solar Reflected Fraction	NaN
Furniture Mass Factor	1.00
Systems	
HVAC System	
Auxilliary vent. system	
DHW system	
Heating	
Radiant Fraction	0.30
Capacity	unlimited
Cooling	
Radiant Fraction	0.00
Capacity	unlimited
Humidity Control	
Min. % Saturation	0 %
Max. % Saturation	100 %
System outside air supply	
Min. Flow Rate	0.80 l/(s·m²)
Add. Free Cooling Capacity	0.00 AC/h
Variation Profile	on continuously
Internal Gains	
Fluorescent Lighting : Ancillary	
Max Sensible Gain	6.00 W/m²
Max Power Consumption	6.00 W/m²
Radiant Fraction	0.45
Fuel	Electricity
Variation Profile	off continuously
Dimming Profile	on continuously
Air Exchanges	
Infiltration	
Type	Infiltration
Variation Profile	NCM NursHome_Bed_Cool_WK1[BRE estimates]
Adjacent Condition	Temperature from Profile
Temperature Profile	
Max A/C Rate	0.25 AC/h

Rooms using this template

Room ID	Name
[STRC0000]	Staircase

Thermal Template: Utility/Storage

Building Regulations	
Room Type	Internal void or warm roof
External Ventilation	0 air changes per hour
Room Conditions	
Heating	
Profile	on continuously
Setpoint: Constant	20 °C
Hot Water consumption	0.00 l/(h·pers)
Cooling	
Profile	on continuously
Setpoint: Constant	25 °C
Model Settings	
Solar Reflected Fraction	NaN
Furniture Mass Factor	1.00
Systems	
HVAC System	
Auxilliary vent. system	
DHW system	
Heating	
Radiant Fraction	0.30
Capacity	unlimited
Cooling	
Radiant Fraction	0.00
Capacity	unlimited
Humidity Control	
Min. % Saturation	0 %
Max. % Saturation	100 %
System outside air supply	
Min. Flow Rate	0.80 l/(s·m^2)
Add. Free Cooling Capacity	0.00 AC/h
Variation Profile	on continuously
Internal Gains	
Fluorescent Lighting : Ancillary	
Max Sensible Gain	6.00 W/m^2
Max Power Consumption	6.00 W/m^2
Radiant Fraction	0.45
Fuel	Electricity
Variation Profile	off continuously
Dimming Profile	on continuously
Miscellaneous : NCM NursHome_Store Eqp	
Max Sensible Gain	2.00 W/m^2
Max Latent Gain	0.00 W/m^2
Max Power Consumption	2.00 W/m^2
Radiant Fraction	0.20
Fuel	Electricity
Variation Profile	off continuously
Air Exchanges	
NCM NursHome_Store Vnt	
Type	Auxiliary Ventilation
Variation Profile	NCM NursHome_Store_Vnt_WK1[BRE estimates]
Adjacent Condition	External Air
Max A/C Rate	1.10 l/(s·m^2)
Infiltration	
Type	Infiltration
Variation Profile	NCM NursHome_Bed_Cool_WK1[BRE estimates]
Adjacent Condition	Temperature from Profile
Temperature Profile	
Max A/C Rate	0.25 AC/h

Rooms using this template

Room ID	Name
[TLTY0000]	Utility/Storage

Thermal Template: NursHome: Toilet

Building Regulations	
Room Type	Heated or occupied room
External Ventilation	0 air changes per hour
NCM Building Type	Nursing/residential home or hostel
NCM Activity	NCM NursHome: Toilet
Room Conditions	
Heating	
Profile	on continuously
Setpoint: Constant	20 ℃
Hot Water consumption	6.53 l/(h·pers)
Cooling	
Profile	on continuously
Setpoint: Constant	25 ℃
Model Settings	
Solar Reflected Fraction	0.05
Furniture Mass Factor	1.00
Systems	
HVAC System	
Auxilliary vent. system	
DHW system	
Heating	
Radiant Fraction	0.00
Capacity	unlimited
Cooling	
Radiant Fraction	0.00
Capacity	unlimited
Humidity Control	
Min. % Saturation	0 %
Max. % Saturation	100 %
System outside air supply	
Min. Flow Rate	0.00 l/(s·m²)
Add. Free Cooling Capacity	0.00 AC/h
Variation Profile	on continuously
Internal Gains	
People : NCM NursHome_Bed Occ	
Max Sensible Gain	61.00 W/P
Max Latent Gain	39.00 W/P
Occupant Density	10.00 m²/person
Variation Profile	NCM NursHome_Bed_Occ_WK1[BRE estimates]
Fluorescent Lighting : NCM NursHome_Bed Lit	
Max Sensible Gain	4.16 W/m²
Max Power Consumption	4.16 W/m²
Radiant Fraction	0.45
Fuel	Electricity
Variation Profile	NCM NursHome_Bed_Light_WK1[BRE estimates]
Dimming Profile	on continuously
Air Exchanges	
NCM NursHome_Bed Vnt	
Type	Auxiliary Ventilation
Variation Profile	NCM NursHome_Bed_Vnt_WK1[BRE estimates]
Adjacent Condition	External Air
Max A/C Rate	1.00 l/(sm²)
NCM Permeability-based infiltration	
Type	Infiltration
Variation Profile	on continuously
Adjacent Condition	External Air
Max A/C Rate	0.25 AC/h

Rooms using this template

Room ID	Name
[WC__0000]	WC
[WC2_0000]	WC2

Constructions associated with this model

	ID	Description	U-value CIBSE (W/m²·K)	Total shading coefficient (glazed only)	No. of rooms
Roof	R17	Vahid-Type 2 - Uninsulated tile roof	3.110		13
Ceiling	TYP30000	Type 3 - Vahid- Exposed ceiling	1.136		13
External Wall	WALL	vahid-External Wall	0.653		13
Internal Partition	P22	Vahid - plaster/brick/plaster	1.333		13
Ground Floor	S21	Vahid-Type 3 - Uninsulated concrete floor	0.390		13
Door	DOOR	Vahid-wooden door	2.161		12
External Wall	TYP10000	Type 1- Brick/block cavity wall	0.348		12
External Wall	TYP10001	Type 1- Brick/block cavity wall	0.348		0
Rooflight	RGDPK6	low-e double glazing (6mm+6mm) (2002 regs)	2.030	0.736	0

Macroflo Templates

Template:	**default**
Rooflight	Rooflights (closed)
External Glazing	Rooflights (closed)
Internal Glazing	Rooflights (closed)
Door	Doors (closed)

Rooms using this template

Room ID	Room Name
[BED10000]	Bed1
[BED20000]	Bed2
[BED30000]	Bed3
[DNNG0000]	Dining room
[HALL0000]	Hall
[HLL20000]	Hall2
[KTCH0000]	Kitchen
[LVNG0000]	Living room
[STRC0000]	Staircase
[STDY0000]	Study room
[TLTY0000]	Utility/Storage
[WC__0000]	WC
[WC2_0000]	WC2

Electric Lighting Templates

Template:	**default**		
Luminance Level	500 cd/m²	Luminaire:	DULCET: CROMPTON DULCET WITH OPAL DIFFUSER (source: unknown file)
Limiting Glare Index	19	Lamp:	1203: 1200mm Polylux T8 lamp
Working Surface Height	0.850 m	Lamp Colour:	WW: 3450.0 lm, lmf=3
Mounting Height	2.7 m		
Luminaire Maintenance Factor (LMF)	0.90		
Room Surface Maintenance Factor (RSMF)	0.90		
Lamp-Lumen Maintenance Factor (LLMF) Replacement period	5000.00		
Lamp Survival Factor (LSF)	1.00		

Rooms using this template

Room ID	Room Name
[BED10000]	Bed1
[BED20000]	Bed2
[BED30000]	Bed3
[DNNG0000]	Dining room
[HALL0000]	Hall
[HLL20000]	Hall2
[KTCH0000]	Kitchen
[LVNG0000]	Living room
[STRC0000]	Staircase
[STDY0000]	Study room
[TLTY0000]	Utility/Storage
[WC__0000]	WC

Radiance Surface Templates

Template:	**default**
Opaque	
Roof	Roof
Ceiling	Floor/Ceiling
External Wall	External Wall
Internal Partition	Internal Partition
Ground Floor	Ground
Door	Door
Glazed	
External Glazing	External Glazing
Internal Glazing	Internal Glazing
Rooflight	Roof

Rooms using this template

Room ID	Room Name
[BED10000]	Bed1
[BED20000]	Bed2
[BED30000]	Bed3
[DNNG0000]	Dining room
[HALL0000]	Hall
[HLL20000]	Hall2
[KTCH0000]	Kitchen
[LVNG0000]	Living room
[STRC0000]	Staircase
[STDY0000]	Study room
[TLTY0000]	Utility/Storage
[WC__0000]	WC
[WC2_0000]	WC2

Room Attributes Templates

Template:	**default**
Circulation Area	0.0%
Lettable Area	100.0%

Rooms using this template

Room ID	Room Name
[BED10000]	Bed1
[BED20000]	Bed2
[BED30000]	Bed3
[DNNG0000]	Dining room
[HALL0000]	Hall
[HLL20000]	Hall2
[KTCH0000]	Kitchen
[LVNG0000]	Living room
[STRC0000]	Staircase
[STDY0000]	Study room
[TLTY0000]	Utility/Storage
[WC__0000]	WC
[WC2_0000]	WC2

Room Settings

Room Name	Floor Area (m²)	Volume (m³)
Bed1	22.0	66.0
Bed2	25.0	75.0
Bed3	25.0	75.0
Dining room	27.5	82.5
Hall	31.5	94.5
Hall2	34.5	103.5
Kitchen	22.5	67.5
Living room	22.0	66.0
Staircase	3.0	9.0
Study room	9.0	27.0
Utility/Storage	9.0	27.0
WC	4.5	13.5
WC2	4.5	13.5