The Role of Climate in Affecting Energy Demand/Supply in the State of Qatar

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ABSTRACT

The study attempts to investigate the impact of Climatic factors on the present and future energy demand/supply in the State of Qatar. The effects of climatic parameters such as temperature, humidity and wind on electric energy consumption and the contamination of its distribution systems were analysed. The possibilities of using solar insolation and wind to generate power were also discussed. It was found that daily and seasonal temperature distribution greatly affect electric energy supply, and that maintenance cost is high due to the pollution caused by weather elements. The potential use of renewable solar energy and wind power in the State of Qatar is great given that reliable and cost effective systems are developed.

INTRODUCTION

It is generally believed that weather and climate data is an important resource in itself and can be used to make life safer, healthier and happier (Hobbs, 1980; Battan, 1983). From an energy view point climate is a liability and a resource (McKay and Allsopp, 1980). In other words climate has a dual character, that of a hazard and of a resource. Climate is a factor to be contended with in most phases of conventional energy system activities. It also dictates the potential supply of renewable energy sources.

The hazardous aspects of climate has preoccupies man for a long time. Much effort has been spent on technologies that counter excessive heat, cold, humidity, snow, winds and other manifestations of climate. Over one-third of the energy consumed in industrialized North America and about 50% of that consumed in Europe is used to overcome the direct and indirect consequences of climate (McKay and Allsopp, 1980). On the other hand climate has provided man with energy for as many as 2000 years. Historical evidence indicates that man has used wind power for pumping water, grinding grains and most recently generating electricity (Lipman, 1982; Nagrial, 1983; Abdalla, 1982).

The recent interest in utilizing renewable energy sources stems from the global problem of increasing demand for energy, the mounting costs of conventional fuels as well as the national desires for energy independence (Lovins, 1979). Moreover, due to environmental considerations and safety requirements for nuclear power stations, solar energy and wind power may become viable and clean source of alternative energy. Several recent studies show that by the year 2050 direct and indirect solar energy (wind power) and conservation must meet 60% of the world's demand as by then gas will almost be exhausted and coal cannot even meet 10% of the energy demand, while nuclear power with all its hazardous side effects and high cost problems will meet 10–30% of the demand (Al-Saleh, 1985; Sayigh, 1986).

The interest in the role of climate on energy demand and supply is growing. The important literature is cited on Ahti (1975), Halacy (1977), Bach et. al. (1980), Batton (1983) and Clazonetti and Solomon (1987). There is also an ever mounting literature on solar and wind power application systems particularly in especialized periodicals such as solar erergy, applied energy and solar and wind technology. McVeigh (1979), Rapp (1981) and Lipman (1982) represent the standard texts in the subject. In the Arab World solar energy programs started about 1970 and since then several conferences and workshops were held on the state of the art and their proceedings were published. The most recent of these are OAPEC, 1979; Kettani and Malik, 1979; Alawi et. al., 1983, 1986.

The present study is intended to investigate the impact of climatic factors on energy demand/supply in the State of Qatar and the ways in which climate can be exploited in responding to energy needs. An understanding of climate is necessary for the effective and efficient transmission, distribution and use of electrical energy. Climate is also a control of most processes that are central to the supply of renewable energy. It is generally believed that in the State of Qatar the long severe summers are the main reason behind increasing power demand (Al–Houty, 1983), and that the distribution of electrical power is subject to several climatic hazards (Babikir, 1986). The State of Qatar also lies in the geographical region that receives about 70% of the extraterrestrial radiation intensity, the highest in the world, a fact that reflects the high potentialities of direct and indirect solar energy (McKay and allsopp, 1980; Sayigh, 1986).

Climate

The state of Qatar lies in the middle of the western coast of the Arabian Gulf, between 24° 27' – 26° 11' N and 50° 45' – 51° 40' E. It lies wholly within the subtropical hot and arid region (Walter & Lieth, 1960) or the torrid subregion of the northern desert belt (Pike, 1978; FAO, 1981). According to the Koppen climatic classification the interior of the peninsula lies within the climatic region BWhs (hot desert climate with winter rainfall), while the narrow coastal strip lies within BWhsi (the same but with low temperature range) (Sharaf, 1980; Babikir, 1986). This northern hemisphere desert belt is characterized by high temperatures, hot dry summer winds, high relative humidity for the greater part of the year and a scanty rainfall which is varibale both in time and space.

Generally speaking areas lie between 35 degrees North and South latitude receive sufficient solar insolation.

Figure 1 shows average sunshine hours. The average sunshine in Doha is 9.4 hours. High sunshine could reach 10.56 hours for the period from May to September, while low sunshine is 7.7 hours in December and 7.8 hours in March. The average total solar radiation in Doha is 5.28 Kwh/m^2. The highest values occur during the months of June and July (6–7 Kwh/m^2), while the lowest values occur in December toFebruary (3.58Kwh/m^2 in December)(Figure 2). Temperatures are high during summer and warm in winter with an annual mean maximum and minimum of 32.7° and 21.4°C respectively (Figure 3). Mean temperatures for the summer months (June, July, August) rise to over 40°C and they are down the between 12° and 15°C during winter months (December, January and February) (Figure 3). Absolute maximum temperature recorded in Doha was 49°C on June 5th, 1962, while the absolute minimum temperature recorded was 3.8°C in Doha in January 21st 1969.

Figure 4 Shows wind speed and direction at Doha Airport. The average wind speed is high in both winter and summer but slightly higher in summer (can reach up to 33 knots per hour in June). The dominant wind is the prevailing NNW (Shamal) which is a characteristic of the whole of Arabian Gulf (Babikir and Jackson, 1985; Babikir, 1986).

Being a peninsula protruding in a shallow sea with high temperatures, Qatar is a rather humid place with maximum humidity approaching 100% sometimes (annual mean 59%). Relative humidity varies between winter months (>60%) and summer months (>50%) (Figure 5). It also varies slightly between the coastal strip and the interior. As Qatar lies in the southern margins of areas affected by winter midlatitude atmospheric depressions, rainfall is scanty (annual average 98mm. in Doha). Rainfall varies in time and space. In 1962 the total rainfall was less than half a millimetre, while it was well above 300 (302.8mm.) millimetres in 1964. A few rains, especially in the south, are autumn and spring thunderstorms with hail and lightning.

Energy Demand/Supply

1. Electric Power

Direct Effects of Demand

Electric power generation and consumption are closely related to the daily distribution of temperatures as well as to their seasonal changes. The demand for electrical power increases sharply during the summer months when there are increasing demands for electrically-powered air-conditioning and refrigeration systems. Figure 6 shows the peak of electricity generation in the summer months (June to September), while figure 7 shows the maximum and minimum daily load curves for two selected days form the months of July and February. The daily peak in July corresponds with the hot afternoon hours (13–15 hours).

Electric Power Distribution

The distribution of electric power in the State of Qatar is subject to several climatological hazards. The most common is the heavy contamination to the electric supply system. Equipments and installations are subject to malfunction and failure due to pollution by various weather elements. Dust and sandstorms mixed with salt particles, high humidity, frequent heavy dew and fog and long intervals without rain cause heavy particulate contamination which can lead to equipment damage and service interruptions both of which are expensive (The State of Qatar, 1985). Figure 8 shows that the total number of days of dust and sandstorms, rising sand, rising dust and haze reach over 129 days on the average in Doha. It has also been found that conductor systems generate noise due to defects caused by contamination by dust and other pollutants. Salt and dust pollutants add to the total cost as an extra (creepage) length is needed in the insulator strings. The length of "creepage" is usually related to the degree of pollution expected (Table 1).

analysis for solar radiation, ambient temperature and ground temperature found that results are not symmetric around mid summer and that the yearly average hourly radiation is estimated to be 2.18 Kwh/m^2 with a maximum solar noon radiation in summer of 8.5 Kwh/m^2. They reached the conclusion that these values are relatively low and that high values of relative humidity may be the reason. It must also be mentioned that Qatar has a winter rainy season, with cyclonic storms that may absence the sun for many days in succession.

Since 1960 solar energy applications have developed a great deal. In the Arab Gulf States solar energy programs have steadily progressed since the mid-seventies reaching the point where flat plate collectors are manufactured in Saudi Arabia, and thermal power plants have been installed in Kuwait and Saudi Arabia (Sayigh, 1985, 1986). Moreover solar energy research programs in these two countries, i.e., Saudi Arabia and Kuwait are among the largest in the Arab World (Al-Baharna, 1983).

Some developed applications are encouraging and cheaper than others. In water heating for instance solar collectors have emerged as cost effective to fossil fuel and wood in almost all locations of the world, while the cost of electricity production by a solar thermal plant varies from 5–25 times the conventional methods (Sayigh, 1986). Several other solar thermal energy applications are excellent, such as greenhouse cooling, desalination, hot water supply, solar pond.. etc. There is also a great potential in the usage of photovoltaics in the Arabian Gulf (Sartawi, 1986). Recent studies in other parts of the world show that photovoltaic generators are economically viable as an alternative to small diesel engines for wide range of water supply applications (Danley & Bucciarelli, 1986). The cost of solar desalination systems is also low, technologically simple, and in most cases they can be manufactured using locally available materials (Zein and Al-Dallal, 1986). It was found in Bahrain that distillation increases sharply with increasing solar radiation, and that temperature heats up sea water which increase the condensate substantially (Zein and Al-Dallal, 1986).

In the State of Qatar a solar pilot project was established under the supervision of the Qatari Industrial Development Technical Centre (IDTC) in 1982 which consists of a meteorological and solar measurement station, solar photovoltaic generators, a solar desalination unit and a solar pond collector and storage system (Al-Houty, 1983; Haruni, 1984). A detailed description of the installations is given by Haruni (1984). Unfortunately the project is not in operation at the present time. Interest in solar energy started in the University of Qatar as early as 1980 in the Scientific and Applied Research Centre and the departments of physics and mechanical engineering. A reverse osmosis plant for the desalination of brackish water has been installed in the University campus for the Scientific and Applied Research Centre* . Results are yet to be reviewed and analysed. Serious research has also been conducted in the departments of physics and mechanical engineering. Al-Houty and her colleagues in the department of physics have developed techniques to prepare MIS silicon solar cells. Their efforts have succeeded in developing gold films that give optimum properties such as yielding high electrical conductivity, a high optical transmittance in the useful range of the spectrum for energy conversion, a high optical reflectivity in the useless range of the solar spectrum and a minimum absorbance over the whole range of the spectrum (Al-Houty et. al. 1984). A group of researchers in the mechanical engineering department have been working on developing the storage of solar energy in salt gradient solar ponds (Hassab et. al. 1987a, 1987b). They developed a dynamic solar pond model based on local climatic conditions (solar insolation, ambient temperature and ground tempreature) to predict solar transmission, temperature and salt distribution inside the pond for each day of the year. They concluded that air and ground losses are much lesser than in colder climates.

3. Wind Energy

Wind energy is an indirect form of solar energy as 5% of the incident solar radiation absorbed by the earth's atmosphere is converted into wind energy (Musgrove, 1984; Quaraeshi et. al., 1984; Sayigh, 1986). In recent years there has been extensive interest in wind power generation (Lipman, 1982; Nagrial, 1983; Batton, 1983). The main emphasis has been on utilizing wind energy to produce electricity to replace power generation by costly fossil fuels. Moreover, wind power plants are considered clear sources of alternative energy and when compared to nuclear power stations is much safer. The wind power is also well suited for isolated areas, and is also competitive with

* The plant uses 10 Kwh photocells to produce 5 cubic metres.

existing diesel power plants for several applications such as producing fresh water from sea, or brackish water.

Recently several studies were published on the question of wind energy utilization in the Arab Gulf countries (Abdalla and Baghdady, 1984; Ayyash et. al., 1984a, 1984b, 1985, 1986; Abdalla 1986). These investigations showed that there is a high potential for wind power generation in the Arab Gulf countries. The results of research done in Bahrain show that wind energy of mean wind speed 7.4 – 9.3 knots can be utilized in open areas and that wind energy is as powerful as solar energy and it could be used to save other expensive energy sources (Abdalla, 1986).

The economic viability of wind power generating systems was tested in various countries and it was found that the cost depends on mean wind speed and the characteristics of the wind generators. But generally speaking the wind power plants are expensive compared to the present central power stations (Nagrial, 1986). Other applications such as wind pumping systems proved to be cheaper than diesel generated systems (Mobarak et. al., 1986).

In the State of Qatar calculations show that the strong wind (Alshamal – with average wind speed > 10 knots and can reach up to 33 knots) occur in summer months (June, July, August). It also shows a relatively high wind (with an average of 7–10 knots) in winter months (November – February). In the rest of the year wind blows from variable directions (Figure 4). Wind power calculations for similar wind speed (average 9.3 knots) was made for Bahrain and was found that the yearly average power generated is around 138.8 watt/m^2 which was considered positive and satisfactory (Abdalla and Baghdady, 1984; Abdalla, 1986). These results are found comparable to the World Meteorological Organization published estimations where a wind of an average speed of 10 knots/hour (approximately 11.5 miles/hour) generates a wind energy of 150 wh/m^2 (Table 2) (WMO, 1981).

Table (2)
Wind Energy and Wind Speed

Wind Energy Wh/m^2	Wind Speed Mile/hour
00	0.0
100	9.8
150	11.4
200	12.5
250	13.4
300	14.3
400	15.6
1000	21.0

Wh = Watt - hour
Source: WMO (1981)

Discussion and Conclusions

Electric energy and fresh water consumption is expected to go down as authorities in the State of Qatar has already began implementing very strict conservation methods. The progress in building climatology is also helping the situation. New designs are making the most of cooling breezes, installing efficient insulation and protection from hot winds.

The use of fossil fuels for generating electricity in the State of Qatar is depriving the growing industries from a badly needed source of energy. Fortunately there is a great potential in the usage of renewable solar and wind energies. Solar energy has been calculated for Doha to be found equivalent to 225 w/m^2, while wind power of an average wind speed of 9.3 knots is equivalent to 140 w/m^2 (Sayigh 1986). Moreover, the daily and seasonal patterns of wind power supply are compatible with the patterns of power demand in the country, i.e., more supply in summer and during the day time than in winter at night.

The future picture looks optimistic as there is a rapid international progress in the development of reliable and cost effective systems. Taylor (1979) cited in Bach et. al. (1980) showed that low cost solar systems such as ponds and air-inflated plastic-film collectors are likely to achieve attractive cost goals in several developing countries. On-site systems are expected to be competitive with other central utility power in 10–15 years (McKay and Allsop, 1980). In the Arab Gulf countries the usage of photovoltaic generators has been found competitive with small diesel engines (Sartawi, 1986). Thermal power plants have been installed in Saudi Arabia and Kuwait, while Flat plate collectors are manufactured in Saudi Arabia. Other applications such as solar desalination, hot water supply are promising. Wind systems are superior energy extractors (currently 35% efficiency versus 5–15% for solar) and can produce power at costs that are competitive with fossil fuels. Highly reliable and cost effective multi-megawatt turbines have already been constructed in the U.S. and western Europe. However, wind-powered systems have been most useful in isolated localities having small electrical requirements and where batteries can serve as electrical reservoirs.

On the other hand and despite all that optimism, renewable resources are not expected to contribute a major portion of Qatar's energy for many years. Energy obtained by solar cells that convert solar radiation directly to electricity are still far too expensive except in very isolated locations far from conventional sources of electricity. For solar energy applications to be economical and competitive inexpensive solar cells must be produced in large quantities (Battan, 1983). As for wind systems, there are still no adequate techniques for storing large quantities of electricity that might be generated by strong winds at night when power requirements are low. Another major disadvantage of wind systems is that wind speeds vary a great deal, and, therefore, the production of electricity bears little relationship, in time to the demand.

In conclusion one must say that reliable quantitative climatic data is essential for the demand/supply and maintenance of electric generation systems as well as for the usage of renewable solar and wind energies. A detailed analysis of atmospheric pollutants is important. Accurate information on hourly intensities of global and direct radiation is essential, while more investigation of wind conditions is needed. Also more knowledge on the economics of alternative renewable energy systems is considered vital for decision-making. Perhaps the final recommendation is that climatologists should work closely with energy researchers, planners, managers, engineers, and possible users to propose strategies for dealing with climatic impacts and recommending suitable conservation methods as well as alternative energy systems.

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Fig. (1) : Average Monthy Sunshine hours at Doha Airport (1962 - 1987).

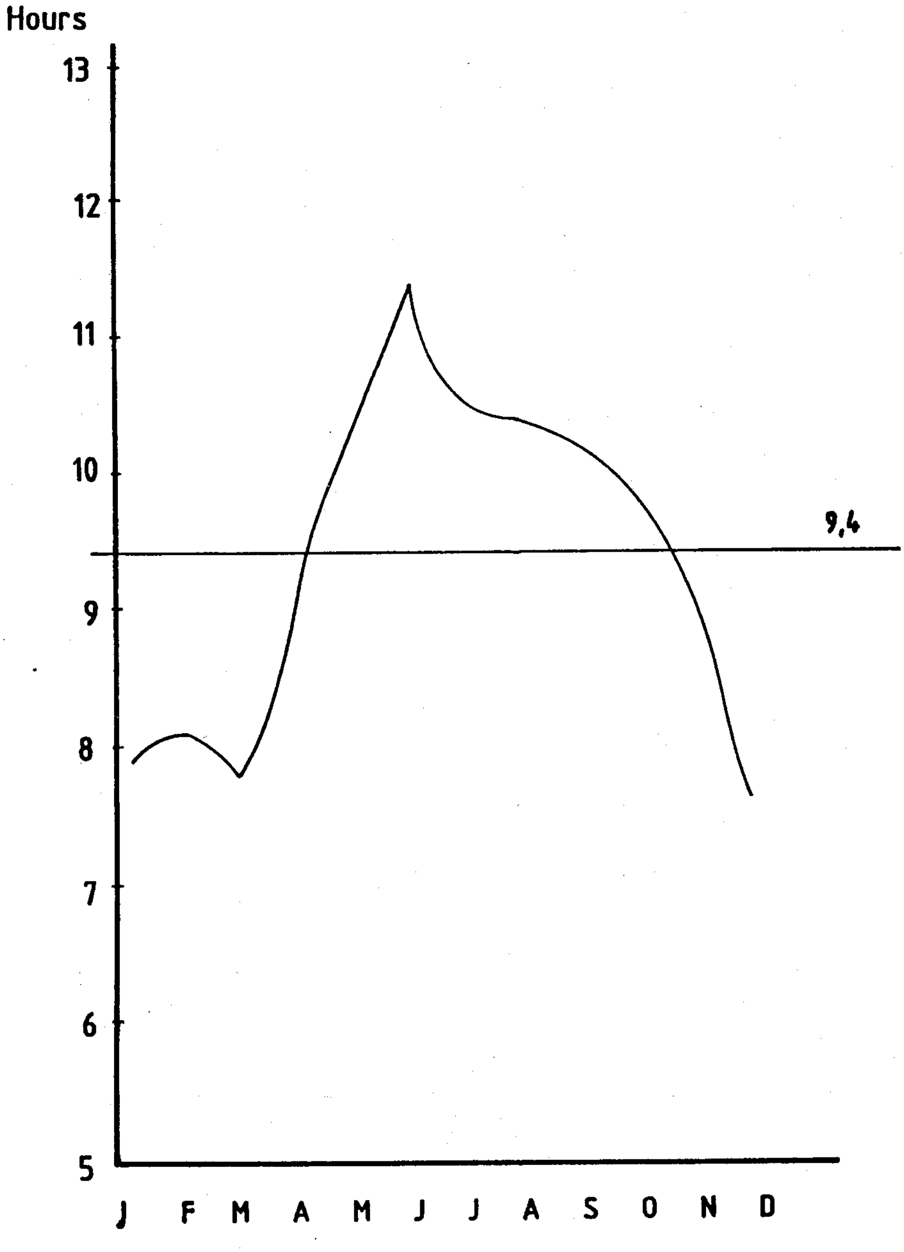


Fig. (2) : Total Solar Radiation at Doha Airport

(1976 - 1986) in mwh/mwh/cm^2.

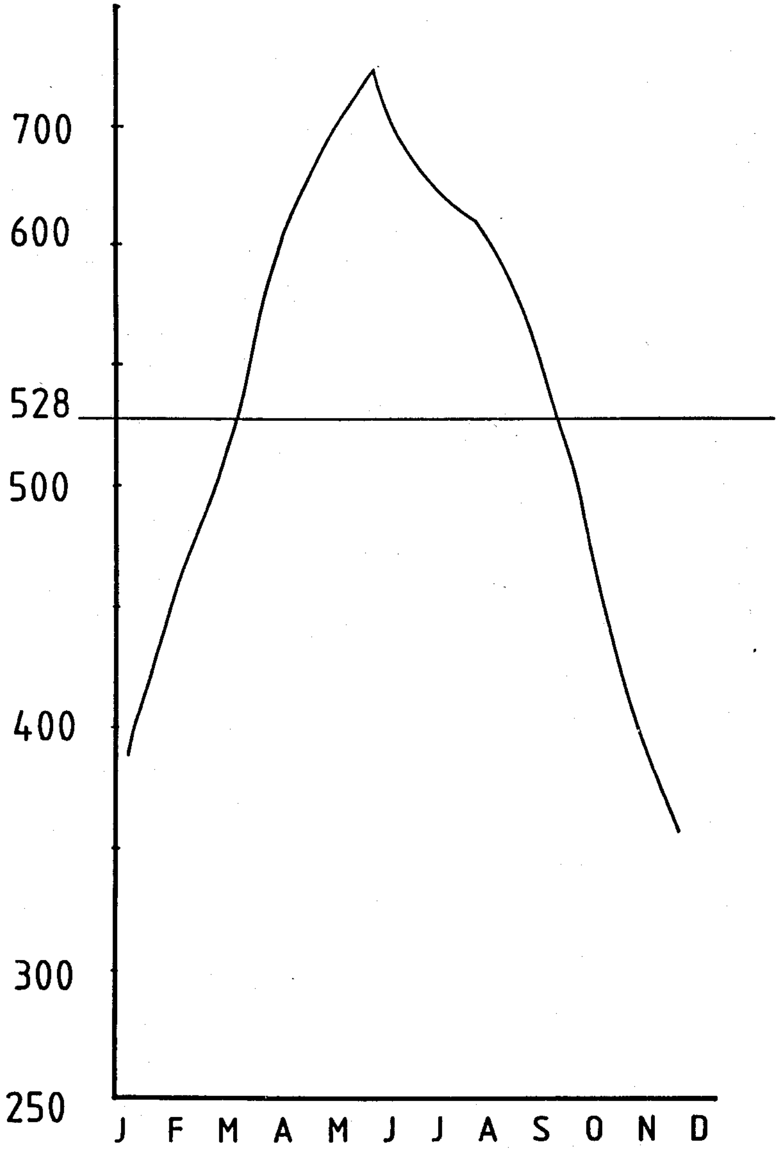


Fig. (3) : Mean Maximum and minimum Temperatures at Doha Airport (1982 – 1987).

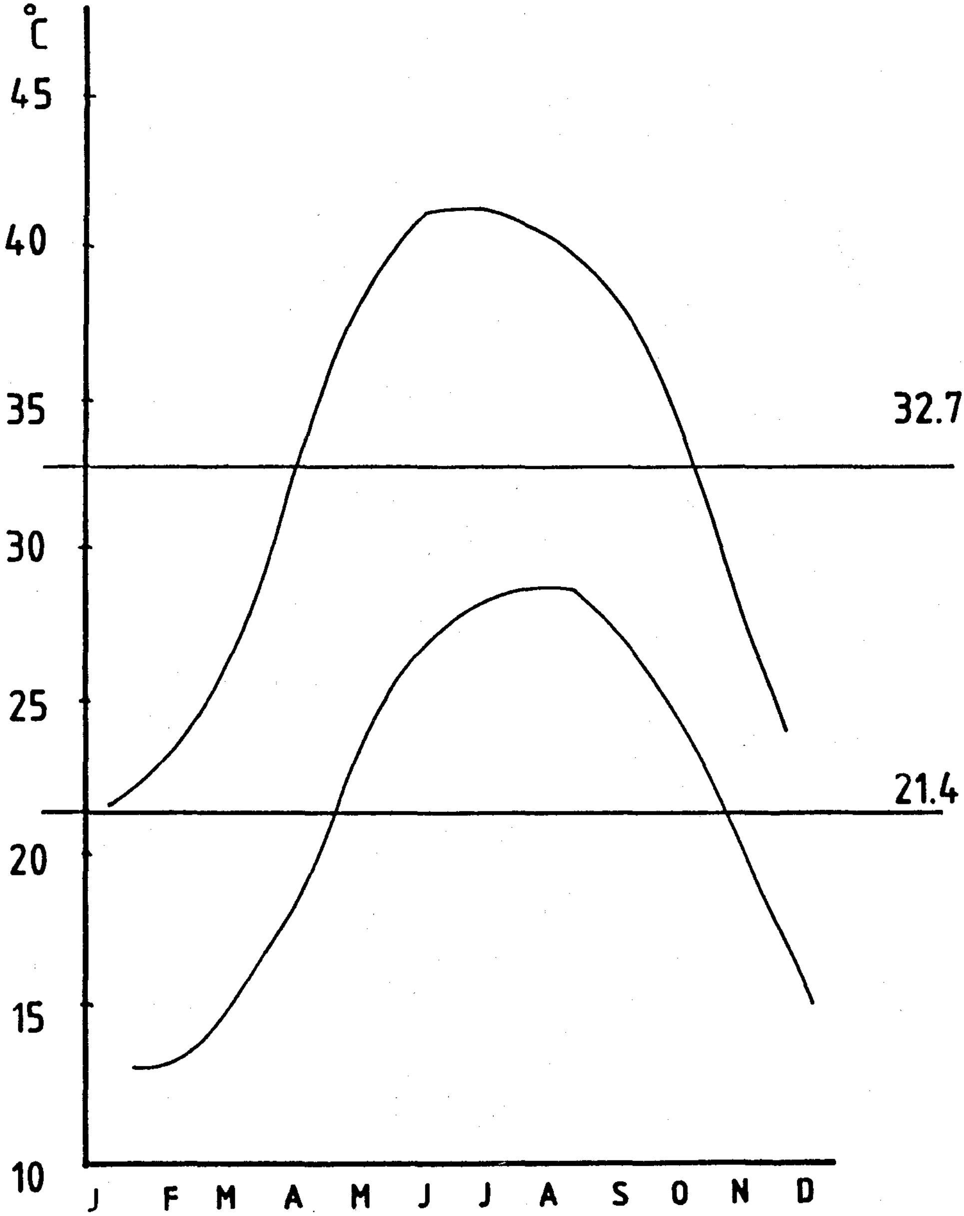
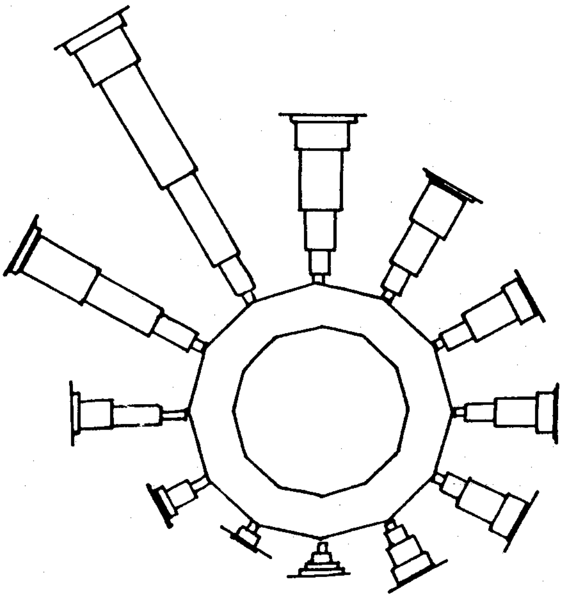


Fig. (4) : Sufrace Windrose (Doha Airport 1975 – 1986).



Total Observations = 105192

Figure in Circle : Percentage of Calms

Segment Length (———) = 10%

Segment Width	Class	Beaufort no
-	01 To 03 Kts	1
—	04 To 06 Kts	2
—	07 To 10 Kts	3
——	11 To 16 Kts	4
——	17 To 21 Kts	5
——	22 To 27 Kts	6
———	28 To 33 Kts	7
———	34 To 40 Kts	8

Fig. (5) : Mean Relatine Humidity at Doha Airport (1962 - 1987).

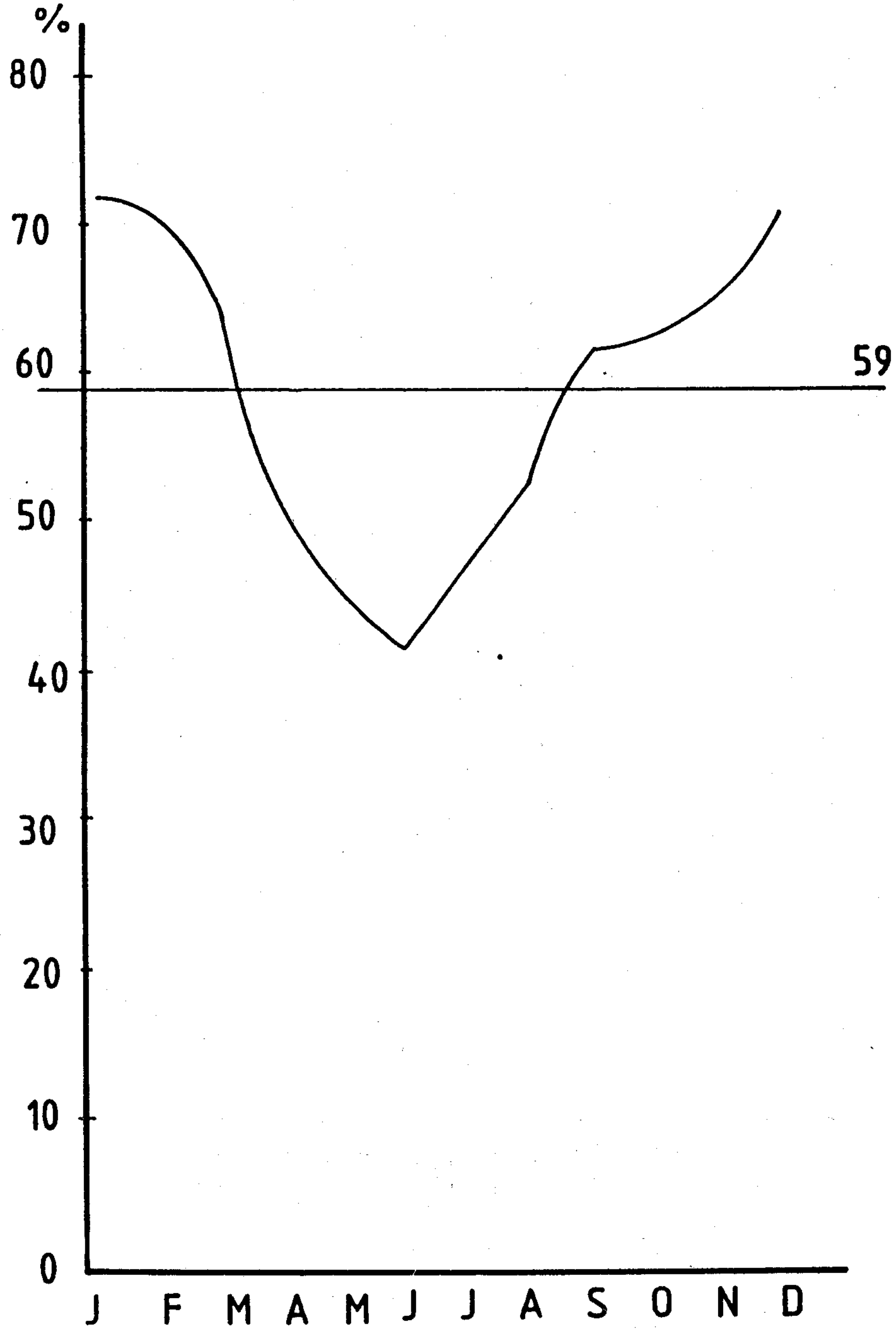
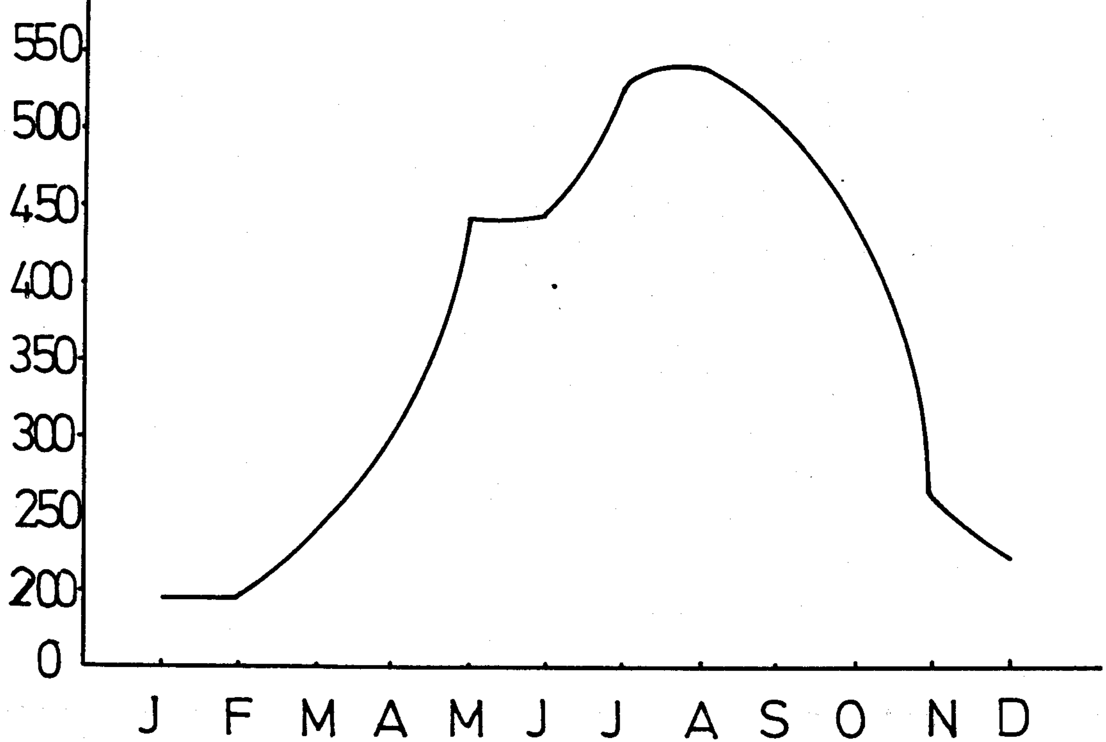


Fig. (6) : Electricity Generation in Qatar in 1987

(Unit 000'K.W./H).



Source : State of Qatar – Annual Statistical Abstract (1988).

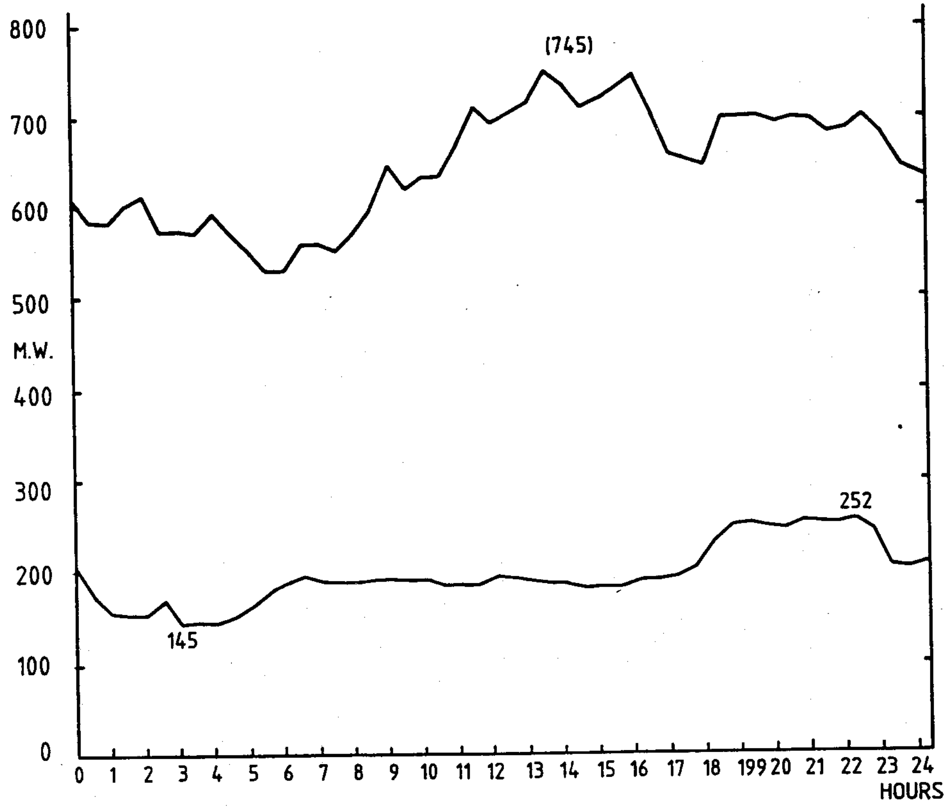


Fig. (7) : Maximum and Minimum Daily Load Curves (Max. 31-7-84, Min. 22-2-84).

Fig. (8) : Total number of days of duststorms Sandstorm, rising sand, rising dust and haze.

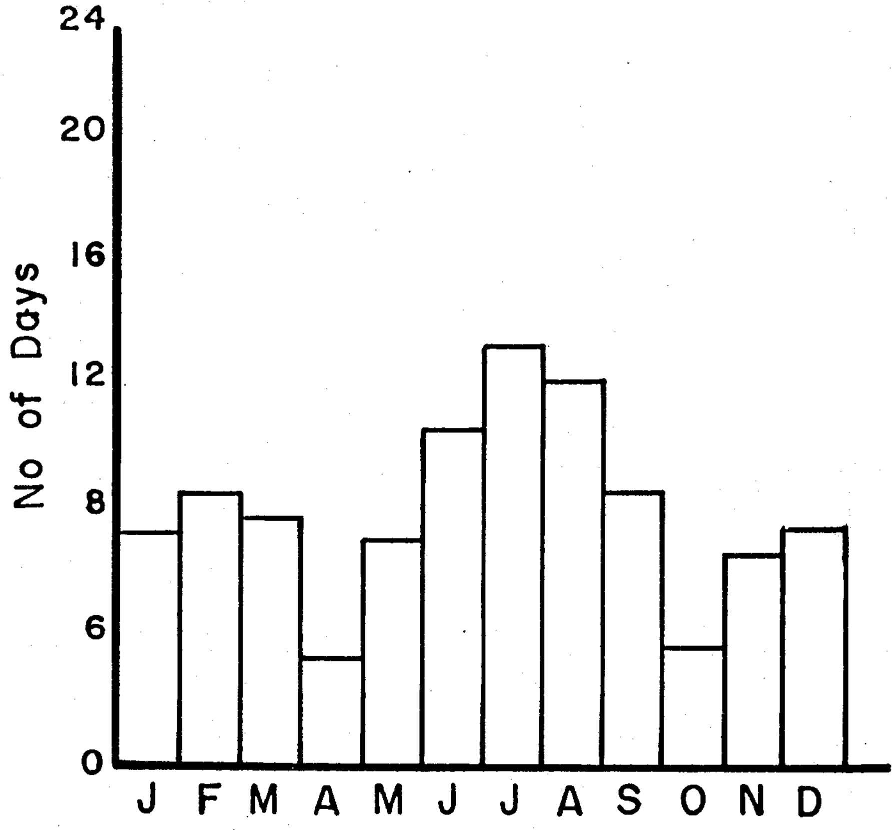
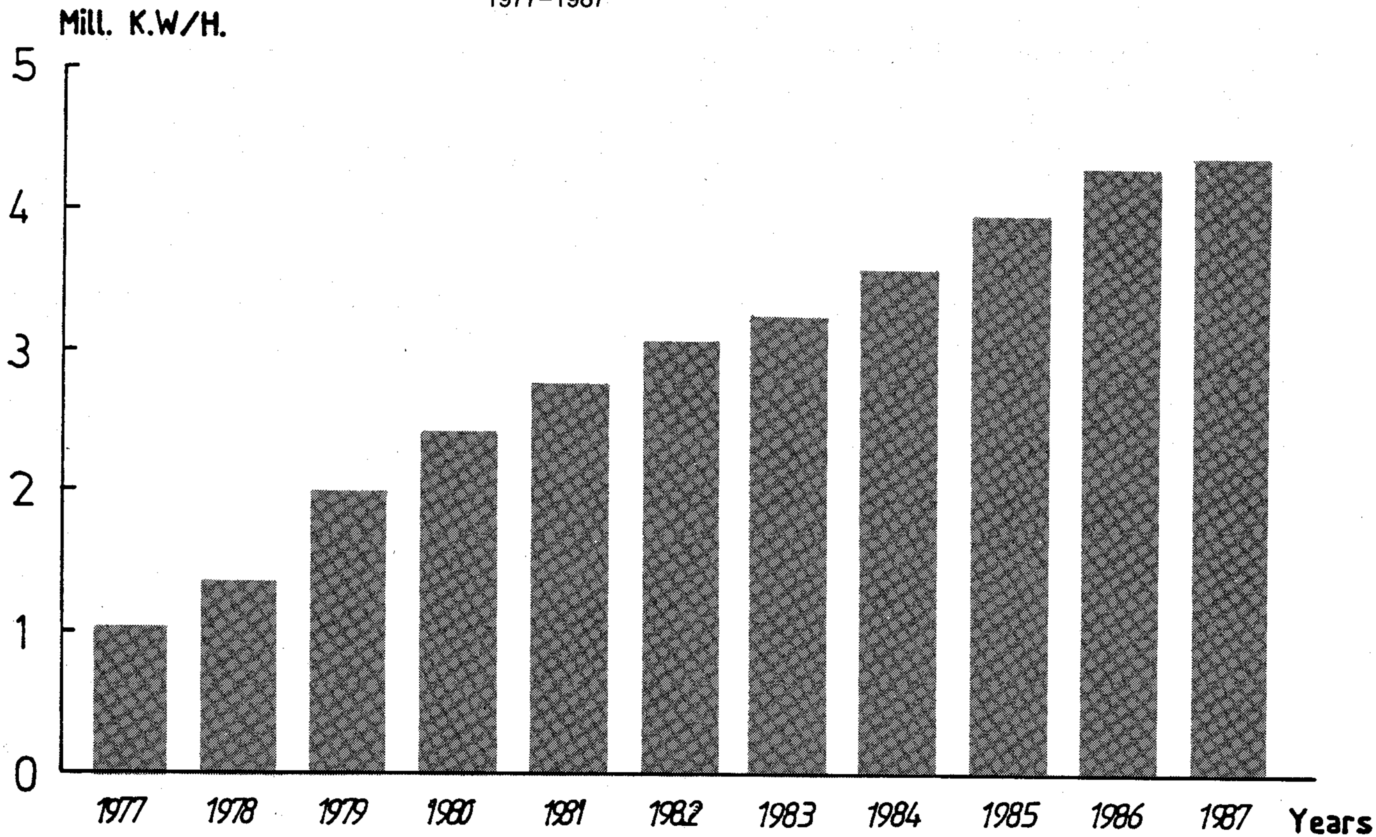


Fig. (9) : Electricity Generation – State of Qatar

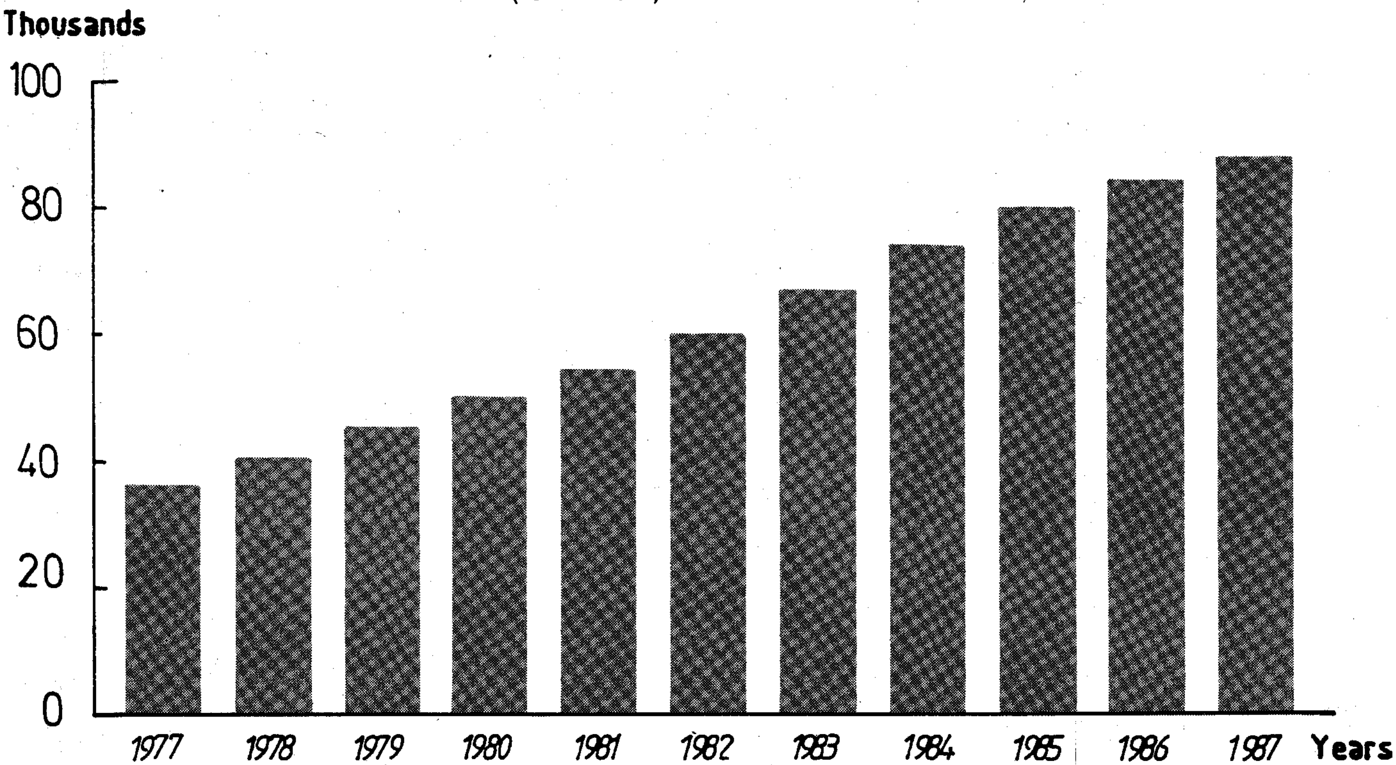
1977–1987



Source: State of Qatar – Annual Statistical Abstract (1988).

Fig. (10) : Number of Electricity Consumers–State of Qatar

(1977 – 1987)



Source : State of Qatar – Annual Statistical Abstract (1988).