

CHAPTER - 3

CONCLUSIONS
AND
SUGGESTIONS
FOR
FUTURE WORK

CONCLUSIONS

We infer the following conclusions from this present study:

- Iso-radiation maps are essential to visualise and quantify the variation of insolation over a country during the year. Such maps are necessary when planning solar energy installations. Previously no precise maps existed based on data from Pakistan. Our maps are constructed using all the available data recorded in Pakistan until the end of 2003. The global irradiation values were estimated by the insolation-sunshine relation, equation (36). For greater precision, relation (36) has to be modified by including the effects of elevation, atmospheric turbidity, etc. With the exception of the extreme northern region, during the peak winter where the insolation values fall to as low as $7.5 \text{ MJ m}^{-2} \text{ d}^{-1}$, the country as a whole exhibits an excellent solar climate, available for solar energy conversion systems throughout the year.
- On comparison of figures (25-27) we find both direct and diffused component of solar radiations more pronounced and clear for Klein [178] relationship, while the measured component of global radiation is lesser in magnitude as compared to relationships which yield diffuse radiation almost closer to measured global radiation values which, in fact, is impossible for an solar radiation. Symmetrical distribution over the months compared to other component of radiations. The extraterrestrial, global (measured), the estimated diffused and direct component of radiations from Klein [178] relationship produce a symmetrical average distribution of solar energy over the months. Therefore, the Klein [178] relationship for the estimation of diffuse and direct component of solar radiation is recommended. Our estimate of extraterrestrial distribution of solar energy at Quetta is well accorded compared to relationship by Iqbal [47].

- We conclude that Liu and Jordan [39,191] relationship from diffused radiation is relatively better as compared to page and Iqbal correlations [189,190]. Liu and Jordan [39,191] correlation underestimates diffuse radiation and requires modifications.
- In absence of measured diffuse data, it is not possible to suggest a final empirical correlation for the prediction in Pakistan [247-248]. However after the accuracy of different models and relative percentage error, it is suggested that Liu and Jordan and Hay may be used for an estimation of monthly daily diffuse radiation over Pakistan.
- Hourly wind speed data at Quetta meteorological observatories in Pakistan have been analyzed to determine monthly and annual wind power and these are compared with the monthly mean solar radiation energies for the period 1999-2003. The monthly average wind speed range from 2.5 to 4.4 m/sec while the solar radiation varies from 3.6 to 7.65 KWh/m².
- We found that the maximum solar energy in the form of absorbed heat is intercepted at $s=0$ and $s= \phi -15^{\circ}$, where s is the tilt angle and d is the latitude of Quetta (latitude $30^{\circ} 11' N$, longitude $66^{\circ} 57' E$) which is elevated at a distance of 1799 meters from the sea level . Aluminum sheet is found as the best receptor of solar energy as compared to other flat plate collectors. The thicknesses of all the collectors used are same.
- A decentralized design of solar village electrification is proposed. This study yield to estimate the cost effectiveness as compared to grid electricity, consumption pattern, load, the community needs and requirements for all villages of Pakistan.

- The rainfall data during 1999-2003 shows random behaviour and that no correlation can be established.
- The average maximum and minimum monthly temperatures during 1999-2003, show peaks during months of June, July and August excepting June of 2002. These months belong to summer season at Quetta.
- The ground temperature of Quetta is relatively higher as compared to other parts of the country.
- The maximum humidity at Quetta is observed during the months of winter (December, January and February). The humidity surprisingly becomes maximum in the month of June, 2002 and for the months of March 2002 and 2003.
- The overall trend of humidity over the years shows a decline during months of February to May, a constant during June, July and August and a downward incline during the months of September, October, November and January each year.
- For 2002, a distinct reversal of humidity and temperature is observed which is indeed a unique climatological behaviour.
- A relationship between humidity and temperature is developed which shows a Gaussian trend and provides the best fit to experimental data during 1999-2003, i.e.,

$$H_{th} = \sqrt{H_o^2 \ln_e \left(\frac{T_o}{K} \right)}$$

where H_{th} is the theoretical humidity, H_o and T_o are experimental values of humidity and temperature, respectively and K is the constant for the fit.

- A relationship for solar energy in $MJ/m^2/day$ and its frequency, during 1999-2003 at Quetta, is developed which follows an inverse Guassian behaviour, .i.e.,

$$f_{com} (\%) = k \{ \exp [0.5 (E / E_{th})^2] \};$$

where,

$$k = \exp \{ \sum x \ln f_{com} - 0.5 \sum x / n \} ;$$

and where,

$$\sum x = \sum (E / E_{th})^2.$$

- The overall behaviour of humidity and temperature on solar energy and its frequency shows a reversal i.e., the former is Guassian and the later is inverse Guassian. It further shows that a correlation can be established for such a surprising behaviour which to our knowledge has never been observed or studied.
- A time series analysis is made on data of humidity and temperature variations by computing the auto correlation functions (ACFs), .i.e., by using,

$$R(\tau) = \frac{\sum_{i=1}^{N-\tau} x_i x_{i+\tau} - \frac{1}{N-\tau} \left(\sum_{i=1}^{N-\tau} x_i \right) \left(\sum_{i=\tau+1}^N x_i \right)}{\left[\sum_{i=1}^{N-\tau} x_i^2 - \frac{1}{N-\tau} \left(\sum_{i=1}^{N-\tau} x_i \right)^2 \right]^{1/2} \left[\sum_{i=\tau+1}^N x_i^2 - \frac{1}{N-\tau} \left(\sum_{i=\tau+1}^N x_i \right)^2 \right]^{1/2}}$$

which shows that the first two coefficients ,i.e., auto co-variance coefficients at lag τ are significantly different from zero. The values outside the range $\pm 2 / \sqrt{N}$ are considered significantly different from zero.

- The results of ACFs for humidity and temperature respectively show short term correlations.
- The results of ACFs for humidity and temperature show high seasonal variation.
- The scarcity of rainfall perhaps due to suspended dust particles and pollutants at Quetta valley suggests less occurrence of low pressure at relatively higher altitudes. It is driven away by the pollutants which act as obstruction to coming low air pressure.
- The ARMA (p,q) model of L.Kamal and Y.Zahra Jafri [148] is suitable to predict past values as well as the forecasted wind data of Quetta. Using ARMA (p,q) model, stochastic simulation can be easily done.
- Wind speed sequences are unreliable and relatively unpredictable for the months of October, November and December. This shows that diurnal variations of wind speed should be incorporated in model development because they have a pronounced effect on wind speed frequency distribution.
- The Morkov Transition Matrices (MTM) approach is found relatively better as compared to auto regressive moving average process (ARMA), [149].

- Establishment of wind resource climatology for an area requires the synthesis and presentation of the wind data. In this respect wind contour maps provide a means to visualize and quantify the variation of wind speed over a country during the year. These maps are essential when planning wind power installations. Previously no precise maps existed based on the data from Pakistan. The maps (Figs. 89-101) are constructed using wind speed data for a period of 1999-2003 from 59 locations. From the maps, Figs. (90-101), and the above discussion, the wind potential over the country fall into three main groups, low 1-2 m/s, intermediate at 2-3 m/s and higher at more than 3 m/s. The lowest wind speed occurs in winter, November – February, and the highest during summer, May – August. The March – April and September – October periods are classified as intermediate. However the most promising sites for exploiting wind power, throughout the year, are the coastline, lower Sindh and north – western Balochistan.
- The study reveals that the average wind speed is 3.5 and 4.4 m/s and annual power 22.37 and 51.32 W/m² for Quetta and Karachi, respectively.
- The maximum wind speed and total wind power are received in summer and spring and minimum in other seasons. The most generous months supplying wind speed and power in Pakistan are from June-September and the least are November-February.
- There is a characteristic diurnal variation for each site such as higher mean wind speeds between 0600 and 1800 PST (Pakistan Standard Time) and peaks usually occur at 1200 PST.
- The result of analysis of wind speed data shows better prospects for Wind Energy Conversion Systems (WECS) in Pakistan, that 80%

probability of hourly wind speed is greater than 2.00 m/s for Quetta.

- Strong wind speeds are prevalent on high altitude (Quetta) regions. Economic analysis [87] also shows that utilization of the available wind power potentials in Quetta can be realized at a cheaper cost in relation to other renewable energy sources like solar energy, biomass, etc.
- The daily values of global solar radiation of successive clear sky days when compared to each other are not always equal. This is due to fact that the level of atmospheric pollution depends upon meteorological situations influencing the area.
- The variations of global solar radiation values at Quetta are large during summer and autumn due to fine dust particles, pollutants covering the valley and very low humidity covering the valley. A continuous relative attenuation of the order of 6-4% is due to presence of fine dust particles and pollutants throughout the year.
- The percentage estimation of the total atmospheric pollution in Quetta for summer and winter is 34 % and 59%, respectively. The increased difference is mainly due to combustion of natural gas and mined coal for heating of buildings during winter.
- The occurrence of noise levels at various locations in Quetta city, close to WHO recommended value, suggests that the lead and sulphur dioxide pollutants in Quetta are pronounced as compared to other pollutants. The permissible limit as recommended by WHO leads to seriousness of polluted environment of the city in question and requires proper attention provided there is an adequate monitoring of data for each kind of pollutants and surveillance according to recommendation of EPA (Environmental Protection Agency) . Needless to mention, the ambient air quality standard for each

pollutant can differ from WHO standard from view point of weather and climatological changes occurring at various locations of Quetta. The nitrogen cycle and the photosynthesis process are responsible to maintain natural equilibrium which could be severely effected in general by greenhouse effects, and in particular, by ozone.

- A very simple model is developed for the diffuse luminous efficacy for vertical surfaces facing North, East, South and West. The model has the same mathematical form for the four surfaces, with the two empirical coefficients being different for each of them.
- The model works better when the amount of direct radiation incident on the surface is smaller. For the surface facing North the model offers an excellent performance.
- If one compares the present statistics with those obtained for complex models developed to predict diffuse illuminance on vertical surfaces [10,13,14], the present results for the East and West facing planes are rather acceptable taking into account the simplicity of the model used.
- Current climate models tend to predict gradual climate change. This is no guarantee against unpleasant surprises. Climate models, as well as, the knowledge fed into the models are far from perfect. Rapid changes in atmospheric circulation, of ocean currents, in ecosystem functioning, or in the West Antarctic ice sheet's behavior may not be likely, yet such risks can, at present, neither be excluded nor quantified.
- Much of the public debate focuses on warming, an admittedly likely reaction of the climate system. Disturbing earth's radiation balance, however, may change the climate in a host of other potentially serious ways. Warming need not even be the practically most relevant part of

the response. This is why many climatologists prefer the term climate change to global warming.

For example, spatial and seasonal patterns of precipitation, evaporation, and soil moisture and river run off may shift. These in turn may affect agriculture and freshwater availability, which are critical for many poor countries and a potential source of migrations and conflicts. Cloud patterns, ocean currents, atmospheric circulation or the distribution of extreme weather events may change. Terrestrial and marine life will be affected and may in turn affect the climate via changes, for instance, of carbon storage, evaporation, or albedo. The risk of rapid climate change is linked to many other problems of concern, like population growth, poverty, loss of biodiversity, or stratospheric ozone depletion.

- Building a balanced public perception of the risks posed by climate change is difficult. There is an almost irresistible temptation to view extreme Weather events, like droughts or storms, as signs of climate change, even if they are well within the limits of natural variability. At the same time, gradual change tends to go unnoticed. Natural climatic are up against a long distance race and tend towards a sprinter's outlook.

- Human made greenhouse gases and aerosols will change our climate. There is no free lunch; we cannot alter Earth's radiation balance for nothing. It is uncertain by how much, how swiftly and with what twists the climate will change. This is dubious comfort, since uncertainty cuts two ways. The present best estimates may well overstate the risk, but they may as well understate it. Climate change resembles a gamble with high stakes. Current knowledge of the carbon cycle suggests that atmospheric CO₂ will respond sluggishly to the changes in CO₂ emissions. The response of the climate system to a given CO₂ level takes decades or longer. Barring surprises, the lag time

between changes in CO₂ emissions and their eventual effects on climate is very long.

- It is an open question as to how soon the uncertainties can be narrowed down, and whether climatologists will be able to predict details reliably before they start to happen in the real world. There is a natural inclination to wait and see until we know what we shall have to face. By then it may be too late.
- Continuous monitoring and analysis of variability and trends in key climatic elements is the need of the hour. Weather forecasting systems in the region must be improved and implementable reforms for land use be planned. New techniques for confident projection of regional climate change and its variability, including extreme events must be applied. Coordination and non-governmental organizations (NGOs), communities and the public must be kept aware of the developments on risks of climate change and involve them in planning, adaptation, and mitigation strategies.
- The field is highly complex and calls first for the development of trained manpower. A team of Mathematicians, Hydrologists, Climatologists, Oceanographers and Computer Programmers having a strong background in their respective fields, need to be trained from abroad to go for combating this challenging threat. Network of Meteorological stations, both surface and upper air, on land and sea needs to be further strengthened.
- One target is specifically defined to question the local climatic conditions so that appropriate modifications in climatic model could be introduced. So we emphasized all weather parameter, and considered them to integrate with empirical results. These empirical results will help decide the long-term validity of parametric relationships in climatic

models and indeed help resolving the modified form of climate models. We do not have an access to climate models but our relationships for weather parameters and indeed its influence to proposing a climatic change will help others to introduce modifications into the existing models. Our modeling is more oriented towards empirical and mathematical profiling results. We attempted to review the salient features of the existing climate models to see if any short term local climate modeling will have any impact. We believe that the short-term local climate modeling will help unifying and rendering it to simplified versions of existing climate models.

SUGGESTION FOR FUTURE WORK

- Neural network models and its simulation for weather data are needed.
- Fuzzy logic time prediction modeling and its simulation on weather, wind and solar data are the targeted areas where prediction or forecast of data can be corrected and modified.
- Regression and regression time series analysis are best studies for developing correlations to correct stochastic models.
- Stochastic models such as Morkov chains can be used to generate synthetic values of diverse data.
- Weather and climate algorithmic codes are required to be developed.