CMA Publication No. 231

Making Great Rann of Kutch Capable of Producing Food by Specially Designed Hydroponics System

Girja Sharan
Maha Pratap Chandra

Centre for Management in Agriculture
Indian Institute of Management
Ahmedabad

This CMA publication is a reproduction of the original draft report submitted by the author.

Published and printed by the Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad 380 015.

Foreword

The Rann of Kutch is characterized by high ambient temperatures, wide occurrence of salt-effected soils, poor quality water highly erratic and low rainfall. Nearly the entire Kutch is a difficult place. The Rann is a vast area - 10,800 square miles – about the size of Haryana and Kerala.

The Rann is inaccessible and harsh - no water, heat, stark terrain with no vegetation. It is desirable that this region be developed and possibly made capable of producing food, herbs and other commodities of value. As demand for food increases and yields in humid areas with irrigation get saturated, it will be necessary to improve the productivity of arid and marginal areas. The Rann however holds some of the biggest colonies of flamingoes, wild ass herds which can attract eco-tourists.

Prof. Girja Sharan and his associate Mr. M P Chandra have a totally new vision around this difficult terrain – the vision of an economically productive Rann. Their plan is to turn the Rann into an economically productive territory, accessible and capable of supporting food production and eco-tourism. They have proposed to do this by innovative application of engineering to build new type of eco-tour facilities powered by renewable sources of energy available on location – solar, wind and shallow geothermal. The present study 'Making Great Rann of Kutch Capable of Producing Food by Specially Designed Hydroponics System' outlines the following four basic strategies to achieve this goal:

1. Use onsite energy sources - sun, wind, shallow geo-thermal resources - to produce cheap power in stand-alone mode - to start with 30 KW plant.

2. Use that power to desalinate water and run other utilities.

3. Create an artificially shaded ground with shade nets; install special hydroponics (soil less media) units to produce – vegetables.

4. Develop cost effective solar cottages for tourists with communication and entertainment facility, use deep earth for cooling and heating the cottages.

They have proposed to achieve their goal in stages. There would be R&D challenges at each stage. The region being excessively hot, PV solar would not be as effective unless arrays are kept cool; solar thermal and wind systems will also need to be examined. Desalination of brine would be expensive, and energy intensive; alternatives will therefore need to be developed. There has been no research on hydroponics and soil-less media in the country; that will need to be developed. The work - involving studies and research – is therefore proposed to be carried out in phases. The first phase, which is covered in the present study has the following objectives:

1. To assemble available met data - global soar radiation, ambient Temperatures, wind speed, direction, humidity levels etc. Temperature Regime up to 4 m below ground level; and analyze it to determine. The feasibility for on-site power generation and desalination of water.

2. To share the findings and the feasibility report with the agricultural scientists in a workshop convened for the purpose, scientists working on hydroponics for harsh climates to be invited.

3. To make preliminary exploration of solar desalination to supply water for hydroponics units.

4. If the feasibility of power generation and desalination appear attractive, and taking into account the views emerging from the workshop, take the idea forward. Develop and install a small experimental hydroponics unit for study in a part of the Rann.

I am glad to write the foreword to this report "Making Great Rann of Kutch Capable of Producing Food by Specially Designed Hydroponics System" which deals with the subject of making the Rann of Kutch a productive area. I hope it will be useful to all interested in this subject.

Samar Datta
Chairman, CMA

March 18, 2009

Acknowledgement

We thank Centre for Management in Agriculture for facilities and support. I thank the reviewer of the Ministry of Agriculture for recognizing that visualization of food production possibilities and initiatives to realize these from harsh areas like the Rann of Kutch is important. And for other useful comments.

Girja Sharan
Maha Pratap Chandra

Place: Ahmedabad
Date: February 2009

CONTENTS

1. Big Rann of Kutch

1.1 Big Rann

Kutch is characterized by high ambient temperatures, wide occurrence of salt-effected soils, poor quality water highly erratic and low rainfall. Nearly the entire Kutch is a difficult place. But its northern part - the Great Rann of Kutch – is particularly so (**Figure A-1**). The Rann is a vast area - 10,800 square miles – about the size of Maryland and Rhode Island combined or larger than Haryana and Kerala. The World Wildlife scientists characterized the area as follows:

"Perhaps the bleakest, dustiest, and hottest region in India is the Great Rann of Kutch. It stretches for hundreds of square kilometers in the State of Gujarat, from the frontier with Pakistan's Send Desert, southward to the Little Rann and the Gulf of Kutch. A desolate area of unrelieved, sun-baked saline clay desert, shimmering with the images of a perpetual mirage". During the brief wet season, the mudflat becomes flooded. Then it becomes parched under the relentless, searing heat of the long dry season; the eco-region has one of the highest annual evaporation rates in the region. Average summer temperatures hover around 44°C (but can reach highs of 50°C), and the minimum winter temperatures approach or even drop below freezing. The vegetation consists of grasses and thorny scrub with hardly any large trees."

Rann is inaccessible and harsh - no water, heat, stark terrain with no vegetation. It is desirable that this region be developed and possibly made capable of producing food, herbs and other commodities of value. As demand for food increases and yields in humid areas with irrigation get saturated, it will be necessary to improve the productivity of arid and marginal areas. Moreover the Rann holds some of the biggest colonies of flamingoes, wild ass herds which can attract eco-tourists. To our knowledge there is no initiative to make the Rann accessible and to create conditions so that tourism could become possible. However, there is evidence that the eco-tour potential of the Rann has begun to be appreciated. A NGO has built a resort at Hodka village, on the periphery of the Rann, which offers air-conditioned cottages for tourists. This is a good development. In order that more interior parts of the Rann become similarly accessible, it would be necessary to follow a different engineering model. The complexes will need to be powered on stand alone mode using onsite energy sources, rather than drawing electrical power from the public grid, which does not extend into the Rann. The same would hold for water, which must be produced on site via cost effective desalination process; and perhaps also some fresh food – vegetables- via hydroponics.

1.2 A New Vision - Economically Productive and Hospitable Rann

It is planned to turn the Rann into an economically productive territory, accessible and capable of supporting food production and eco-tourism. This will be done by innovative application of engineering to build new type of eco-tour facilities powered by renewable sources of energy available on location – solar, wind and shallow geothermal. The basic strategy is outlined below.

5. Use onsite energy sources - sun, wind, shallow geo-thermal resources - to produce cheap power in stand-alone mode - to start with 30 KW plant.

6. Use that power to desalinate water and run other utilities.

7. Create an artificially shaded ground with shade nets; install special hydroponics (soil less media) units to produce – vegetables.
8. Develop cost effective solar cottages for tourists with communication and entertainment facility, use deep earth for cooling and heating the cottages.

All this can only be achieved in stages. There would be R&D challenges at each stage. The region is excessively hot, PV solar would not be as effective unless arrays are kept cool; solar thermal and wind systems will need to be examined. Desalination of brine would be expensive, and energy intensive; alternatives will need to be developed. There has been no research on hydroponics and soil-less media in the country; that will need to be developed. Environment friendly means of transport over the Rann surface? Stakeholders in such a vision of the Rann will include Indian defense establishment, Gujarat tourism, ministry of forest and environment, communities who live in parts of the Rann or nearby, tourist industry.

The work - involving studies and research - will be carried out in phases. The first phase has the following objectives.

5. To assemble available met data - global soar radiation, ambient Temperatures, wind speed, direction, humidity levels etc. Temperature Regime up to 4 m below ground level; and analyze it to determine. The feasibility for on-site power generation and desalination of water.

6. To share the findings and the feasibility report with the agricultural scientists in a workshop convened for the purpose, scientists working on hydroponics for harsh climates to be invited.

7. To make preliminary exploration of solar desalination to supply water for hydroponics units.

8. If the feasibility of power generation and desalination appear attractive, and taking into account the views emerging from the workshop, take the idea forward. Develop and install a small experimental hydroponics unit for study in a part of the Rann.

2. Geology Soils and Meteorology

2.1 The area (Rann) has Alluvium, blown sand & millolite sand. Northern half of peninsula is made of alluvium of light brown color and sand, to dark brown or black and clayey in the south. The brown clay is with "kankar" and at some places gravel. The deposits mostly appear to be of estuarine or marine origin. Part of the Rann, due to slight elevation and natural protection from inundation has soil which though saline, can support coarse grasses. This vast pasture land called Banni, supports large population of live-stock mostly cows. Both the little and the large rann of Kutch are salt soaked, liable to flooding in monsoon. Soil is saline and sandy with low water holding capacity. Soils of Lakhpat, Nakhatrana, and Rapar are low in nitrogen, phosphorus, medium in potash. Soil fertility status of Kutch - L.M.M. Deep soil temperature (30 cm) at Kothara stays close to 32 ^{0}C (**Figure 2.5 and 2. 6**).

2.2 Rains

The nearest known isohyets passing through eastern Rann is 400mm to 375 mm (Figure **A-2**). Rainfall at Radhanpur in the year 2004, '05, '06 was 267 mm, 295 mm and 932 mm respectively. At Kothara the mean long term annual precipitation is 300 mm. Large variation is typical of the region. Pan – evaporation data was not monitored at Radhanpur, but for Bhuj it is upwards of 2000 mm.

2.3 Ambient Conditions

Appendix Tables (**A-1 to A-56**) shows the data of ambient conditions for Kothara and Radhanpur, located at the western and eastern edge of the Rann. The three year mean of Kothara data is shown in Figure **2.1 to 2. 4**. Temperatures in Kothara summers reach over 40 ^{0}C. Night time cloud cover observations taken at 20:30 and 23:30 were obtained from the Indian Meteorology Department Observatory at Naliya (Kutch), 10 km northeast of Kothara (Appendix **Tables A-12 to A-26**). Cloud cover begins to appear from early June and continues through September. The extent varied from 2 to 7 octas in June and July, 2 to 8 octas in August and September nights. After October the sky is again generally clear. Only some cover (2 octas) were recorded in January on a few occasions. There are two peaks during the season – one centered over March – April (summer), the other over October (fall). The dew occurrences are low in winter months, November to January. During this period nocturnal wind is from north or north-

east. The moisture level in the air is low. From February to May, during which dew forms frequently, nocturnal wind blow mainly from west or south-west; carrying high levels of moisture.

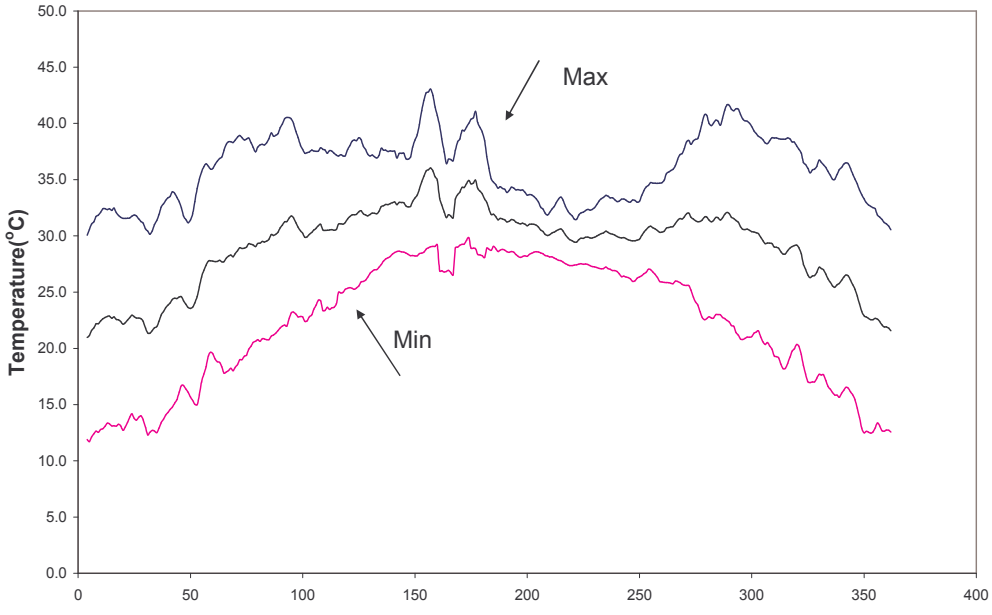


Fig 2.1 : Ambient Air Temperature- Kothara

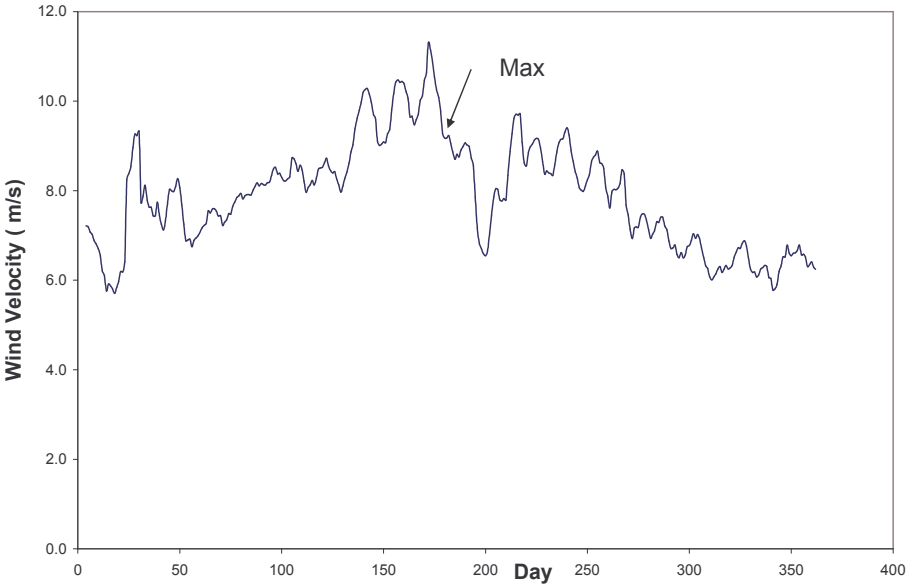


Fig 2.2: Wind Velocity - Kothara

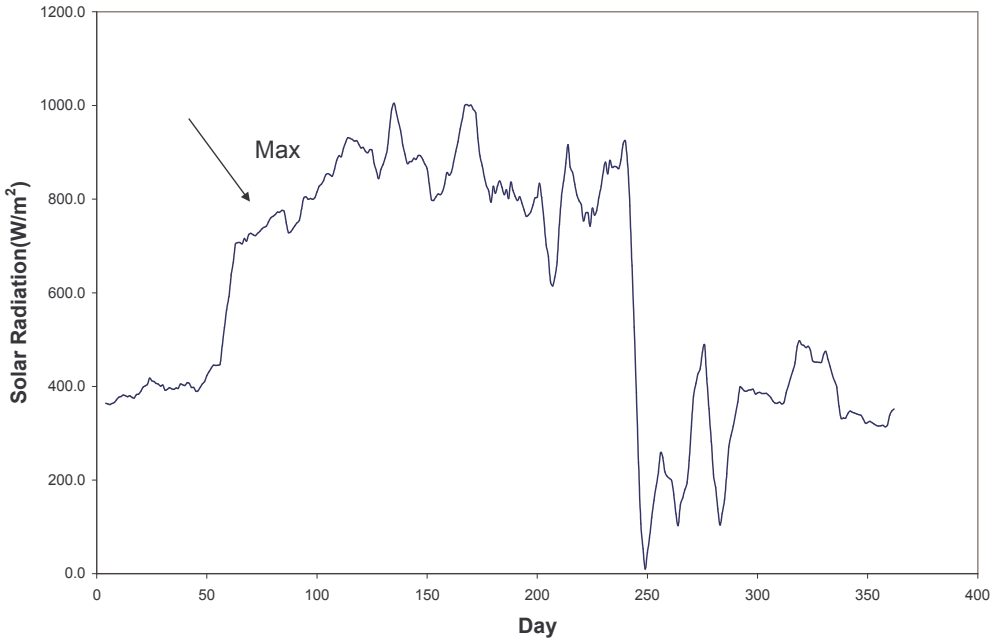


Fig 2.3: Solar Radiation - Kothara

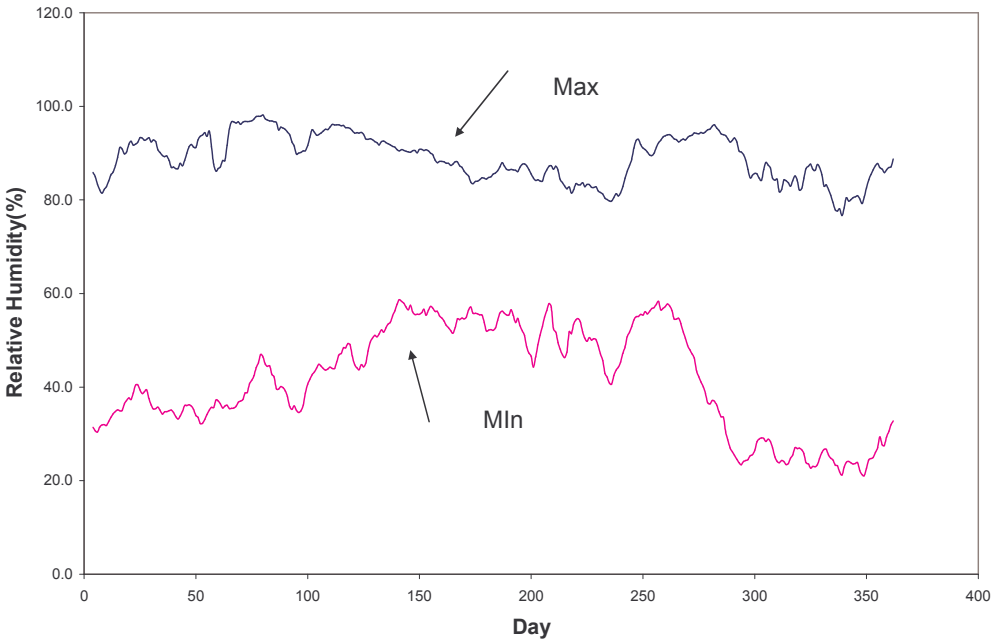


Fig 2.4: Relative Humidity - Kothara

Fig 2.5: Surface Soil Temperature -Kothara

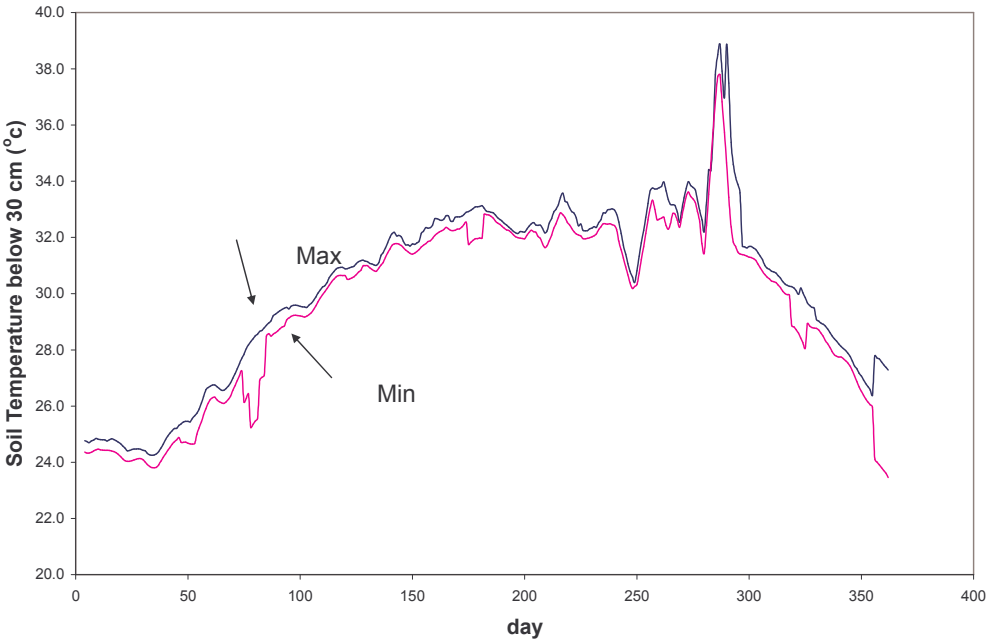


Fig 2.6: Soil Temperature below 30 cm - Kothara

3. Solar desalination

Review of Initiatives

In view of scanty and highly variable rainfall, high temperatures it can be stated that the key to making the Rann productive is the provision of agriculture-quality water. And the only possibility is solar desalination. Initiatives to desalinate and recover water for use in irrigation have been reported from semi-arid areas elsewhere. Wanwiwat et al. (2007) reported results of recovering water from humid greenhouse air by placing a condenser in its path at the end. Condenser was cooled using chilled water from the sump below the pads, several degrees colder than the dew point of the humid air. They reported that even with relatively inefficient condenser (bypass factor 0.92) a maximum of 26.9% of the water use in plant canopy transpiration could be recovered in the pre-monsoon and a maximum of 15.1% in the monsoon period. A maximum of nearly 100% could be recovered in pre-monsoon and 94.3% in the monsoon period if condensers were made more efficient (bypass factor 0.5). The arid area greenhouse does not employ evaporative cooling and the groundwater is not cold enough to drive a condensation process. Under the conditions that prevail in Kutch region - high levels of radiation and high ambient temperatures- solar thermal processes of desalination are being considered.

One such possibility is described by Chaibi (2003). In this schema, one side of the roof of a double-sloped glass house is made of two layers of glass separated by a gap to permit a sheet of brackish water to flow down slowly. The lower glass is slightly darker, upper one clear. Solar radiation heats the water as it flows down. Vapors rise to the cooler upper glass and condense as in stills. The condensate is collected in a sump. Although a full scale system was not made, Chaibi stated that this concept offers the possibility to produce enough water to meet crop needs, in conditions obtaining in Tunis. He observed further that although the transmittance from the solar absorber part is reduced, sufficient PAR radiation is transmitted. Optical properties of the glass covers are critical. It would be desirable to have some spectral selectivity - transmit high levels of PAR radiation and low levels of IR radiation.

Although not for greenhouse use, double-sloped glass covered shallow basin type solar stills have been used in India in the past to produce water for drinking in remote areas including here in Kutch region. Some were large systems in the form of arrays designed to supply up to 5,000 L per day of water. Performance of such stills was studied over several years. Equation (1) gives the input –output correlation (Gomkale, 1988).

$$S_p(t) = 4.63 x 10^{-6} [S_r(t)]^{1.545} \quad \text{..... (1)}$$

Where

Sp (t) distillate output on day t (L/m^2)

S_r (t) solar radiation on day t ($kcal/m^2$)

Sharan and Kumar (1998) examined the possibility of using stand-alone systems made of similar stills to desalinate water for use in irrigation. At the time of that analysis there was shortage of real data. Neither the site specific radiation data nor the actual water consumption of crops was available. The exercise was therefore done via simulation using radiation data of Bhuj (90 km from present greenhouse site), details of which can be seen in the publication referred to. The main conclusion was that the still area needed to meet the crop (tomato) water requirement in open-field will be nearly equal to the cropped area making it infeasible. If the local well water salinity were high, the ratio of stills to crop areas will be even higher. There was no experience of cropping under greenhouse in this area then.

Now onsite radiation and other data are available for Kothara – site of arid area greenhouse facility. Using the daily radiation data in equation (1) quantity of distillate produced during the course of tomato growing season (September to February) was computed (457 mm). The crop water requirement of tomato in the open-field was estimated at 452 mm. The irrigation water given to crop reported by a few farmers who raise tomato, is higher than this value. Thus the required basin area per unit crop area works out to one, similar to the earlier conclusion. Chaibi too observed that stills would not meet the requirement of open-field crop in Tunis area. Several rounds of cropping have been done in arid area greenhouse in the recent years. In the year 2006-07, the two were Okra (July–October) followed by hybrid tomato (November–May). In 2007-08, these were bitter gourds (July–October) followed by hybrid tomato (November–May). The amount of water used in irrigation (via drip) is shown below.

Okra	July 06 - October 06	200 mm
Tomato	November 06 - May 07	260 mm
Bitter gourds	July07 – October 07	150 mm
Tomato	November 07 - May 08	258 mm

Between July and October the distillate output will be 332 mm, against the demand of 200 mm. Between November to May the output will be 591 mm against the demand of 258 mm (**Table 3.1**). Thus, if crops are grown inside greenhouse, still area required per unit crop area reduces to 0.6. Chaibi's statement that solar desalination apparatus on half of glasshouse may be adequate to supply enough water for the crops appears realistic. But having to use half the roof for desalination will

Table 3.1: Estimated distillate output over the months based on solar Radiation data of Kothara

Month	Distillate output on typical day (L m^{-2})	output over month (L m^{-2})
January	2.1	63
February	2.5	76
March	3.3	98
April	3.7	112
May	4.0	120
June	3.6	107
July	1.7	51
August	2.8	85
September	3.6	109
October	2.9	87
November	2.2	67
December	1.8	55
Annual		1029

Most likely limit the effectiveness of this approach to smaller systems, as also observed by Chaibi.

A relatively new process - low temperature thermal desalination (LTTD)- has been developed by desalination group of Institute of Ocean Technology (NIOT), Chennai, India. A large plant producing 100,000 L per day drinking water by desalination of sea, water based on this process has been working at a remote Indian island since 2005 (www.niot.res.in). Sea water is drawn from the surface and fed to a flash chamber which is partially evacuated to lower the boiling point. The temperature of water entering the flash chamber is usually ~ 30° C. The boiling water draws the heat of vaporization from the rest of raw water in reservoir, cooling it by a few degrees. Vapor is led to a condenser where it is condensed to produce fresh water. Condenser is cooled by sea water drawn from 500 m depth where the temperatures are lower, usually ~ 15° C.

Sea water from the surface is referred to as warm stream that from deeper layer as cold stream. The temperature differential between warm and cold streams (Δ T) is the key factor that determines the fraction of raw water converted to fresh water. Equation (2) describes the relationship between condensation and temperature differential (P. Sistla, pers. Commun.).

$$M_f / M_w = (Cp / Lf) * \Delta T \quad \text{.....} \quad (2)$$

Where M_f is mass of fresh water produced, M_w mass of raw water, C_p specific heat of water (~ 4186 J/kg-K) and Lf latent heat of evaporation (~ 2448000 J/kg). Using these values, the above relation can be expressed as,

$$(Mf / M_w) * 100 = \Delta T / 5.85 \quad \text{.....} \quad (3)$$

Equation (3) shows that approximately 1% condensation can be achieved for every 5.85 ^{0}C drop in temperature from warm water. The technology is scalable, does not require much space and near the sea, has low running cost due to the fact that pumping heads are low and the temperature differential is available free. The negative features are - large flows required compared to the amount condensed. In addition to the flow needed to flash vapor, it is also needed to cool the condenser. Waste water also needs to be disposed off. The LTTD system is suited for being located on the sea shore. The sea provides easy source of flows - both warm and cold - and easy sink for disposal. Of course, it needs to be noted that the motivation for developing this technology was to provide drinking water for communities living in remote islands and near sea. The scientists who developed it also indicated that this technology is better suited for large scale desalination.

Two modes are being visualized. One, to build large conventional LTTD plants on the sea shore and distribute the fresh water to greenhouse ranges nearby. Second, adapt the technology to inland locations by using solar energy to create temperature differential - solar assisted LTTD plant. Groundwater which is typically between 30 ^{0}C - 32 ^{0}C in this region could be heated by passage through absorber type solar hot water system to create temperature differential.

3.1 Evacuated solar tube based hot water system

Evacuated solar tubes are being used in some areas for heating water for domestic use. These are able to create differentials of approximately 30 ^{0}C, which could yield higher (4% to 5%) condensation. Evacuated tubes are the absorber of the solar water heater. They absorb solar energy converting it into heat for use in water heating. Commonly these employ "twin-glass tube." Each evacuated tube consists of two glass tubes made from extremely strong borosilicate glass. The outer tube is transparent allowing light rays to pass through with minimal reflection. The inner tube is coated with a special selective coating which features excellent solar radiation absorption and minimal reflection properties. The top of the two tubes are fused together and the air contained in the space between the two layers of glass is pumped out while exposing the tube to high temperatures. This "evacuation" of the gasses forms a vacuum, which is an important factor in the performance or evacuated tubes. A vacuum is an excellent insulator. While the inside of the tube may be 150°C / 304°F, the outer tube is cold to touch. This means that evacuated tube water heaters can perform well even in cold weather when flat plate collectors perform poorly due to heat loss.

In order to maintain the vacuum between the two glass layers, a barium coating is used. During manufacture of the evacuated tube this is exposed to high temperatures which cause the bottom of the evacuated tube to be coated with a pure layer of barium. This barium layer actively absorbs any CO, CO_2, No, O_2, H_2O and H_2 out-gassed from the evacuated tube during storage and operation, thus helping to maintaining the vacuum. Evacuated tubes are aligned in parallel; the angle of mounting depends upon the latitude of site. In a North South orientation the tubes can passively track heat from the sun all day. In an East West orientation, they can track the sun all year round. Solar Evacuated Tube Specifications are given below.

Length (nominal)	1500 mm
Outer tube diameter	58 mm
Inner tube diameter	37 mm
Glass thickness	1.6 mm
Thermal expansion	3.3 x 10 °C
Material	Borosilicate Glass 3.3
Absorptive Coating	Graded (A1-N/Al)
Absorptance	>92% (AM 1.5)
Emmitance	<8% (80°C)
Vacuum	P < 5 x 10^{-3} Pa
Stagnation Temperature	> 200°C
Heat Loss	< 0.8W/(m^2°C)
Maximum Strength	0.8 MPa

System Capacity: 2 x 2500; System cost: Rs.5,40,000/- for system with SS tank. For use in irrigation context these are expensive and will not be feasible in greenhouse on account of cost.

3.2 Flat-plate collector hot water system

A solar collector is a special kind of heat exchanger that transforms solar radiant energy into heat. In the solar collector, energy transfer is form a distance source of radiant energy to a fluid. The performance of solar collector is describe by a cross sectional area of collector that indicate the distribution of incident solar energy into useful energy gain and thermal loss. The system consists of collector, storage tank installed at a level higher than the collector and connecting pipes. As the collector get heated up in the sun, temperature gradient cause density variations gives rise to the fluid flow through the collector. As the cold water enters the collector at the bottom at a temperature t_1 and leaves at a higher temperature t_2 after collecting some heat from collector.

For calculation data was taken for date 24 Nov 2007.

$$\frac{T_{fo} - T_a - \frac{S}{U_L}}{T_{fi} - T_a - \frac{S}{U_L}} = \ell^{-\left(\frac{Ac\,U_L F'}{M\,Cp}\right)}$$

$$m = \left[\frac{U_L}{(k \times t)}\right]^{1/2}$$

Fin efficiency factor,

$$F = \frac{\tanh\left[m(W-D)/2\right]}{\left[m(W-D)/2\right]}$$

Collector efficiency factor,

$$F' = \frac{\frac{1}{U_L}}{W\left[\frac{1}{U_L\left(D+(W-D)F\right)} + \frac{1}{\prod \times D \times h_{fi}}\right]}$$

Overall heat loss coefficient,

$$U_L = U_t + U_b + U_e$$

Top heat loss coefficient,

$$Ut = \left[\left(\frac{1}{h_1}\right) + \left(\frac{1}{h_2}\right)\right]^{-1}$$

Top loss heat transfer coefficient from collector,

$$h_1 = h_1 c + h_1 r$$

Top loss heat transfer coefficient from cover to ambient,

$$h_2 = h_2 c + h_2 r$$

Radioactive heat transfer coefficient from plate to cover,

$$h_{1r} = \varepsilon_{eff}\,\sigma \frac{(Tp+273)^4 - (Tc+273)^4}{Tp - Tc}$$

$$\varepsilon_{eff} = \left[\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_c} - 1\right]^{-1}$$

Radioactive heat transfer coefficient from cover to ambient,

$$h_{2r} = \varepsilon_c\,\sigma \left[\frac{(Tc+273)^4 - (T_{sky}+273)^4}{Tc - Ta}\right]$$

Convective heat transfer coefficient from plate to cover,

$$h_{1c} = Nu\frac{k}{L}$$

$$Nu = 1 + 1.44\left[1 - \frac{1708}{Ra\cos\beta}\right]^{+}\left[1 - \frac{\sin(1.8\beta)^{1.6}\,1708}{Ra\cos\beta}\right] + \left[\left(\frac{Ra\cos\beta}{5830}\right)^{\frac{1}{3}} - 1\right]^{+}$$

$$Ra = Gr \times \Pr$$

$$\Pr = \frac{\nu}{\alpha}$$

$$Gr = \frac{g\beta' L^3 \Delta T}{\nu^2}$$

Convective heat transfer coefficient from cover to ambient,

$$h_{2c} = 2.8 + 3V$$

Back heat loss coefficient,

$$U_b = \frac{\kappa}{L}$$

Where,

T_{fo} - Outlet fluid temperature, ^{o}C

T_a - Ambient temperature, ^{o}C

T_{fi} -Inlet fluid temperature, ^{o}C

Tp - Temperature of absorber plate

Tc - Temperature of cover

T_{sky} - Sky temperature

S - Solar radiation absorbed by collector, W/m^2

L - Thickness of insulator

U_L - Overall heat transfer coefficient, W/m^2

U_t - Top heat loss coefficient

U_b - Back heat loss coefficient

U_e - Edge heat loss coefficient

ε_c - Cover emittance

ε_p - Absorber plate emittance

β' - Coefficient of volumetric thermal expansion

h_1 - Top loss heat transfer coefficient from collector

h_2 - Top loss heat transfer coefficient from cover to ambient

h_1c - Convective heat transfer coefficient from plate to cover

h_2c - Convective heat transfer coefficient from cover to ambient

h_{1r} - Radioactive heat transfer coefficient from plate to cover

h_2r - Radioactive heat transfer coefficient from cover to ambient

ν - Kinematics viscosity

α - Thermal diffusivity

V- Wind velocity

Cp - Specific heat of water, kJ/kg ^{o}C

F' - Collector efficiency factor

β - System inclination

D - Inner diameter of tube

W - Tube spacing

t - Plate thickness

k -Thermal conductivity

Ac - Collector area, m^2

M - Mass flow rate, lit/hr

Hfi - Heat transfer coefficient, W/m^2

F- Standard efficiency factor

g - Acceleration due to gravity

σ - Stefan Boltzman constant

Nu - Nusselt Number

Ra - Raleigh Number

Gr - Grashof number

Pr - Prandtl number

Temperature of outlet water is the function of length of tube, solar radiation, and mass flow rate and wind velocity**.** **Tables 3.2 to 3.4,** show the results of computations using the above correlations. **Figures 3.1 to 3.3** show the same graphically. As expected the temperature gain rises almost linearly with the rise in absorber area per unit tube length, and declines with the increase in flow rate. Using this data , it can be stated that scaling up the flow rates to feed a greenhouse will be possible with flat plate systems , but the initial costs will be as prohibitive as in case of evacuated tubes system.

Table 3.2: Temperature gain and absorber area - flow rate 22 lit/hr

Sr. No.	Absorber area, (m^2)	Mass flow rate (lit/hr)	Output water temperature (^oC)	Temperature gain(ΔT) (^oC)
1.	2	22	34.9	8.9
2.	3	22	38.9	12.9
3.	4	22	42.7	16.7
4.	5	22	46.1	20.1
5.	6	22	49.3	23.3
6.	8	22	55.0	29.0
7.	10	22	60.0	34.0

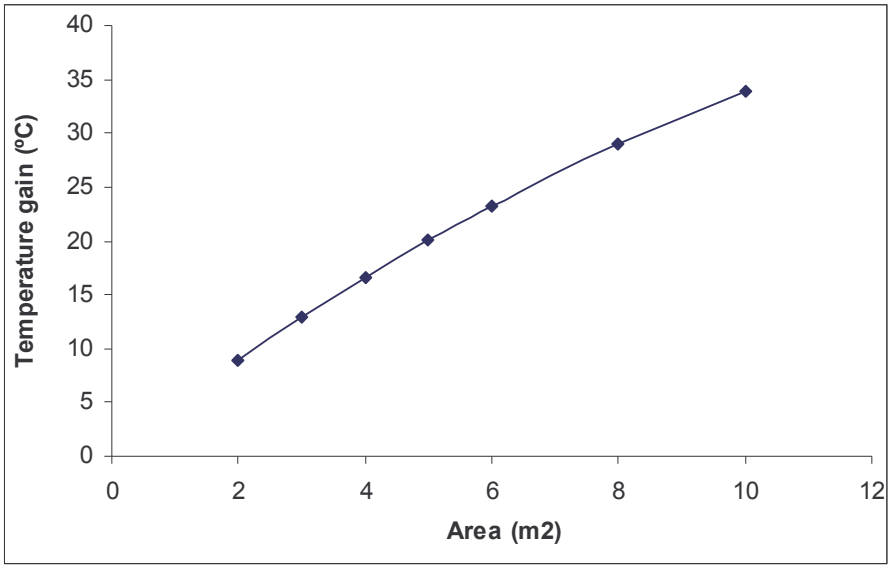


Figure 3.1 Temperature gain and absorber area - flow rate 22 lit/hr

Table 3.3: Temperature gain and absorber area - flow rate 30 lit/hr

Sr. No.	Collector area, m^2	Mass flow rate (lit/hr)	Output water temperature	Temperature gain (^oC)
1.	2	30	32.7	6.7
2.	3	30	35.7	9.7
3.	4	30	38.7	12.7
4.	5	30	41.5	15.5
5.	6	30	44.0	18.0
6.	8	30	48.9	22.9
7.	10	30	53.2	27.2

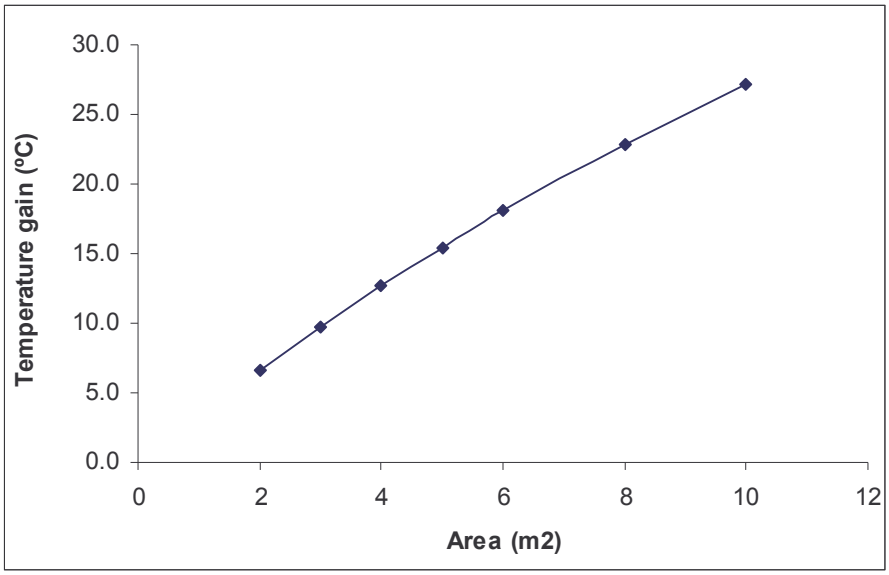


Figure 3.2 Temperature gain and absorber area - flow rate 30 lit/hr

Table 3.4: Temperature gain and absorber area - flow rate 40 lit/hr

Sr. No.	Collector area, m^2	Mass flow rate	Output water temperature	Temperature gain (^oC)
1.	2	40	31.0	5.0
2.	3	40	33.4	7.5
3.	4	40	35.7	9.7
4.	5	40	37.9	11.9
5.	6	40	40.0	14.0
6.	8	40	44.0	18.0
7.	10	40	47.7	21.7

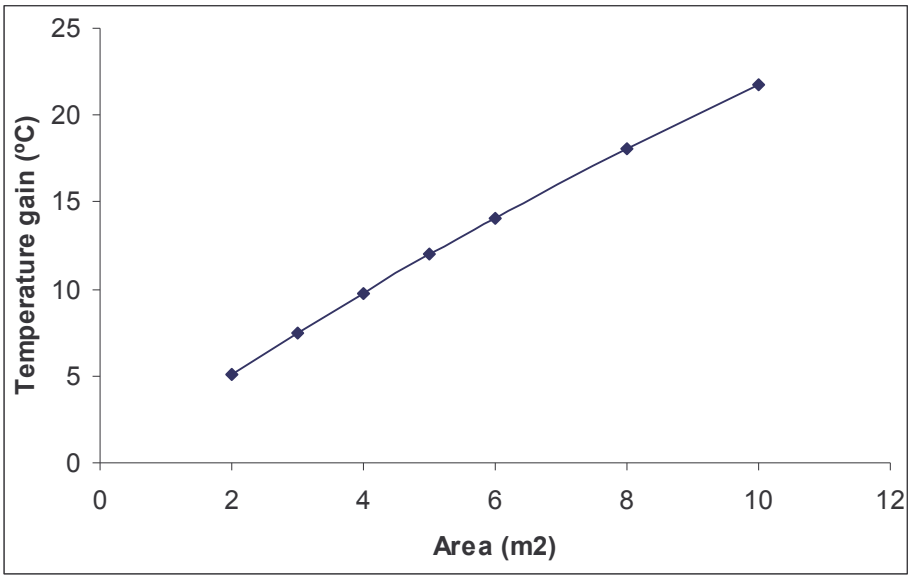


Figure.3.3. Temperature gain and absorber area - flow rate 40 lit/hr

3.3 Pool Solar Hot Water System

Pool solar hot water systems are not common in the country. These are much cheaper. It was, therefore, decided to try out such systems. A prototype was constructed for trial at Kothara. It consists of PP tubes connected in parallel, two headers, supply water tank and storage of hot water (**Figure 3.1**). Entire module is supported on wooden frame and placed on ground at angle of. The tubes diameter 20mm and header diameter 50mm, length of tubes 3 meter and header are also 3 m. Wood frame has slope 24^{o} south facing. This angle is nearly equal to the latitude of the location. Tubes are covered on top with transparent PE plastic sheet.

Specifications	
Length (m)	3
Width (m)	3
Height (m)	1.25
Length of PPR tubes (m)	3
Diameter of PPR tubes (mm)	20
Number of tubes	25
Header length (m)	3
Header diameter (mm)	50
Accessories size (end cap , elbow ,T)mm	50
Transparent plastic PE (m^2)	18
Sand (ft^3)	100
Raw water tank (lit.)	200
Hot water tank (lit)	80

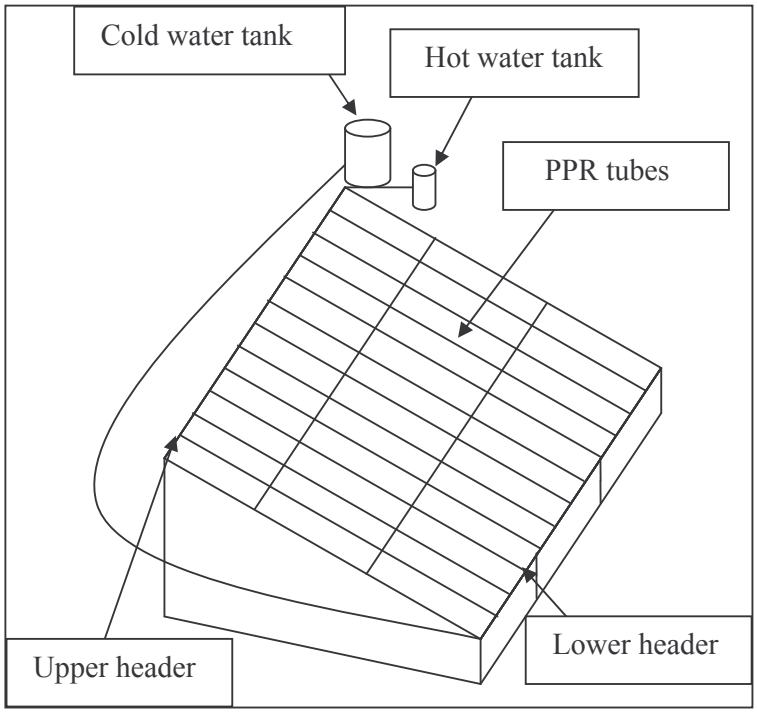


Figure: 3.4 solar hot water prototypes

Cold water drawn from well is filled in the supply tank. It enters through lower header and rises up the tubes, getting warmer as it travels. Upper header opens to hot water tank. Total flow rate was kept at 1 lit./minute. The tubes act as absorbers. Temperature of supply water tank was measured at 9 am and 2 pm. Hot water tank temperatures were measure interval of one hour. By deep stick type digital electric temperature sensor. Data is shown in **Tables 3.5- 3.13**.

Performance

The temperature differential between warm and cold water (ΔT) is the key factor that determines the fraction of cold water converted to hot water. Investigations were therefore carried out using solar pool heaters that use polypropylene tubes as absorbers. Measurements were made for three consecutive days in each month in 2007. The temperature differential achieved under ambient conditions at Kothara in most months was approximately 15^0 C, similar to that available at sea. This suggested that if absorber area was increased, length of tubes increased, it may be possible to augment the temperature gain to about 20^0 C, which would make it feasible for the larger output. The initial costs of the pool type systems are nearly a third of the other two discussed earlier.

Table: 3.5 Prototype Pool Solar hot water test data - September 2007

SN	Hour of day	September data								
		21 (°C)	22 (°C)	23 (°C)	24 (°C)	25 (°C)	26 (°C)	27 (°C)	29 (°C)	30 (°C)
1	9	--	36.6	34.7	35.2	30.8	35.5	36	35	34
2	10	--	40.2	39.6	35.8	33.2	39.7	41	39	38.8
3	11	--	45.2	44.1	38.8	39.5	44.3	45.6	37	42.1
4	12	45	49.7	48	41.2	45.2	47	49.2	38.7	46.7
5	13	48	51.1	44	45.4	49.3	51.2	51.5	39	44.8
6	14	49	49	43.5	40.5	50.7	51.8	50.4	39.1	44.8
7	15	43.3	50.9	44.2	41	47.2	50.7	51.8	36.5	45
8	16	42.6	46.7	42.5	40	41	50.5	49.3	34.3	44
9	17	41.2	43.6	41.2	38	39	47.2	46	33.6	42.5
Sky Condition		S C	Clear	cloudy	cloudy	S C	Clear	Clear	Clear	Clear
Raw water temperature 30-36 °C from 9am to 17 pm										
S C – Scattered cloud										

Table: 3.6 Prototype Pool Solar hot water test data - October 20007

SN	Hour of day	October data										
		1 (oC)	2 (oC)	3 (oC)	4 (oC)	5 (oC)	6 (oC)	7 (oC)	8 (oC)	9 (oC)	10 (oC)	11 (oC)
1	9	35.6	34.2	34.3	32.3	30.4	30.5	31	32.8	35.1	34.3	34
2	10	37.6	36.1	36.5	36	35.6	35.1	35.4	36.3	39.5	37.7	38.2
3	11	39.7	38.4	38	39.7	38.3	39.4	40.6	40.5	41.2	39.1	41.1
4	12	43	40.4	40.6	42.3	40.7	43.7	42.8	43.2	42.6	41.3	44.1
5	13	44.5	42	41.8	43.7	42.3	45.2	45.2	45.5	44.6	44	45.7
6	14	44.5	43.5	42.3	44.5	43.1	45	45.8	44.3	42	43.3	45.4
7	15	44	42.8	40.2	40.6	41.3	43.8	43.7	42.6	44.1	43	44.9
8	16	42.2	41.5	41	38.2	40	42.6	42.3	40.3	41.3	40.7	43.8
9	17	39.3	40	38.7	36.5	39.2	39.2	40.8	35.6	39.6	40	41
Sky Condition		Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Raw water temperature 30-36 oC from 9 am to 17 pm												

Table: 3.7 Prototype Pool Solar hot water test data - November 2007

SN	Hour of day	November data				
		21 (oC)	22 (oC)	23 (oC)	24 (oC)	25 (oC)
1	9	--	31.2	29.9	26.4	28.5
2	10	35.2	34.9	34.3	32.8	32.5
3	11	38.7	39.8	36.9	36.5	37
4	12	44	44.2	42.3	40.6	40.2
5	13	45	45.2	43.8	43.1	43.7
6	14	44.8	46.6	44.7	44.7	45.2
7	15	44.3	44.6	44	42.7	42
8	16	41	42.4	42.8	40.7	40.3
9	17	38.9	39.2	40.2	37.5	36.6
Sky Condition		Clear	Clear	Clear	Clear	Clear
Raw water temperature		**28-34 oC**		**from 9 am to 17 pm**		

3.8 Prototype Pool Solar hot water test data - December 2007

SN	Hour of day	December data								
		1 (oC)	2 (oC)	3 (oC)	15 (oC)	16 (oC)	17 (oC)	29 (oC)	30 (oC)	31 (oC)
1	9	30.5	25.9	24.3	18.3	17.5	17.7	20.4	17.8	17.8
2	10	32.1	28	26.8	22.8	21.5	22.1	24	23.2	21.7
3	11	34.2	32.6	30	26.2	25.7	26.4	28	27.4	27
4	12	39.6	34.9	31.9	28.9	28.6	28.4	32	29.3	30.8
5	13	45.8	37.4	35.2	31.8	31.2	32	34.9	32.5	31.9
6	14	46.2	39.1	36.4	32.5	32.8	33.2	39	37.5	33
7	15	41.5	39.2	37.9	32.7	32	32.9	32.3	38	31.3
8	16	38.1	36.2	36.9	31.7	30.5	32.5	32	36.5	30.5
9	17	35.1	34.5	34.2	29.2	28.2	30.2	31.4	34.2	27.3
Sky Condition		Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Raw water temperature		**20-25 oC**		**from 9 am to 17 pm**						

Table: 3.9 Prototype Pool Solar hot water test data - January 2008

SN	Hour of day	January data								
		1 (oC)	2 (oC)	3 (oC)	15 (oC)	16 (oC)	17 (oC)	29 (oC)	30 (oC)	31 (oC)
1	9	17.4	16	17.5	19.2	19.7	19.7	18.1	18.4	18.7
2	10	24.5	21.5	22	22.5	24.2	24.1	20.7	21.8	23.1
3	11	27.3	25.6	25.1	25	27.6	26.5	25.4	26.8	27.4
4	12	31.5	28.8	30.3	26.2	32.4	29.1	27.7	31.3	30.1
5	13	33.7	32.2	32	29.3	35.1	34.4	27.8	32.7	33.1
6	14	35.3	32.6	33.3	34.3	37.1	35.1	26.6	36.5	33.8
7	15	37.1	32.2	34.5	36.6	38.8	35	23.1	36.7	33.9
8	16	31.8	30.9	33	35.6	38.6	34.5	23.7	33.2	31.6
9	17	29	28.7	30	33	36.1	29.8	28.1	31.2	31.1
Sky Condition		Clear	Cloudy	S C	Clear	Clear	S C	D C	Clear	Clear

Raw water temperature 18-26 oC from 9 am to 17 pm

S C – Scattered cloud , DC – Dance cloud

Table: 3.10 Prototype Pool Solar hot water test data - February 2008

SN	Hour of day	February data				
		1 (oC)	2 (oC)	14 (oC)	15 (oC)	16 (oC)
1	9	18.4	17.2	17.3	17.5	21.2
2	10	24.6	22.1	22.2	25.3	27.1
3	11	27.8	24.1	27	29.4	30.8
4	12	31.1	26.7	30.1	34.2	34.4
5	13	32.7	28.3	35.1	36.7	38.8
6	14	34	31.8	37.6	29.6	40.3
7	15	34.1	31.7	37.4	40.3	40.3
8	16	35	30.2	37.1	39.5	37.9
9	17	31.1	26.2	33.4	37	36.4
Sky Condition		Clear	S C	Clear	Clear	Clear

Raw water temperature 18-27 oC from 9 am to 17 pm

Table: 3.11 Prototype Pool Solar hot water test data - March 2008

SN	Hour of day	March data	
		2 (oC)	3 (oC)
1	9	23.9	24.7
2	10	30.5	31.5
3	11	36.1	35.2
4	12	40.6	38
5	13	41.4	40.2
6	14	42.1	42.4
7	15	42	42.2
8	16	40.1	39.9
9	17	36.5	38.6
Sky Condition		clear	clear
Raw water temperature	**24-33 oC**	**from 9 am- 17 pm**	

Table: 3.12 Prototype Pool Solar hot water test data - April 2008

SN	Hour of day	April data							
		2 (oC)	3 (oC)	15 (oC)	16 (oC)	17 (oC)	28 (oC)	29 (oC)	30 (oC)
1	9	28	29.3	32.8	29.7	30.1	36.4	31.3	33.3
2	10	30.9	31.2	35.4	35.3	35.4	39.5	38.4	37.4
3	11	36.9	32.2	38	40.4	42.2	42.8	41.6	40.1
4	12	38.6	33.1	41.2	43.5	43.3	45.6	43.2	38.9
5	13	40.1	35.8	42.4	45	44.7	46.4	43	41.6
6	14	41.2	34.9	42.8	45.8	46.3	46.9	44.5	42.3
7	15	34.7	36.4	42.5	45	46	46.5	43.7	42.2
8	16	34.3	38.1	40.7	42.7	43.6	45	42.3	41.4
9	17	30.2	35.8	38.5	40.1	41.4	43	41.1	40.1
Sky Condition		S C	S C	clear	clear	clear	clear	S C	cloudy
Raw water temperature	**28-36 oC**	**from 9 am-17 pm**							

SC- Scattered cloudy

Table: 3.13 Prototype Pool Solar hot water test data - May 2008

SN	Hour of day	May data				
		14 (oC)	15 (oC)	16 (oC)	29 (oC)	30 (oC)
1	9	32.6	33.3	32	30.5	32.2
2	10	36.6	35.8	36	38.6	37.8
3	11	40.4	37.5	39.3	41.1	40.6
4	12	42.1	41.1	41.1	42.4	41.1
5	13	42.7	43	43	44.1	42.9
6	14	44	43.7	43.6	44	41.7
7	15	43.7	42.7	43.1	42.7	42.6
8	16	42.6	41	41.1	42.5	41.2
9	17	40.2	39	38.3	41.7	39.5
Sky Condition		S C	S C	S C	S C	cloudy

Raw water temperature **29-37 oC** **from 9 am to 17 pm**
SC-Scattered cloud

4. Economics

Configuration of Pilot Production Complex

Configuration of the proposed pilot complex is shown in Figure 4.1. It will consist of the following .

1. Power plant (20 -30 kW) hybrid solar PV and wind turbine
2. A solar cottage – with ETHE cooling to work as office
3. One solar desalination plant - possibly water pyramid type of 1000 lpd fresh water from brine , water storage and salt ponds
4. Drip type hydroponics unit for trial production of vegetables
5. Condenser-on-ground type Dew-rain harvest system - 2000 m^2 surface
6. Instrumentation and data acquisition system

Solar Cottage: Solar cottage is a small unit of size 450 square feet . It will be office of scientists.

Desalination Unit: Desalination unit converts saline water into potable drinking unit. A Dutch engineer has installed a demonstration unit at Mandvi which is suitable for such areas. It is called Water Pyramid. The structure uses solar energy for evaporation and condensation process. The demonstration unit has a capacity to produce 1000 liters of potable drinking water from 4000litres of saline water. Rejected 3000 liters of brine is used for making salt.

Drip type hydrponics unit

This will be developed locally.

Earth Tube Heat Exchanger based cooling system:

Earth Tube Exchanger based cooling/heating system works on the principle that temperature at about 4-5 meter below earth's surface remains constant. Mass of the earth is enormous such that earth acts as a sink to absorb heat and also to release as per the need. The system can be designed for natural low cost air conditioning system to protect humans and the plants in the solar cottage and the Greenhouse.

Dew-rain harvest system:

Coastal areas are rich in dew. Studies conducted by Prof Girja Sharan show that on an average 0.3 liters per square meter dew can be collected in Kutch every night during the dew season. Dew

season in Gujarat extends to 8 months. During balance four months rain water can be harvested. Together, dew and rains can provide 140 liters of water per year per square meter.

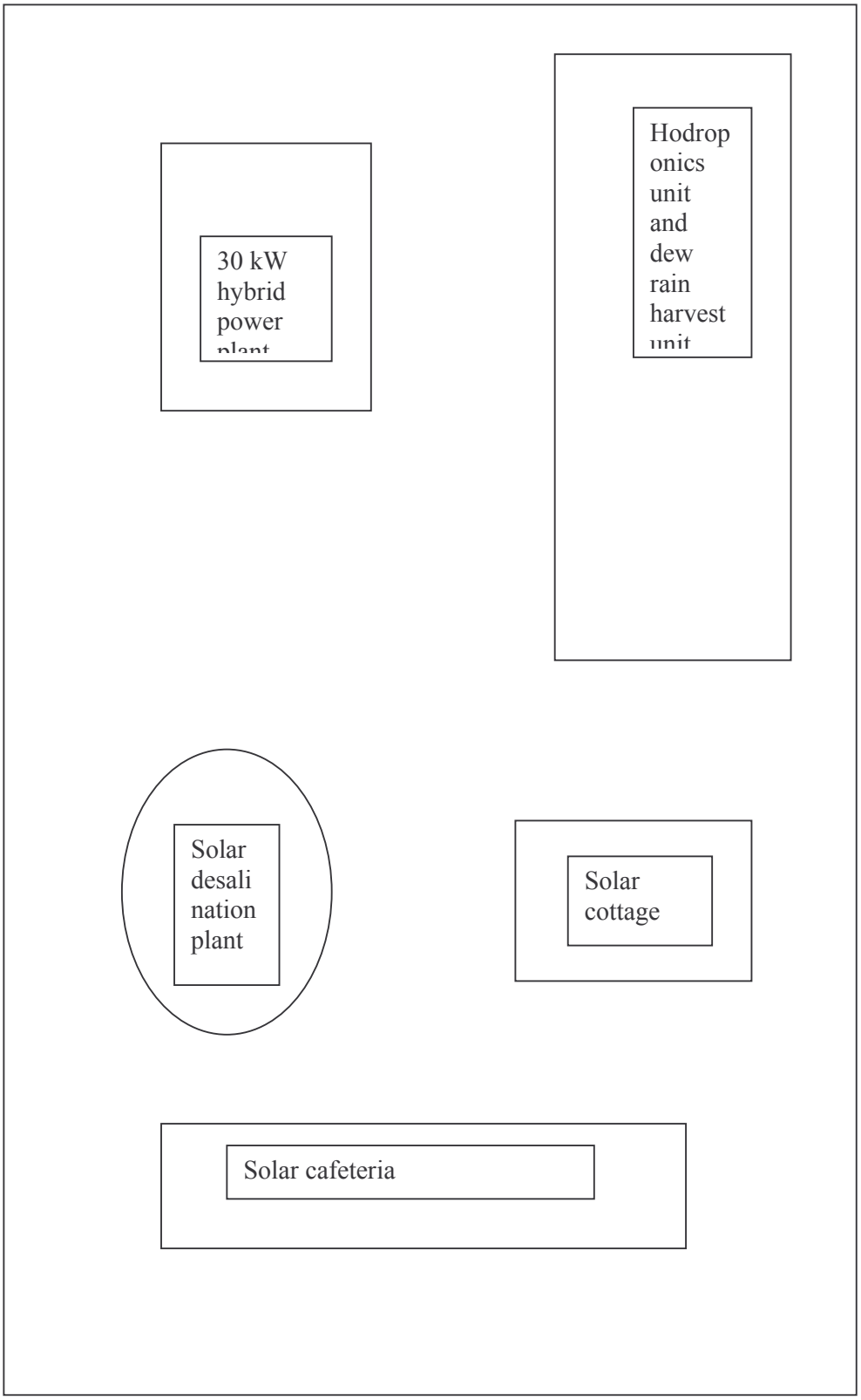
Pilot Cost:

The following figures are approximates based on discussions with industry and research institutions.

Hybrid power plant 30 kW	Rs 3,000,000 . 0
A solar cottage and café (450sq ft)	Rs. 500,000 . 0
Water pyramid	Rs 1,500,000 . 0
Drip type hydroponics unit 200 m^2	Rs 400,000 . 0
Dew-rain harvest system (2000 m^2)	Rs 500,000 . 0
Shading net , fencing , gate , and other facilities	Rs 500,000 . 0
Research staff salaries , running expenses and consumables	Rs 1,000,000 . 0
Total	**Rs. 7,400,000 . 0**

The pilot unit will be installed and results of the production and the value of the produce and other costs and returns will be presented in the next phase.

Figure -1 **Proposed Pilot production unit - Rann**



5. Summary and conclusions

1. Rann of Kutch is a large area which is presently not used for any economic activity. It is barren, with no water, high temperatures and virtually no cultivable lands. It is desirable that the Rann be considered for development using recent advances in onsite power generating systems (solar and wind) , solar desalination technology and hydroponics - the techniques of growing plants in soil-less media.

2. Among the challenges, the solar desalination is the most formidable. It is argued that preheating the ground water with modified pool type solar hot water systems and the recently developed technology - Low Temperature Thermal Desalination - be tried out.

3. Small scale prototype of pool type systems has yielded temperature gains in winters of 10-15 ^{0} C. Further improvement appears feasible by increasing the absorber area and absorber tube lengths.

This will be tried out in the second phase.

References

Chaibi, M. Thameur 2003. Greenhouse Systems with Integrated Water Desalination for Arid Areas Based on Solar Energy, Unpublished doctoral thesis, Swedish University of Agricultural Sciences, Alnarp.

Gomkale, S.D. 1988. Operational experience with solar stills in an Indian village and their contribution to the drinking water supply. Desalination 69: 177-182.

John A. Duffie & William A. Beckman 'Solar Engineering of Thermal Processes' (1991) A-Wiley inter science publication. John Wiley & sons, Inc New-York. Page no. 250-329

Sharan, G. and Jethva, K. 2007. "Cooling and Heating of Greenhouse in Arid Area by Earth Tube Heat Exchanger", Paper presented in GreenSys 2007 Symposium, October 4-7, Naples.

Sharan, G. and Sanjay Kumar. 1998. Feasibility of Integrating Solar Desalination with Playhouse in Kutch. *SESI Journal*, 8:1.

Wanwiwat, Lovichit, Kubota Cheiri, Choi C. Y. and Schoonderbeek J 2007. Greenhouse Water Recovery System for Crops Production in Semi-Arid Climate, ASABE Annual International Meeting, Minneapolis, 17-20 June.

APPENDICES

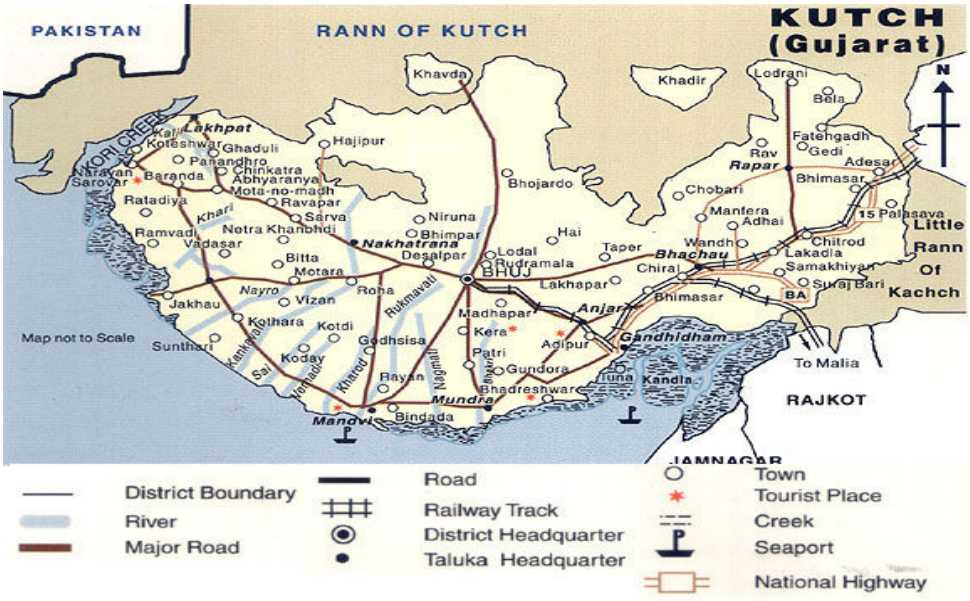


Figure A-1 Rann of Kutch

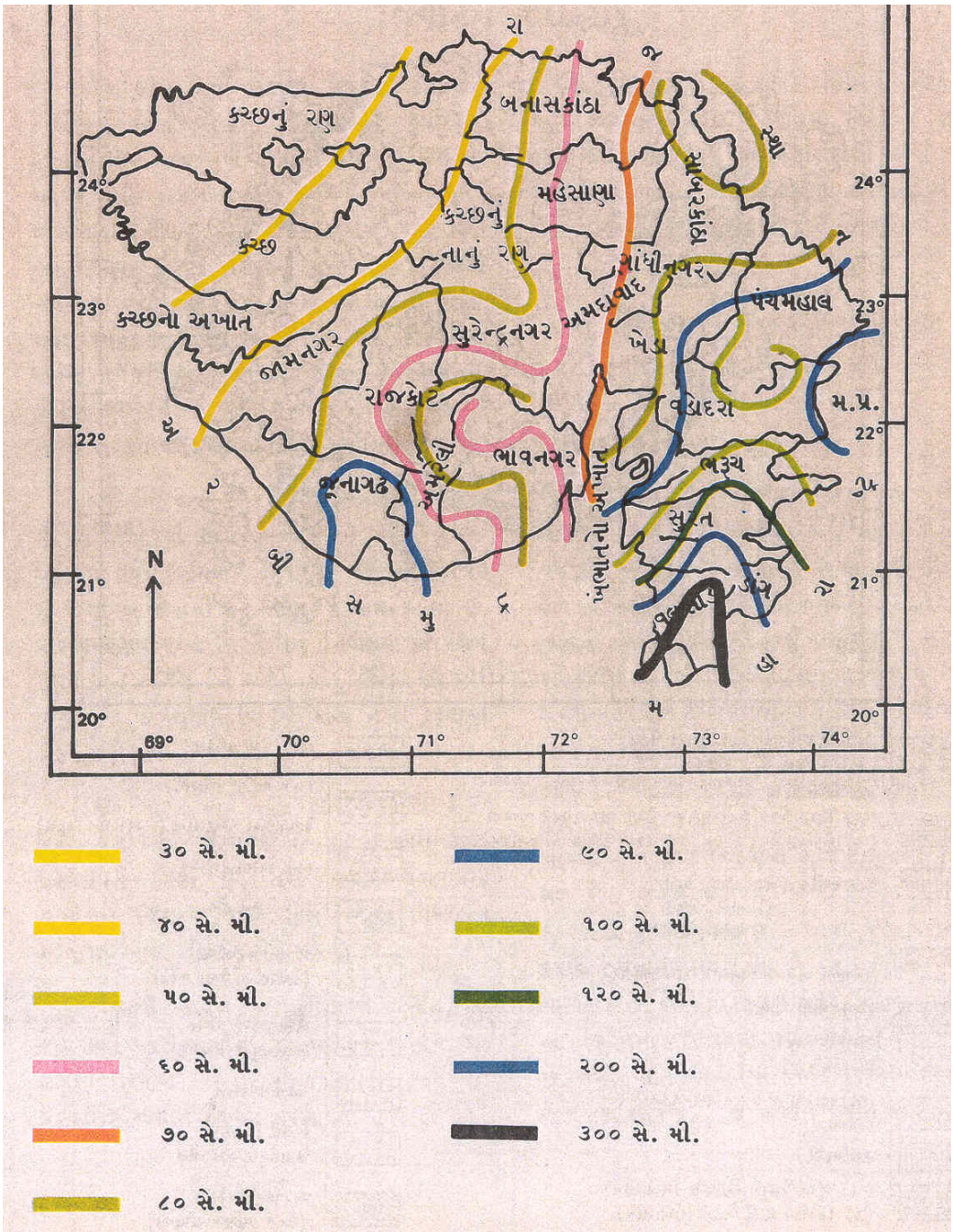


Fig. A-2 Annual Rainfall (Isohyets) of Gujarat

Table A-1: Ambient Temperature (Kothara-Kutch) - ° C

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	16.9	19.5	23.1	25.7	27.8	30.0	28.7	27.2	25.5	25.9	22.6	18.8
1	16.3	18.9	22.4	25.3	27.5	29.8	28.6	27.3	25.4	24.8	21.8	18.2
2	15.7	18.5	21.7	24.8	27.3	29.7	28.5	27.0	25.2	24.4	21.1	17.6
3	15.3	18.0	21.1	24.5	27.2	29.6	28.4	26.9	24.8	24.0	20.2	17.1
4	14.8	17.6	20.7	24.1	26.8	29.5	28.3	26.8	24.8	23.5	19.6	16.9
5	14.3	17.3	20.3	23.8	33.2	29.3	28.2	27.1	24.7	23.2	19.3	16.4
6	14.0	16.8	27.2	23.6	26.7	29.1	28.2	26.8	24.8	23.3	19.0	16.2
7	14.5	16.3	19.9	24.2	28.1	29.8	28.3	26.9	24.8	24.4	18.8	16.0
8	15.7	16.6	21.4	28.3	30.1	31.0	28.6	27.8	26.7	28.2	22.0	16.8
9	20.5	21.2	27.3	32.0	32.2	31.4	29.3	28.6	28.3	32.0	27.7	21.3
10	25.1	25.5	31.4	34.5	33.9	33.4	30.4	29.8	29.9	35.5	31.4	25.0
11	28.5	28.9	34.1	36.1	35.0	34.6	31.3	30.7	31.2	37.4	33.9	28.2
12	30.8	31.1	36.1	37.3	35.8	35.2	32.0	31.3	32.0	39.0	36.1	30.4
13	31.4	32.4	37.1	37.7	36.4	35.9	32.3	31.6	32.6	40.1	37.6	31.0
14	32.1	33.2	37.5	37.7	36.6	35.9	32.1	32.0	32.7	40.0	38.0	32.1
15	32.4	33.2	36.8	37.2	36.4	34.5	31.7	32.0	31.4	39.2	37.5	31.9
16	31.8	32.7	34.8	36.6	35.8	35.1	31.2	31.6	31.8	38.1	36.7	31.9
17	30.6	31.8	33.8	35.3	34.6	34.3	30.9	30.8	31.0	36.7	35.5	30.3
18	28.4	30.2	32.0	33.6	33.1	33.2	30.5	30.1	29.8	34.5	33.5	28.0
19	25.5	27.9	29.5	31.7	31.5	32.3	30.0	29.0	28.1	31.5	29.8	25.2
20	22.1	24.7	26.8	29.6	30.1	31.3	29.7	28.0	26.7	29.6	27.1	23.0
21	19.9	22.8	25.1	28.4	29.2	30.6	29.3	27.6	26.3	28.3	25.1	21.3
22	18.4	21.4	24.1	27.5	28.6	30.5	29.2	27.4	26.0	27.1	24.0	20.2
23	17.8	20.3	23.1	26.7	28.2	30.2	29.1	27.2	25.7	26.2	22.9	19.2

Table A-2: Wind Velocity (Kothara-Kutch) - m / s

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	3.2	3.0	4.2	2.7	4.8	7.6	3.3	6.4	6.2	2.3	2.9	3.1
1	3.0	3.2	3.6	2.6	4.7	6.8	3.7	6.5	5.3	2.9	2.4	2.9
2	3.0	3.4	4.0	2.5	5.0	8.9	3.4	6.2	3.5	3.5	2.3	2.9
3	3.0	3.9	3.7	2.6	5.3	6.5	3.8	6.0	4.3	2.9	2.4	3.3
4	3.1	3.1	3.8	2.9	4.9	6.8	3.8	6.0	3.9	2.3	2.3	3.7
5	3.1	2.9	2.1	3.4	4.8	6.4	3.1	6.5	3.9	4.5	2.6	3.2
6	2.9	3.0	2.3	3.5	4.5	6.3	2.9	5.8	4.0	2.9	2.4	3.1
7	3.1	4.1	1.8	3.4	5.2	6.3	3.7	5.6	4.3	3.0	2.3	3.2
8	3.7	2.8	2.3	4.6	6.3	7.0	3.3	6.6	5.5	5.3	3.1	3.4
9	4.0	4.7	5.4	5.2	7.4	7.8	4.0	7.2	5.8	4.2	3.8	4.1
10	5.2	5.0	5.4	5.9	7.9	8.0	4.0	7.2	6.6	4.1	4.5	4.7
11	5.7	6.0	6.0	6.1	8.1	8.4	4.2	7.8	6.6	4.5	5.2	5.3
12	6.1	6.3	6.2	6.3	8.4	9.0	4.3	8.0	7.0	5.2	5.3	6.0
13	6.3	6.7	6.6	6.3	8.9	9.3	4.7	8.3	7.5	5.8	5.3	5.7
14	6.3	6.8	7.3	7.1	9.1	9.7	5.1	8.5	7.5	6.4	5.5	5.7
15	6.7	7.1	7.5	6.6	9.1	9.7	5.3	8.3	7.0	6.6	5.6	5.9
16	6.4	7.0	7.2	6.8	9.2	9.3	5.3	8.2	7.2	6.1	5.8	6.0
17	6.2	7.1	7.5	6.3	8.6	9.1	5.0	8.2	6.6	6.1	5.2	5.7
18	5.3	6.6	6.9	6.0	8.2	8.6	4.5	7.7	6.5	5.3	4.6	5.4
19	4.3	6.0	5.9	5.9	7.6	8.1	4.1	7.4	5.8	4.2	3.8	3.9
20	3.4	4.4	4.9	5.3	6.9	7.5	3.8	7.0	5.3	3.5	2.7	3.0
21	3.0	3.5	4.0	4.9	6.2	7.0	3.6	6.6	4.8	2.7	2.7	3.0
22	3.1	2.8	3.4	3.9	5.7	7.0	3.6	6.5	4.5	2.6	2.7	3.0
23	2.8	3.3	2.7	3.4	5.4	7.1	3.4	6.2	4.7	2.5	3.1	2.8

Table A-3: Solar Radiation (Kothara-Kutch) - W / m^2

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	40.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	222.6	0.0	0.0	78.9	119.8	90.0	0.0	0.0	39.5	122.6	0.0	7.7
8	416.2	40.6	130.0	323.9	286.7	260.5	74.0	151.8	247.8	332.5	140.4	25.4
9	574.4	250.0	361.3	539.6	482.6	454.2	216.1	249.0	472.3	542.3	332.1	271.2
10	677.2	440.5	569.4	717.4	661.9	646.1	352.0	508.8	685.0	679.3	496.3	429.6
11	720.8	595.1	736.8	837.8	815.8	822.2	498.3	645.2	823.1	785.9	619.8	565.8
12	725.0	706.9	836.0	899.5	910.0	911.4	585.7	791.2	904.6	827.0	705.5	675.7
13	685.5	776.7	879.3	914.1	951.7	962.7	658.8	842.9	948.4	824.4	746.2	678.4
14	582.3	781.8	882.9	901.8	952.1	922.1	618.9	825.9	929.6	764.3	727.0	649.8
15	420.0	743.5	852.1	836.8	894.2	856.9	572.6	741.9	847.4	675.4	657.1	608.7
16	228.6	664.8	732.9	718.9	787.3	719.1	423.8	720.9	730.1	537.0	539.1	496.1
17	56.9	530.9	576.4	549.2	621.6	540.4	327.5	523.0	552.7	332.5	373.3	316.2
18	0.0	342.8	375.9	331.0	415.6	329.7	214.3	312.6	308.1	127.1	184.4	136.1
19	0.0	133.5	152.3	107.8	197.5	3.2	92.7	148.2	107.5	0.0	0.0	5.7
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A-4: Relative Humidity (Kothara-Kutch) - per cent

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	71.3	70.8	80.5	85.0	85.4	79.4	83.3	71.2	72.2	80.9	73.9	80.6
1	72.0	71.5	81.3	86.2	86.6	80.3	84.2	72.4	73.7	82.7	75.0	80.8
2	73.8	73.4	82.5	86.9	87.3	81.1	85.2	72.4	75.1	80.9	77.1	80.5
3	74.6	74.2	83.7	88.0	88.3	81.9	86.1	73.1	76.6	84.2	77.9	80.6
4	75.9	75.7	84.7	88.5	88.9	82.3	86.8	73.8	77.8	85.5	78.2	81.1
5	76.9	76.7	85.4	88.7	89.4	82.5	87.4	74.5	78.0	86.6	79.1	80.7
6	78.0	77.9	85.5	88.7	90.3	83.3	87.8	74.4	77.9	86.6	79.2	81.4
7	78.8	78.8	85.5	90.3	90.5	83.6	87.9	74.4	76.9	86.8	79.5	82.1
8	76.8	76.4	86.8	89.3	86.1	80.9	86.7	73.1	74.3	83.9	80.4	82.4
9	70.6	69.4	85.3	78.8	74.4	72.9	82.5	66.4	64.1	73.7	74.1	81.1
10	59.5	56.9	64.2	60.6	63.8	65.7	77.2	54.5	49.0	56.6	51.6	70.9
11	39.7	37.4	47.3	49.5	56.7	58.5	71.1	46.4	37.7	41.6	39.8	54.8
12	29.0	26.7	39.1	43.4	52.9	54.4	66.3	39.5	31.9	33.2	29.8	41.4
13	28.2	26.6	36.2	41.0	50.6	51.5	62.8	35.8	30.2	27.5	24.6	34.1
14	25.3	23.8	35.3	39.0	48.9	50.7	61.4	32.4	28.8	24.4	20.8	31.1
15	24.9	23.3	35.7	41.3	49.0	51.4	62.5	31.7	27.9	24.7	23.9	30.1
16	26.0	24.2	34.6	42.3	50.5	53.5	64.7	32.5	30.7	27.9	25.4	33.6
17	28.0	26.6	36.6	44.1	53.9	56.4	66.1	36.3	37.2	32.9	25.3	37.2
18	35.4	34.4	41.2	48.8	58.7	59.9	69.2	42.6	44.4	45.0	33.5	46.9
19	48.7	48.1	48.3	58.2	66.0	63.5	69.5	51.1	53.6	58.8	47.7	60.3
20	60.3	59.8	61.8	69.4	73.2	70.0	72.7	59.6	61.8	66.5	59.6	69.0
21	67.7	67.3	70.8	76.8	78.5	74.4	77.0	64.3	66.5	71.8	65.8	74.1
22	71.0	70.6	75.8	80.5	81.7	76.5	79.6	66.8	69.5	75.3	70.0	77.5
23	73.3	72.9	78.3	83.3	83.6	78.0	81.1	69.1	71.9	76.4	73.2	79.8

Table A-5: Wind Direction
November 04 Suthari - Kutch

Hour of day	5-Nov		10-Nov		27-Nov	
	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass
0	5	N	17	NNE	21	NNE
1:00	54	NE	27	NNE	71	ENE
2:00	42	NE	1	N	43	NE
3:00	5	N	355	N	5	N
4:00	352	N	353	N	27	NNE
5:00	22	NNE	9	N	40	NE
6:00	16	NNE	351	N	346	NNW
7:00	42	NE	355	N	354	N
8:00	10	N	28	NNE	35	NE
9:00	52	NE	7	N	26	NNE
10:00	113	ESE	2	N	75	ENE
11:00	60	ENE	338	NNW	68	ENE
12:00	41	NE	60	ENE	142	SSE
13:00	125	ESE	285	WNW	86	E
14:00	222	SW	251	WSW	199	SSW
15:00	213	SW	309	NW	168	SSE
16:00	206	SSW	315	NW	273	W
17:00	235	SW	323	NW	245	WSW
18:00	284	W	331	NNW	275	W
19:00	291	WNW	324	NW	236	SW
20:00	27	NNE	347	NNW	44	NE
21:00	22	NNE	353	N	62	ENE
22:00	347	N	8	N	5	N
23:00	20	NNE	0	N	39	NE

Table A-6: Wind Direction
December 04 Suthari - Kutch

Hour of day	3-Dec		17-Dec		31-Dec	
	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass	Bearing (Degree)	Direction Compass
0	28	NNE	24	NNE	14	NNE
100	27	NNE	32	NNE	358	N
200	1	N	23	NNE	353	N
300	355	N	1	N	354	N
400	353	N	4	N	343	NNW
500	9	N	5	N	307	NW
600	351	N	19	NNE	352	N
700	355	N	100	E	348	NNW
800	28	NNE	102	ESE	295	WNW
900	8	N	107	ESE	283	WNW
1000	2	N	64	ENE	293	WNW
1100	338	NNW	317	NW	134	SE
1200	285	WNW	51	NE	141	SSE
1300	285	WNW	202	SSW	296	WNW
1400	251	WSW	209	SSW	298	WNW
1500	309	NW	209	SSW	296	WNW
1600	315	NW	45	NE	310	NW
1700	323	NW	46	NE	300	WNW
1800	331	NNW	232	WSW	290	WNW
1900	324	NW	296	WNW	298	WNW
2000	347	NNW	14	NNE	315	NW
2100	353	N	10	N	325	NW
2200	8	N	1	N	326	NW
2300	0	N	15	NNE	341	NNW

Table A-7: Wind Direction
January 05 Suthari – Kutch

Hour of day	1-Jan		17-Jan		25-Jan	
	Azimuth Bearing (Degree)	Direction compass	Azimuth Bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass
0	16	NNE	14	NNE	2	N
100	25	NNE	81	E	18	NNE
200	2	N	21	NNE	101	E
300	340	NNW	83	E	28	NNE
400	335	NNW	61	ENE	38	NE
500	7	N	107	ESE	83	E
600	52	NE	12	NNE	113	ESE
700	65	ENE	31	NNE	357	N
800	130	SE	352	N	4	N
900	115	ESE	358	NNE	12	NNE
1000	21	NNE	210	SSW	87	E
1100	30	NNE	182	S	80	E
1200	185	S	143	SE	155	SSE
1300	225	SW	188	S	333	NNW
1400	54	NE	264	W	29	NNE
1500	33	NNE	294	WNW	14	NNE
1600	48	NE	332	NNW	116	ESE
1700	45	NE	276	W	33	NNE
1800	285	W	265	W	358	N
1900	290	WNW	312	NW	349	N
2000	355	N	314	NW	158	SSE
2100	12	NNE	291	WNW	358	N
2200	18	NNE	358	N	351	N
2300	7	N	13	NNE	150	SE

Table A-8: Wind Direction
February 05 Suthari – Kutch

Hour of day	3-Feb		16-Feb		27-Feb	
	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass
0	6	N	270	W	24	NNE
100	357	N	285	WNW	7	N
200	345	NNW	265	WSW	39	NNE
300	357	N	305	NW	1	N
400	10	N	50	NE	14	NNE
500	39	NNE	305	NW	42	NE
600	3	N	315	NW	350	N
700	342	NNW	322	NW	20	NNE
800	48	NE	321	NW	11	N
900	128	SE	329	NNW	22	NNE
1000	348	N	334	NNW	25	NNE
1100	39	NE	318	NW	60	ENE
1200	215	SW	337	NNW	56	NE
1300	229	SW	310	NW	226	SW
1400	204	SSW	356	N	272	W
1500	259	W	287	WNW	285	WNW
1600	250	WSW	211	SSW	264	WSW
1700	201	SSW	333	NW	230	WSW
1800	269	W	305	WNW	209	SSW
1900	291	WNW	320	NW	305	NW
2000	267	W	305	NW	342	NNW
2100	6	N	275	W	17	NNE
2200	179	S	260	WSW	3	N
2300	160	SSE	290	WNW	328	NNW

Table A-9: Wind Direction
March 05 Suthari- Kutch

Hour of day	2-Mar		8-Mar		15-Mar	
	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass	Azimuth Bearing (Degree)	Direction compass
0	354	NNW	225	SW	350	N
100	245	WSW	248	WSW	352	N
200	5	N	325	NNW	6	N
300	75	ENE	9	NNW	355	N
400	199	SSW	341	NNW	350	N
500	213	SSW	327	NNW	361	N
600	212	SSW	53	NE	10	N
700	227	SW	6	N	34	NE
800	232	WSW	314	NW	59	ENE
900	262	W	316	NW	42	NE
1000	197	SSW	314	NW	323	NW
1100	235	SW	330	NNW	259	W
1200	215	SW	345	NNW	244	WSW
1300	238	WSW	245	WSW	278	W
1400	255	WSW	267	W	280	W
1500	289	WNW	277	W	307	NW
1600	260	W	270	W	259	W
1700	233	SW	227	SW	274	W
1800	255	WSW	256	WSW	333	NNW
1900	218	SW	283	WNW	335	NNW
2000	235	SW	300	WNW	345	NNW
2100	254	WSW	289	WNW	347	NNW
2200	131	SE	316	NW	358	N
2300	231	SW	335	NNW	11	N

Table A-10: Wind Direction
April 05 Suthari- Kutch

Hour of day	01-Apr		07-Apr		15-Apr	
	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass
0	348	NNW	241	WSW	344	NNW
100	358	N	245	WSW	359	N
200	358	N	229	SW	356	N
300	357	N	257	WSW	357	N
400	357	N	268	W	33	NNE
500	81	E	297	WNW	6	N
600	342	NNW	239	WSW	332	NNW
700	357	N	269	W	345	NNW
800	335	NNW	252	WSW	22	N
900	357	N	284	WNW	312	NW
1000	15	NNE	250	WSW	344	NNW
1100	91	E	275	W	358	N
1200	75	ENE	263	W	343	NNW
1300	284	WNW	280	W	266	W
1400	300	WNW	241	WSW	289	WNW
1500	284	WNW	306	NW	318	NW
1600	329	NNW	297	WNW	251	WSW
1700	297	WNW	331	NNW	282	WNW
1800	255	WSW	270	W	275	W
1900	319	NW	330	NNW	294	WNW
2000	351	N	319	NW	255	WSW
2100	358	N	285	WNW	290	WNW
2200	1	N	332	NNW	253	WSW
2300	349	N	331	NNW	301	WNW

Table A-11: Wind Direction

May 05 Suthari - Kutch

Hour of day	13-May		20-May		27-May	
	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass	Azimuth bearing (Degree)	Direction compass
0	279	W	223	SW	246	WSW
100	251	WSW	262	W	310	NW
200	287	WSW	324	NW	292	WNW
300	261	W	262	W	259	WSW
400	304	WSW	291	WNW	324	NNW
500	327	NW	305	WNW	271	W
600	318	NW	273	W	225	SW
700	256	WSW	282	WNW	245	WSW
800	292	WNW	261	W	240	WSW
900	273	W	251	WSW	289	W
1000	252	WSW	278	W	297	WNW
1100	263	W	291	WNW	179	S
1200	282	WNW	245	WSW	232	WSW
1300	282	WNW	260	W	322	NNW
1400	242	WSW	276	W	311	NW
1500	236	SW	265	W	331	NNW
1600	230	SW	300	WNW	307	WNW
1700	232	SW	272	W	225	SW
1800	263	W	286	WNW	264	W
1900	320	NW	264	W	328	NW
2000	275	W	262	W	294	WNW
2100	305	WNW	268	W	276	W
2200	274	W	254	WSW	232	SW
2300	285	WNW	281	WNW	330	NNW

Table A-12: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (January-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	Calm(0)

Table A-13: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (February-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
29	0	0	0	0	0	0	0	Calm(0)

Table A-14: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (March-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	2	2	2	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	W(270)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	Calm(0)

Table A-15: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (April-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	W (270)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	SW(230)

Table A-16: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (April-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	NA	NA	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA	NA	NA
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	W(270)
30	0	0	0	0	0	0	0	Calm(0)

Table A-17: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (May-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm (0)
7	0	0	0	0	0	0	0	W(270)
15	4	3	0	0	0	0	3	W(270)
23	5	1	0	0	0	0	1	S(180)
30	0	0	0	0	0	0	0	W(270)

Table A-18: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (May-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	5	2	0	0	0	0	2	SW(230)
23	0	0	0	0	0	0	0	SW(230)
30	0	0	0	0	0	0	0	W(270)

Table A-19: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (June-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	5	5	0	0	0	0	5	W(270)
7	5	3	0	0	0	0	3	W(270)
15	5	3	7	4	0	0	7	Calm(0)
23	5	3	0	0	0	0	3	SW(230)
30	4	2	0	0	0	0	2	WSW(250)

Table A-20: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (June-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	5	4	0	0	0	0	4	W(270)
7	5	2	0	0	0	0	2	W(270)
15	5	2	7	4	0	0	6	Calm(0)
23	5	3	0	0	0	0	3	SW(230)
30	4	2	0	0	0	0	2	WSW(250)

Table A-21: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (July-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	4	4	0	0	0	0	4	W(270)
7	4	4	3	2	0	0	7	W(270)
15	5	2	0	0	0	0	2	Calm(0)
23	5	2	0	0	0	0	2	W(270)
30	5	4	0	0	0	0	4	SSW(200)

Table A-22: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (July-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	2	0	0	0	0	2	Calm(0)
7	4	3	0	0	0	0	3	W(270)
15	5	1	0	0	0	0	1	WSW(250)
23	0	0	0	0	0	0	0	W(270)
30	5	5	3	1	0	0	6	W(270)

Table A-23: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (August-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	4	4	7	3	0	0	7	W(270)
7	5	4	2	4	1	1	8	Calm(0)
15	0	0	0	0	0	0	0	W(270)
23	5	3	3	1	0	0	4	W(270)
30	5	4	0	0	0	0	4	Calm(0)

Table A-24: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (August-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	4	3	7	4	0	0	7	W(270)
7	5	4	2	4	1	1	8	W(270)
15	0	0	0	0	0	0	0	W(270)
23	5	3	3	1	0	0	4	W(270)
30	5	5	0	0	0	0	5	W(270)

Table A-25: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (September-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	W(270)
15	5	4	2	8	1	1	8	Calm(0)
23	0	0	0	0	0	0	0	NW(320)
30	0	0	3	4	0	0	4	Calm(0)

Table A-26: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (September-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	5	2	0	0	0	0	2	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	5	2	2	8	1	1	8	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	5	2	4	4	0	0	6	Calm(0)

Table A-27: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (October-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	N(360)

Table A-28: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (October-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	5	6	0	0	0	0	6	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	Calm(0)

Table A-29: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (November-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	N(360)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	Calm(0)

Table A-30: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (November-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	Calm(0)

Table A-31: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (December-04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	NE(50)
30	0	0	0	0	1	1	1	Calm(0)

Table A-32: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (December -04)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	N(360)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	NE(50)
30	0	0	0	0	0	0	0	Calm(0)

Table A-33: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (January -05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	NE (05)
15	0	0	x	9	0	0	4	Calm(0)
23	0	0	0	9	0	0	2	Calm(0)
30	0	0	0	0	0	0	0	N (360)

Table A-34: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (January -05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	NW (320)
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	x	9	0	0	4	Calm(0)
23	0	0	0	9	0	0	4	Calm(0)
30	0	0	0	0	0	0	0	N (360)

Table A-35: Cloud cover and Wind direction data at 8:30 p.m. at Naliya (February-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0))
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	NW (320)
23	0	0	0	0	0	0	0	Calm(0)
28	0	0	0	0	0	0	0	W (270)

Table A-36: Cloud cover and Wind direction data at 11:30 p.m. at Naliya (February-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0))
7	0	0	0	0	0	0	0	Calm(0)
15	0	0	0	0	0	0	0	W (270)
23	0	0	0	0	0	0	0	Calm(0)
28	0	0	0	0	0	0	0	Calm(0)

Table A-37: Cloud cover and wind direction data at 8:30 p.m. at NALIYA (March -05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	Ac-3	0	x	9	0	0	4	Calm(0)
7	0	0	0	0	0	0	0	W (270)
15	0	0	0	0	0	0	0	W (270)
23	0	0	0	0	0	0	0	W (270)
30	0	0	0	0	0	0	0	NE (020)

Table A-38: Cloud cover and wind direction data at 11:30 p.m. at NALIYA (March -05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	NW (320)
15	0	0	0	0	0	0	0	Calm(0)
23	0	0	0	0	0	0	0	Calm(0)
30	0	0	0	0	0	0	0	Calm(0)

Table A-39: Cloud cover and Wind direction data at 8:30 p.m. at Naliya (April-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	W (270)
7	0	0	0	0	0	0	0	W (270)
15	0	0	0	0	0	0	0	Calm(0)
23	Ac-3	0	NA	NA	0	0	1	W (270)
30	0	0	0	0	0	0	0	W (270)

Table A 40: Cloud cover and Wind direction data at 11:30 p.m. at Naliya (April-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	W (270)
15	0	0	0	0	0	0	0	Calm(0)
23	Ac-3	0	NA	NA	0	0	2	W (270)
30	0	0	0	0	0	0	0	W (270)

Table A-41: Cloud cover and Wind direction data at 8:30 p.m. at Naliya (May-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	W (270)
7	NA	NA	0	0	0	0	3	W (270)
15	0	0	0	0	0	0	0	W (270)
23	Sc-5	NA	0	0	0	0	5	W (270)
30	0	0	0	0	0	0	0	W (270)

Table A-42: Cloud cover and Wind direction data at 11:30 p.m. at Naliya (May-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	Calm(0)
7	0	0	0	0	0	0	0	W (270)
15	0	0	0	0	0	0	0	W (270)
23	Sc-5	NA	0	0	0	0	4	W (270)
30	0	0	0	0	0	0	0	SW (230)

Table A-43: Cloud cover and Wind direction data at 8:30 p.m. at Naliya (June-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	W (270)
7	NA	NA	0	0	0	0	3	WSW (250)
15	0	0	0	0	0	0	0	W (270)
23	NA	NA	0	0	0	0	3	SW (230)
30	As-2	0	NA	NA	1	1	8	WSW (250)

Table A-44: Cloud cover and Wind direction data at 11:30 p.m. at Naliya (June-05)

Date	Cloud cover data							Wind direction
	Low		Medium		High		Total	
	Form	Amount (Okta)	Form	Amount (Okta)	Form	Amount (Okta)		
1	0	0	0	0	0	0	0	W (270)
7	NA	NA	0	0	0	0	2	WSW (250)
15	Sc-4	0	0	0	0	0	3	W (270)
23	NA	NA	0	0	0	0	6	SW (230)
30	As-2	0	NA	NA	1	1	8	WSW (250)

Table A-45 Ambiant Conditions - Radhanpur
January - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	17.3	13.1	26.0	17.2	23.5	10.1	0.0
2	17.3	12.6	23.4	15.0	23.7	10.2	0.0
3	15.2	11.1	23.9	14.0	21.4	8.4	0.0
4	14.7	10.2	23.4	13.7	20.0	8.9	0.0
5	13.7	10.0	24.0	13.9	19.3	8.7	0.0
6	14.6	10.2	24.1	14.6	19.5	9.0	0.0
7	15.2	10.8	24.4	14.7	20.0	10.0	0.0
8	15.0	10.9	24.4	14.7	20.6	11.2	0.0
9	15.2	11.1	24.8	15.2	20.8	12.1	0.0
10	16.0	12.1	25.0	15.2	21.3	12.7	0.0
11	16.4	12.3	25.4	15.4	21.0	12.5	0.0
12	16.2	12.1	25.9	15.9	21.0	12.1	0.0
13	16.9	12.7	26.5	17.0	22.0	11.5	0.0
14	17.1	12.9	26.4	17.0	22.5	11.5	0.0
15	18.0	13.9	26.3	17.2	23.0	12.6	0.0
16	18.0	14.3	26.4	17.3	23.0	12.9	0.0
17	17.6	14.5	25.7	14.8	23.3	13.9	0.0
18	17.3	13.2	25.3	16.1	22.3	14.0	0.0
19	17.6	12.5	25.1	15.9	22.5	11.8	0.0
20	17.7	12.5	24.9	15.8	21.5	11.8	0.0
21	17.8	13.1	24.4	15.9	21.5	11.5	0.0
22	19.2	13.6	25.5	16.3	21.5	11.2	0.0
23	19.5	13.8	26.3	16.5	21.8	11.5	0.0
24	19.5	13.1	26.2	16.9	22.3	12.3	0.0
25	18.7	13.2	25.9	16.7	22.5	13.0	0.0
26	19.0	13.1	26.7	16.7	22.5	13.3	0.0
27	18.9	13.6	26.8	17.1	23.3	13.3	0.0
28	18.4	12.0	26.7	17.4	23.8	12.0	0.0
29	18.5	12.4	27.1	17.5	23.8	11.5	0.0
30	18.9	12.8	28.4	18.1	24.0	11.8	0.0
31	18.7	13.1	28.4	18.1	24.0	11.7	0.0

Table A-46 Ambient Conditions - Radhanpur
February - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	19.4	12.6	28.6	19.1	24.0	11.8	0.0
2	19.5	12.8	29.1	18.9	24.0	12.5	0.0
3	19.7	13.0	28.9	18.7	24.4	13.1	0.0
4	20.2	13.6	29.3	19.0	24.8	14.3	0.0
5	20.8	13.7	29.1	19.5	25.3	15.2	0.0
6	21.1	16.4	29.5	19.7	25.5	15.2	0.0
7	21.8	17.9	29.4	19.3	25.5	15.0	0.0
8	22.3	17.9	29.4	19.9	25.5	15.3	0.0
9	22.7	18.2	29.6	20.6	25.5	15.8	0.0
10	22.9	18.4	29.8	20.9	25.9	16.5	0.0
11	21.5	16.9	29.9	21.2	25.8	16.0	0.0
12	22.1	17.3	30.0	21.3	25.5	16.5	0.0
13	23.1	17.9	30.1	21.4	25.8	16.8	0.0
14	23.6	19.0	30.0	21.2	26.0	17.4	0.0
15	23.8	18.8	30.4	22.5	26.3	17.4	0.0
16	23.3	18.0	29.9	22.3	26.0	17.3	0.0
17	24.0	17.1	29.9	21.1	26.5	16.3	0.0
18	18.8	16.6	28.0	19.1	26.2	14.5	0.0
19	22.0	17.2	28.4	19.4	24.5	15.5	0.0
20	21.9	17.0	27.9	18.5	24.8	13.7	0.0
21	21.2	14.8	28.4	18.2	24.3	14.3	0.0
22	20.8	15.0	27.9	18.2	25.4	15.3	0.0
23	21.8	15.2	28.4	18.1	24.5	15.8	0.0
24	22.1	15.5	29.0	19.1	25.0	16.8	0.0
25	22.8	16.1	29.6	19.2	24.9	17.3	0.0
26	23.5	16.6	29.1	20.1	25.8	17.8	0.0
27	24.1	17.2	29.2	20.2	25.8	18.5	0.0
28	24.5	17.6	29.3	20.7	26.5	19.3	0.0

Table A-47 Ambient Conditions - Radhanpur
March - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	24.4	18.3	29.1	20.9	27.4	19.5	0.0
2	23.3	19.2	29.8	20.9	25.5	19.5	0.0
3	23.9	19.0	29.5	20.8	25.8	19.9	0.0
4	23.5	18.9	29.2	20.8	25.9	19.4	0.0
5	24.0	18.5	29.2	20.9	26.0	19.5	0.0
6	24.4	19.3	29.6	21.3	26.3	18.8	0.0
7	24.0	19.2	28.1	23.0	26.3	17.0	0.0
8	25.0	19.3	27.5	22.9	26.0	16.9	0.0
9	24.4	19.7	27.1	22.0	24.0	17.0	0.0
10	24.3	19.4	27.5	22.0	25.8	17.0	0.0
11	25.0	19.9	27.7	22.2	26.5	18.0	0.0
12	25.4	20.3	28.7	22.8	27.8	18.8	0.0
13	25.7	20.8	28.8	22.8	28.3	19.0	0.0
14	26.4	20.8	28.6	23.0	27.8	19.5	0.0
15	26.1	20.2	31.3	20.1	27.8	19.8	0.0
16	26.3	20.7	31.4	20.0	28.5	19.5	0.0
17	26.4	20.6	32.3	20.9	28.5	20.3	0.0
18	27.0	21.1	32.5	21.1	29.0	20.8	0.0
19	27.5	21.2	32.3	20.8	29.3	20.5	0.0
20	27.3	20.7	33.0	21.8	29.3	20.5	0.0
21	27.3	20.2	32.5	21.8	29.3	20.5	0.0
22	27.3	19.8	32.3	21.4	29.0	20.5	0.0
23	26.3	19.3	32.5	21.6	29.0	20.5	0.0
24	26.5	19.1	32.9	21.6	29.1	21.0	0.0
25	26.9	19.8	32.9	21.7	29.3	20.8	0.0
26	27.9	20.6	32.6	21.8	29.3	20.8	0.0
27	27.8	20.4	32.8	21.8	29.5	20.8	0.0
28	28.1	20.9	33.5	21.3	29.5	21.0	0.0
29	28.6	19.5	33.4	21.0	30.8	20.8	0.0
30	29.0	19.9	33.6	20.3	31.3	20.3	0.0
31	28.6	19.3	33.5	20.3	31.5	20.5	0.0

Table A-48 Ambient Conditions - Radhanpur
April - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	0C	0C	0C	0C	0C	0C	mm
1	28.2	18.5	33.7	20.5	30.5	19.8	0.0
2	28.5	18.7	33.4	20.9	36.0	20.0	0.0
3	28.5	18.6	33.7	20.9	35.5	20.4	0.0
4	28.6	18.6	33.5	21.2	35.3	20.5	0.0
5	28.7	19.5	34.0	21.9	35.5	20.6	0.0
6	29.0	19.9	33.9	22.0	36.0	21.1	0.0
7	29.0	19.7	33.3	21.4	35.8	21.0	0.0
8	27.4	19.9	33.0	21.5	35.4	19.0	0.0
9	27.7	20.4	32.7	20.7	34.4	18.7	0.0
10	27.8	20.7	32.5	21.2	34.4	18.5	0.0
11	27.8	20.8	32.6	21.4	34.5	18.8	0.0
12	28.1	20.8	32.8	21.1	34.8	19.8	0.0
13	28.8	21.4	33.0	21.3	35.5	20.5	0.0
14	28.8	21.5	32.1	21.5	35.6	20.3	0.0
15	28.7	21.6	32.4	21.7	35.5	20.3	0.0
16	28.8	21.7	31.6	20.2	36.3	20.5	0.0
17	28.8	21.7	31.5	19.8	35.8	20.5	0.0
18	29.0	22.1	32.0	20.7	36.3	20.8	0.0
19	29.1	22.0	32.7	21.0	36.2	20.4	0.0
20	29.7	22.2	33.1	21.9	31.5	20.8	0.0
21	29.7	22.1	33.9	22.1	31.8	20.8	0.0
22	30.0	22.9	34.0	22.3	32.3	21.8	0.0
23	30.4	23.0	34.0	22.4	32.0	22.5	0.0
24	30.9	23.3	34.5	22.7	32.0	22.5	0.0
25	30.5	22.0	34.9	23.5	31.8	22.3	0.0
26	30.7	22.0	34.9	23.2	31.0	22.5	0.0
27	30.7	22.0	34.9	23.5	31.5	22.8	0.0
28	30.0	21.8	35.0	23.8	31.8	22.8	0.0
29	30.4	21.6	35.3	24.0	32.5	22.3	0.0
30	30.9	21.8	35.0	23.9	32.8	23.0	0.0

Table A-49 Ambient Conditions - Radhanpur
May - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	30.8	22.2	35.3	24.2	34.8	23.3	0.0
2	30.7	21.9	35.3	24.3	33.0	23.8	0.0
3	30.1	22.0	35.4	24.0	32.9	23.3	0.0
4	30.1	22.9	35.4	23.8	32.9	22.8	0.0
5	30.3	22.8	35.2	23.6	32.5	22.8	0.0
6	30.2	22.6	35.3	23.7	32.5	22.6	0.0
7	30.8	22.3	35.3	23.9	33.0	23.2	0.0
8	31.0	22.7	35.4	24.0	33.0	23.3	0.0
9	30.9	22.6	35.7	24.2	32.8	23.5	0.0
10	31.1	23.0	36.0	24.4	32.9	23.6	0.0
11	31.3	23.1	36.0	23.7	32.9	23.7	0.0
12	31.5	23.2	36.1	23.2	33.0	23.8	0.0
13	31.7	23.0	36.1	23.1	33.0	23.7	0.0
14	31.1	23.4	36.3	23.3	33.5	24.0	0.0
15	31.3	23.5	35.6	23.4	34.0	24.5	0.0
16	31.4	23.4	35.6	25.3	34.5	24.5	0.0
17	31.3	23.5	35.9	23.4	34.8	24.8	0.0
18	31.0	23.4	35.8	23.3	34.5	24.0	0.0
19	31.0	23.3	35.8	23.3	34.0	23.5	0.0
20	30.3	24.7	35.0	26.9	32.5	23.0	0.0
21	30.6	25.1	35.1	26.4	32.5	23.0	0.0
22	30.6	25.1	35.3	26.5	32.5	23.0	0.0
23	30.7	25.0	36.5	25.4	33.0	23.5	0.0
24	31.2	25.2	36.8	25.4	33.0	23.5	0.0
25	31.7	25.5	37.0	26.0	33.8	27.5	0.0
26	32.0	25.4	37.0	26.2	33.5	23.0	0.0
27	30.3	24.9	32.5	26.9	34.0	24.3	0.0
28	29.2	26.4	33.0	26.6	30.5	23.9	15.0
29	28.9	26.9	32.8	25.1	30.5	24.4	11.5
30	29.0	25.2	32.9	26.0	30.5	24.3	0.0
31	31.5	26.7	35.0	26.0	32.5	22.3	0.0

Table A-50 Ambient Conditions - Radhanpur
June - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	31.7	27.7	30.2	26.0	33.0	22.8	0.0
2	33.5	25.4	32.7	26.5	32.8	22.6	11.0
3	31.5	27.2	32.9	26.1	33.0	23.3	0.5
4	30.9	26.5	32.8	27.5	33.0	24.0	0.0
5	30.5	26.9	32.3	26.7	32.8	24.3	0.0
6	30.7	26.6	32.4	26.5	32.3	23.5	0.0
7	30.8	27.0	32.5	26.3	32.4	23.8	0.0
8	31.6	27.7	32.6	26.3	33.0	23.8	0.0
9	31.3	27.4	32.3	26.4	32.8	23.9	0.0
10	31.4	27.2	32.3	26.5	32.5	23.8	0.0
11	30.8	27.3	31.8	26.3	32.3	23.8	0.0
12	30.6	27.8	31.1	27.0	32.0	23.8	0.0
13	30.7	27.5	32.6	27.5	31.8	23.2	3.0
14	30.3	27.2	33.2	27.0	31.5	22.8	0.0
15	29.3	26.0	32.9	26.8	31.8	23.0	0.0
16	29.7	26.0	33.3	26.5	32.3	23.0	0.0
17	29.8	26.2	33.4	26.8	32.3	23.3	0.0
18	29.8	26.2	33.4	27.0	32.3	23.7	0.0
19	30.4	26.7	33.4	27.2	32.3	23.3	0.0
20	30.5	27.1	34.3	26.9	32.4	24.3	0.0
21	30.9	27.0	34.7	27.3	32.3	24.3	0.0
22	30.8	27.3	34.5	27.1	32.4	24.3	0.0
23	31.4	26.9	33.7	27.0	33.0	25.3	0.0
24	31.9	26.3	32.0	27.4	33.5	25.3	1.0
25	30.3	26.3	31.3	28.5	33.0	24.3	0.0
26	29.8	26.0	31.0	28.4	32.3	23.5	5.0
27	29.1	25.1	27.6	27.6	30.5	22.2	2.0
28	29.4	26.9	27.9	26.4	30.3	21.8	19.5
29	29.9	26.8	28.6	26.8	31.5	22.1	15.5
30	28.8	27.4	29.4	26.6	30.8	22.0	2.0

Table A-51 Ambient Conditions - Radhanpur
July - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	29.1	27.3	30.1	26.7	30.3	22.0	5.0
2	28.8	27.7	28.2	27.6	31.8	21.9	3.5
3	29.0	27.9	29.4	28.3	31.3	21.5	0.8
4	29.2	28.0	31.2	29.4	30.5	21.5	0.0
5	29.3	28.3	30.2	28.5	29.5	21.5	5.8
6	27.7	25.8	29.4	27.2	28.9	20.0	40.0
7	27.3	25.2	29.7	27.0	28.5	20.7	0.0
8	27.1	25.0	30.0	26.1	28.8	20.5	0.0
9	27.7	25.3	29.9	25.5	29.3	21.0	0.0
10	28.2	25.0	30.3	25.3	29.8	21.3	0.0
11	28.5	25.6	30.5	25.0	30.2	21.8	0.0
12	29.0	25.7	30.5	25.0	30.0	22.1	0.0
13	29.4	25.6	30.0	25.0	30.3	22.1	0.0
14	29.2	25.8	30.0	25.0	30.3	22.4	0.0
15	28.9	25.7	29.3	27.2	30.0	22.7	0.0
16	28.4	25.2	29.7	27.1	30.0	23.0	3.0
17	29.0	25.4	29.7	26.7	29.8	21.8	1.0
18	28.7	25.2	30.3	25.6	29.9	22.0	3.0
19	30.7	25.9	33.3	26.2	31.9	22.8	0.0
20	29.7	25.8	33.3	26.0	31.0	23.0	0.0
21	29.7	26.1	31.6	27.6	30.9	23.7	0.0
22	29.2	25.9	31.2	27.2	30.3	22.9	4.0
23	29.2	27.7	30.6	26.9	31.0	23.2	14.0
24	28.6	27.1	30.7	26.5	29.8	22.4	21.5
25	29.0	27.2	30.9	26.3	30.7	22.5	0.0
26	29.0	27.3	31.5	26.0	30.4	22.5	0.0
27	28.9	26.9	29.5	29.0	30.0	22.4	0.0
28	28.0	27.8	28.9	28.9	28.8	21.5	7.0
29	25.7	26.6	27.4	26.9	26.7	19.5	56.0
30	26.0	25.2	27.1	26.7	27.2	20.0	0.0
31	25.4	25.1	26.7	26.7	26.3	19.8	2.0

Table A-52 Ambient Conditions - Radhanpur
August - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	24.2	24.2	26.5	26.5	25.5	19.5	15.0
2	24.4	24.1	26.7	26.7	25.5	19.5	133.5
3	24.8	24.4	26.7	26.7	25.8	19.5	6.0
4	24.4	24.2	26.8	25.5	25.8	20.0	7.3
5	25.4	23.7	27.4	25.2	26.8	20.5	0.0
6	25.9	25.1	27.4	26.2	28.3	21.3	32.0
7	24.8	24.2	27.1	26.1	29.0	21.4	1.0
8	26.6	25.4	27.1	26.5	28.3	21.0	1.0
9	26.5	26.1	27.9	26.4	27.5	15.8	7.5
10	26.5	25.2	28.5	26.5	27.2	22.0	3.0
11	26.3	25.2	28.6	26.6	26.8	22.3	2.5
12	26.3	25.1	28.6	25.6	27.0	22.4	0.0
13	25.5	23.8	29.3	26.0	26.7	22.5	0.0
14	25.9	25.0	28.9	25.8	27.1	22.5	0.0
15	25.4	25.0	29.3	26.3	26.8	22.8	55.0
16	25.9	25.1	29.2	26.9	27.3	22.8	7.5
17	25.6	24.4	29.1	26.7	27.0	23.0	0.0
18	25.7	23.7	28.8	26.5	27.5	23.4	2.0
19	25.8	24.7	28.6	26.5	28.0	22.8	112.0
20	25.6	23.9	28.4	26.5	28.0	22.8	5.0
21	25.7	23.8	28.5	26.2	27.5	22.3	0.0
22	25.9	24.0	28.6	25.4	27.9	22.4	0.0
23	26.3	24.0	29.3	25.5	28.3	22.6	0.0
24	27.6	25.0	29.7	26.1	30.0	22.3	0.0
25	27.6	25.0	29.8	25.6	29.8	22.3	0.0
26	27.7	25.6	29.4	25.9	29.5	22.3	2.5
27	27.6	26.0	29.8	27.1	29.8	22.3	0.0
28	27.7	25.8	29.9	26.2	30.3	21.7	0.0
29	27.5	25.8	29.9	25.8	31.2	22.3	0.0
30	27.8	25.7	29.4	25.3	31.3	22.5	0.0
31	28.6	26.5	29.5	25.5	31.3	23.5	0.0

Table A-53 Ambient Conditions - Radhanpur
September - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	28.6	26.4	29.9	25.2	31.0	23.4	0.0
2	29.1	26.3	29.9	25.5	31.5	23.3	0.0
3	28.5	25.2	29.4	25.5	30.2	22.5	0.0
4	28.2	24.7	29.1	25.4	30.0	22.3	0.0
5	28.6	25.4	29.3	25.4	29.8	22.4	0.0
6	28.3	25.3	28.5	26.8	29.9	22.5	0.0
7	27.3	25.7	28.5	27.6	28.8	21.0	0.0
8	28.3	25.9	28.3	26.6	28.3	20.8	0.0
9	28.2	26.0	27.5	26.5	28.8	20.8	0.0
10	27.6	25.5	28.2	26.4	29.3	21.3	0.0
11	28.2	25.1	28.7	26.3	29.8	21.8	0.0
12	28.2	25.2	29.5	26.0	29.8	22.0	0.0
13	28.3	25.3	29.7	26.1	30.0	22.2	0.0
14	28.6	25.6	29.6	27.2	30.8	22.3	0.0
15	28.4	26.1	29.8	27.5	30.3	21.8	0.0
16	28.2	26.2	29.9	27.9	30.7	22.3	0.0
17	27.4	25.8	28.8	27.1	29.4	22.0	0.0
18	27.9	25.5	30.4	27.3	29.7	22.5	0.0
19	28.4	26.6	30.3	27.3	30.8	23.0	0.0
20	28.4	26.3	31.1	27.5	30.8	24.0	0.0
21	28.4	26.3	30.3	27.8	31.0	25.0	0.0
22	28.3	26.0	30.3	28.8	31.4	25.2	0.0
23	28.5	26.2	28.4	26.5	31.2	24.0	0.0
24	27.3	25.2	30.2	26.2	30.4	24.9	0.0
25	27.7	25.5	30.5	26.7	30.3	24.9	0.0
26	28.5	25.5	31.1	26.3	30.8	24.6	0.0
27	27.6	25.3	30.3	26.3	30.8	25.0	0.0
28	27.6	25.5	30.9	26.4	30.2	24.8	0.0
29	28.3	25.7	31.9	26.1	30.5	25.2	0.0
30	28.6	25.3	31.6	26.0	30.8	25.3	0.0

Table A-54 Ambient Conditions - Radhanpur
October - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	28.4	24.9	30.6	26.0	30.8	25.3	0.0
2	29.2	25.2	31.2	26.0	30.5	25.4	0.0
3	28.7	25.1	31.9	26.3	31.2	25.5	0.0
4	29.4	25.7	32.1	26.3	31.3	25.8	0.0
5	29.6	25.9	31.8	26.1	31.3	25.8	0.0
6	29.1	25.7	31.7	26.3	30.5	25.5	0.0
7	28.9	25.5	31.7	26.2	30.5	25.0	0.0
8	28.3	25.6	31.2	26.2	30.6	25.3	0.0
9	28.8	25.3	31.3	26.1	30.8	25.4	0.0
10	28.8	25.2	31.2	26.0	30.8	25.5	0.0
11	28.8	25.0	31.2	25.8	30.8	25.5	0.0
12	28.7	25.2	31.2	25.4	30.9	25.3	0.0
13	28.3	24.6	31.3	25.4	30.3	25.0	0.0
14	28.2	24.3	31.5	25.6	31.0	24.5	0.0
15	28.2	24.4	32.1	25.7	30.8	25.3	0.0
16	28.8	24.7	32.1	25.8	31.5	25.8	0.0
17	28.9	24.4	32.6	25.5	31.2	25.8	0.0
18	28.9	23.8	33.0	25.6	31.2	25.7	0.0
19	28.5	21.9	32.7	25.3	29.8	25.3	0.0
20	28.6	22.1	32.9	24.9	30.0	25.3	0.0
21	27.7	21.6	32.8	24.4	29.5	24.5	0.0
22	27.5	21.0	32.3	22.1	29.8	24.0	0.0
23	27.1	21.4	32.5	21.9	29.5	23.8	0.0
24	27.5	21.1	32.2	22.6	29.4	23.5	0.0
25	27.8	21.4	32.3	22.8	30.0	23.9	0.0
26	27.8	21.8	32.2	22.8	29.9	24.2	0.0
27	28.1	22.0	32.3	22.9	30.3	23.2	0.0
28	28.2	21.4	32.2	22.5	30.5	24.6	0.0
29	28.6	21.3	31.9	22.3	30.0	24.0	0.0
30	27.9	21.2	31.9	22.3	29.5	23.9	0.0
31	27.5	20.9	31.7	21.9	29.0	23.5	0.0

Table A-55 Ambient Conditions - Radhanpur
November - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	27.5	20.6	31.6	21.8	29.0	23.3	0.0
2	27.5	20.4	31.1	21.7	28.8	23.0	0.0
3	27.5	20.2	31.2	21.7	28.8	22.9	0.0
4	27.3	20.0	31.4	21.8	28.7	23.0	0.0
5	27.3	20.7	31.3	21.6	28.8	22.5	0.0
6	27.6	20.9	31.4	21.9	28.8	22.7	0.0
7	27.3	20.5	31.3	21.9	28.3	22.0	0.0
8	27.6	20.5	31.1	21.5	28.5	22.0	0.0
9	27.1	20.6	31.1	21.4	28.7	22.0	0.0
10	26.4	20.2	30.9	21.1	28.2	21.5	0.0
11	26.6	20.1	31.1	21.1	28.0	21.0	0.0
12	26.3	20.0	30.4	20.5	28.3	21.2	0.0
13	25.9	19.6	30.4	20.7	28.6	21.0	0.0
14	25.8	19.3	30.4	20.5	28.3	21.3	0.0
15	25.4	18.9	30.5	20.4	28.3	21.1	0.0
16	25.7	19.0	30.3	20.6	27.8	21.0	0.0
17	25.9	19.2	30.1	20.2	28.0	21.3	0.0
18	25.2	18.7	30.0	20.0	27.5	21.0	0.0
19	25.1	18.5	29.4	19.9	26.9	20.5	0.0
20	25.1	18.4	29.4	19.9	27.0	20.8	0.0
21	25.3	18.7	29.9	20.0	26.5	20.5	0.0
22	25.3	18.1	29.9	20.0	26.5	23.5	0.0
23	24.5	18.3	30.0	20.1	26.3	19.8	0.0
24	24.5	18.2	29.9	20.1	26.3	19.8	0.0
25	24.9	18.6	29.9	19.9	26.5	19.9	0.0
26	24.3	17.6	29.8	19.7	26.4	19.0	0.0
27	24.6	17.1	29.1	19.3	26.0	18.7	0.0
28	22.1	16.0	29.3	19.3	27.4	16.4	0.0
29	22.0	15.8	28.4	19.0	23.7	16.3	0.0
30	21.8	15.4	28.0	18.8	23.4	16.0	0.0

Table A-56 Ambient Conditions - Radhanpur
December - Mean of two years 05-06

Date	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Rainfall
	Dry Bulb	Wet Bulb	Dry Bulb	Wet Bulb	Maximum	Minimum	
	7:38 AM	7:38 AM	2:38 PM	2:38 PM	of 24 h	of 24 h	in 24 h
dd	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	^{0}C	mm
1	28.4	24.9	30.6	26.0	30.8	25.3	0.0
2	29.2	25.2	31.2	26.0	30.5	25.4	0.0
3	28.7	25.1	31.9	26.3	31.2	25.5	0.0
4	29.4	25.7	32.1	26.3	31.3	25.8	0.0
5	29.6	25.9	31.8	26.1	31.3	25.8	0.0
6	29.1	25.7	31.7	26.3	30.5	25.5	0.0
7	28.9	25.5	31.7	26.2	30.5	25.0	0.0
8	28.3	25.6	31.2	26.2	30.6	25.3	0.0
9	28.8	25.3	31.3	26.1	30.8	25.4	0.0
10	28.8	25.2	31.2	26.0	30.8	25.5	0.0
11	28.8	25.0	31.2	25.8	30.8	25.5	0.0
12	28.7	25.2	31.2	25.4	30.9	25.3	0.0
13	28.3	24.6	31.3	25.4	30.3	25.0	0.0
14	28.2	24.3	31.5	25.6	31.0	24.5	0.0
15	28.2	24.4	32.1	25.7	30.8	25.3	0.0
16	28.8	24.7	32.1	25.8	31.5	25.8	0.0
17	28.9	24.4	32.6	25.5	31.2	25.8	0.0
18	28.9	23.8	33.0	25.6	31.2	25.7	0.0
19	28.5	21.9	32.7	25.3	29.8	25.3	0.0
20	28.6	22.1	32.9	24.9	30.0	25.3	0.0
21	27.7	21.6	32.8	24.4	29.5	24.5	0.0
22	27.5	21.0	32.3	22.1	29.8	24.0	0.0
23	27.1	21.4	32.5	21.9	29.5	23.8	0.0
24	27.5	21.1	32.2	22.6	29.4	23.5	0.0
25	27.8	21.4	32.3	22.8	30.0	23.9	0.0
26	27.8	21.8	32.2	22.8	29.9	24.2	0.0
27	28.1	22.0	32.3	22.9	30.3	23.2	0.0
28	28.2	21.4	32.2	22.5	30.5	24.6	0.0
29	28.6	21.3	31.9	22.3	30.0	24.0	0.0
30	27.9	21.2	31.9	22.3	29.5	23.9	0.0
31	27.5	20.9	31.7	21.9	29.0	23.5	0.0