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Comfort Zone Calculation & Climatic Condition for a Typical Building Located in the Darjeeling Hills

Samar Thapa has completed his M Sc in Environmental Science from Sikkim Manipal University. Two of his papers viz. 'Energy Efficiency in Buildings' and 'Biomass Briquetting' have also been accepted for publication.

Abstract

Samar Thapa calculates the extent of heat dissipation inside the building of the Salesian College, Sonada, Darjeeling, based on collected data on the temperature conditions in the four seasons, in Darjeeling. It is a brief study on climatic condition, comfort zone calculation and Psychrometric charts utilizing the Solar data and Solar Chart for 27.1° N Latitude where the Hill Station of Darjeeling is Located. It is a part of a bigger study based on "Energy Conservation in the proposed new campus at Salesian College, Sonada."

Keywords: Comfort Zone, Thermal Neutrality, Climatic Conditions in Darjeeling, Temperature.

Introduction[1]

Energy Conservation is of prime importance, not only for saving the environment by reducing the CO_2 emission but also for saving the fossil fuel reserve. Some form of energy utilisation that takes place in a building occurs in the form of space heating, cooling, ventilating, lighting, etc, which can be considerably reduced if the building is constructed with proper design. In this article, we would seek to calculate the comfort zone and climatic condition for the building of Salesian College, Sonada, Darjeeling.[2]

Climatic Conditions (General):

Darjeeling has a moderate climate with four major distinct seasons in a year.

The Summers (March to mid-May) are mild with maximum temperature never crossing 25°C. Hence, there is virtually no requirement for cooling even during the summer months. This pleasant climate attracts lots of tourists from the plains, who want to get relief from the intense Indian summer. The Prolonged Monsoons (mid-May to mid-September) are heavy, (can cross 100 cms within 24 hrs), with intense torrential rain causing roadblocks. The Autumn (mid-September to mid-November) is usually

1 Samar Thapa, "Solar Passive Heating for the Proposed New Campus at Salesian College, Sonada", Thesis submitted for M.Tech, Devi Ahilya Vishwavidhyalaya, Indore, 2010.

2 The college is an educational institution sponsored by the Salesian Province of Kolkata where the students do their undergraduate degree from the North Bengal University. Salesian College was established in Shillong, in 1933, and was shifted to the present site in Darjeeling in 1938. Originally, it was affiliated to the Calcutta University. In 1962, the College was disaffiliated from Calcutta University and became one of the founding colleges of the North Bengal University.

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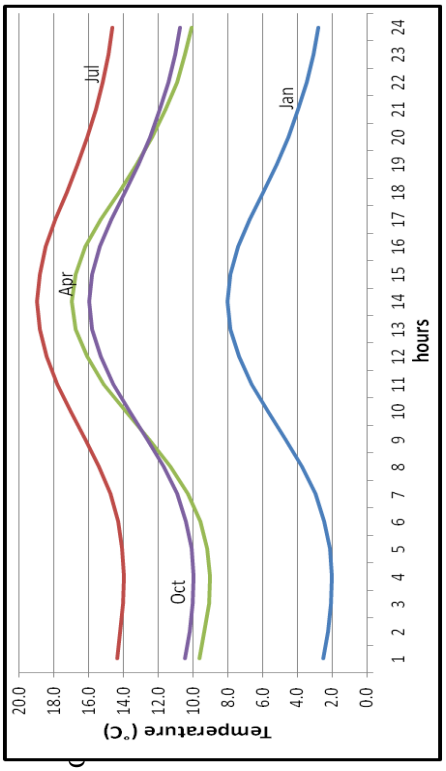
accompanied by intermittent rainfall. The Winters (mid-November to February) have a cool climate within the average range of 5°C to 7°C. Minimum temperature in this season can be freezing at-3°C. Snowfalls are not common even during winters.

Temperatures:

The average yearly temperature variation in Darjeeling is less. It is about 100C-150C. Daily variation range is more pronounced in winters (that is, about 150C), than that during the summers or monsoons.

The average temperature is shown in the following Table 1. The hourly temperature for each of the months in Darjeeling is recorded in the table. The temperature in degree celcius is also plotted in graph 1, where the temperature is recorded at each hour. Finally, plotting all the points the hourly movement of temperature is obtained



Hourly Temperature data for Darjeeling.. for hourly calculations following empirical relation was used:
Th = daily temp. – (% h x daily range), where daily range = Tmax – Tmin ; and % h is given as

Time(h)	%	Time	%	Time	%
1	87	9	71	17	10
2	92	10	56	18	21
3	96	11	39	19	34
4	99	12	23	20	47
5	10 0	13	11	21	58
6	98	14	3	22	68
7	93	15	0	23	76

Table 1

Average Hourly Temperatures (°C) for Darjeeling

th	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	avg T
	2.5	2.2	2.1	2.0	2.1	2.4	3.0	3.7	4.6	5.7	6.6	7.3	7.8	8.0	7.8	7.4	6.7	6.0	5.2	4.5	3.9	3.4	3.1	2.8	4.6
	2.6	2.3	2.1	2.0	2.1	2.5	3.1	4.0	5.1	6.3	7.4	8.2	8.8	9.0	8.8	8.3	7.5	6.6	5.7	4.9	4.2	3.7	3.3	2.9	5.1
	6.6	6.3	6.1	6.0	6.2	6.6	7.3	8.3	9.5	10.9	12.2	13.1	13.8	14.0	13.8	13.2	12.3	11.3	10.2	9.4	8.6	7.9	7.4	7.0	9.5
	9.6	9.3	9.1	9.0	9.2	9.6	10.3	11.3	12.5	13.9	15.2	16.1	16.8	17.0	16.8	16.2	15.3	14.3	13.2	12.4	11.6	10.9	10.4	10.0	12.5
	12.5	12.2	12.1	12.0	12.1	12.4	13.0	13.7	14.6	15.7	16.6	17.3	17.8	18.0	17.8	17.4	16.7	16.0	15.2	14.5	13.9	13.4	13.1	12.8	14.6
	13.4	13.2	13.1	13.0	13.1	13.4	13.8	14.5	15.2	16.1	16.9	17.5	17.9	18.0	17.9	17.5	17.0	16.3	15.7	15.1	14.6	14.2	13.9	13.7	15.2
	14.4	14.2	14.1	14.0	14.1	14.4	14.8	15.5	16.2	17.1	17.9	18.5	18.9	19.0	18.9	18.5	18.0	17.3	16.7	16.1	15.6	15.2	14.9	14.7	16.2
	14.3	14.2	14.0	14.0	14.1	14.3	14.6	15.2	15.8	16.4	17.1	17.6	17.9	18.0	17.9	17.6	17.2	16.6	16.1	15.7	15.3	15.0	14.7	14.5	15.7
	13.4	13.2	13.1	13.0	13.1	13.4	13.8	14.5	15.2	16.1	16.9	17.5	17.9	18.0	17.9	17.5	17.0	16.3	15.7	15.1	14.6	14.2	13.9	13.7	15.2
	10.5	10.2	10.1	10.0	10.1	10.4	11.0	11.7	12.6	13.7	14.6	15.3	15.8	16.0	15.8	15.4	14.7	14.0	13.2	12.5	11.9	11.4	11.1	10.8	12.6
	6.5	6.2	6.1	6.0	6.1	6.4	7.0	7.7	8.6	9.7	10.6	11.3	11.8	12.0	11.8	11.4	10.7	10.0	9.2	8.5	7.9	7.4	7.1	6.8	8.6
	3.5	3.2	3.1	3.0	3.1	3.4	4.0	4.7	5.6	6.7	7.6	8.3	8.8	9.0	8.8	8.4	7.7	7.0	6.2	5.5	4.9	4.4	4.1	3.8	5.6

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In the following Table 2, the monthly average maximum and minimum temperatures (in degree celcius) is recorded for the twelve months of the year. Also, in columns (3), (4) and (5), the recorded temperature and the average air temperature are given respectively. Also the mean temperature is calculated to get an idea of the average.

Table 2: Monthly average Max and Min Temp (°C)

Month temp (^{0}C)	Avg. Min temp (^{0}C)	Avg. Max temp (^{0}C)	Recorded Min temp (^{0}C)	Recorded Max temp (^{0}C)	Avg. air (^{0}C)
jan	2	8	-3	16	5
feb	2	9	-2	17	5.5
mar	6	14	-1	23	10
apr	9	17	1	24	13
may	12	18	6	25	15
jun	13	18	8	24	15.5
jul	14	19	9	25	16.5
aug	14	18	11	25	16
sep	13	18	10	25	15.5
oct	10	16	4	23	13
nov	6	12	2	19	9
dec	3	9	-1	17	6
mean	8.67	14.67	3.67	21.92	11.67

Source: NASA - Retscreen Software

However,in the background of the climatic conditions of Darjeeling given in the above tables, the thermal comfort of the individual depends upon many factors. Starting with thermal sensation, a man's thermal comfort is also affected by his expectation and many other psychological and social influences.

At the sensory level the useful notion is "thermal neutrality" (Tn), which is the temperature averaged for a large sample, when the individuals feel neither cold nor hot.

$Tn = 17.6 + (0.31 \times Tavg.)$ For $18.5 < Tn < 28.5°$ C

The width of comfort zone (the range of conditions within which the majority of people would feel comfortable) is taken as ± 2.5°C about thermal neutrality, if Tavg. is an annual mean temperature.

Factors Affecting Heat Dissipation

All forms of the heat dissipation depend on the following environmental conditions, which are, therefore, determinants of the thermal comfort.

- Air Temperature (DBT)
- Air movement (Wind speed)

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- Humidity (AH)
- Mean radiant temperature (MRT)

Air movement accelerates convective heat dissipation from the skin as long as the air temperature is less than the skin temperature. It also increases the evaporative heat losses.

Humidity ranging between 4 - 12 g/kg have little effect on thermal sensation but a very low humidity would dry out the mucous membranes, and therefore it is unpleasant.

The last term MRT is mean radiant temperature of the surroundings, obtained by averaging the temperature of surfaces to which the body is exposed, weighted by the solid angle suspended by each.

In view of the four factors of heat dissipation, the latest thermal index is constructed to express the combined effect of four environmental variables in a single number which is called standard effective temperature (SET), combines the effect of DBT and humidity, when MRT is same as DBT and there is no significant air movement (such as indoors). Up to 14°C, the SET coincides with the DBT (vertical) lines, and above 14°C , it coincides with DBT at the 50% RH curve. But it should be noted that the SET lines have a slope of 0.025 x (DBT - 4) for each g/kg vertical distance.

The comfort zone is however plotted on the psychrometric chart using the thermal neutrality level (Tn) and the standartd effective temperature (SET), by the following procedure:[3]

1. The annual mean temperature is found (Tavg.);
2. Thermal Neutrality (Tn) is calculated from the above expression;
3. This temp. is plotted on the chart on the 50% RH curve;
4. The lower limit L = Tn - 2.5 and upper limit U = Tn + 2.5 are marked on 50% RH;
5. Draw the corresponding SET lines, as the side boundaries; and
6. Mark the upper AH boundary at the 12 g/kg level and the lower boundary at 4 g/kg.

Following the steps mentioned for plotting the comfort zone, the comfort zone for Darjeeling is calculated below:

Comfort Zone Calculations for Darjeeling:

Tav = Annual mean temperature = 11.7°C

3 Daikin Psychrometric - Software free version, *url.www.daikineurope.com.*

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(1) Neutrality Temperature, Tn = 17.6 + (0.31 x Tav)

= 17.6 + (0.31 x 11.7)

= 21.227° 21.23° C

(2) Width of Comfort Zone (on 50% R.H. curve):

Width of the Comfort Zone is taken as ± 2.5°C about the thermal neutrality:

Lower limit, L = 21.23°C - 2.5°C = 18.73°C

Upper limit, U = 21.23°C + 2.5°C = 23.73°C

(3) Slope of SET lines:

Slope = 0.025 x (DBT - 14)

For L = 18.73°C, slope = 0.025 x (18.73 - 14) = 0.11825

And the corresponding AH (L) = 8.5 g/kg

For U = 23.73°C, slope = 0.025 x (23.73 - 14) = 0.24325

And the corresponding AH (L) = 11.625 g/kg

(4) The upper and lower ranges of absolute humidity (AH) for the comfort condition is taken as:

Upper range = 12 g/kg

Lower range = 4 g/kg

(5) The base line intercepts of the two boundaries are

For L - intercept = 18.73°C + (8.5 x 0.11825)°C

= 19.74°C

For U - intercept = 23.73°C + (11.625 x 0.24325)°C

= 26.56°C

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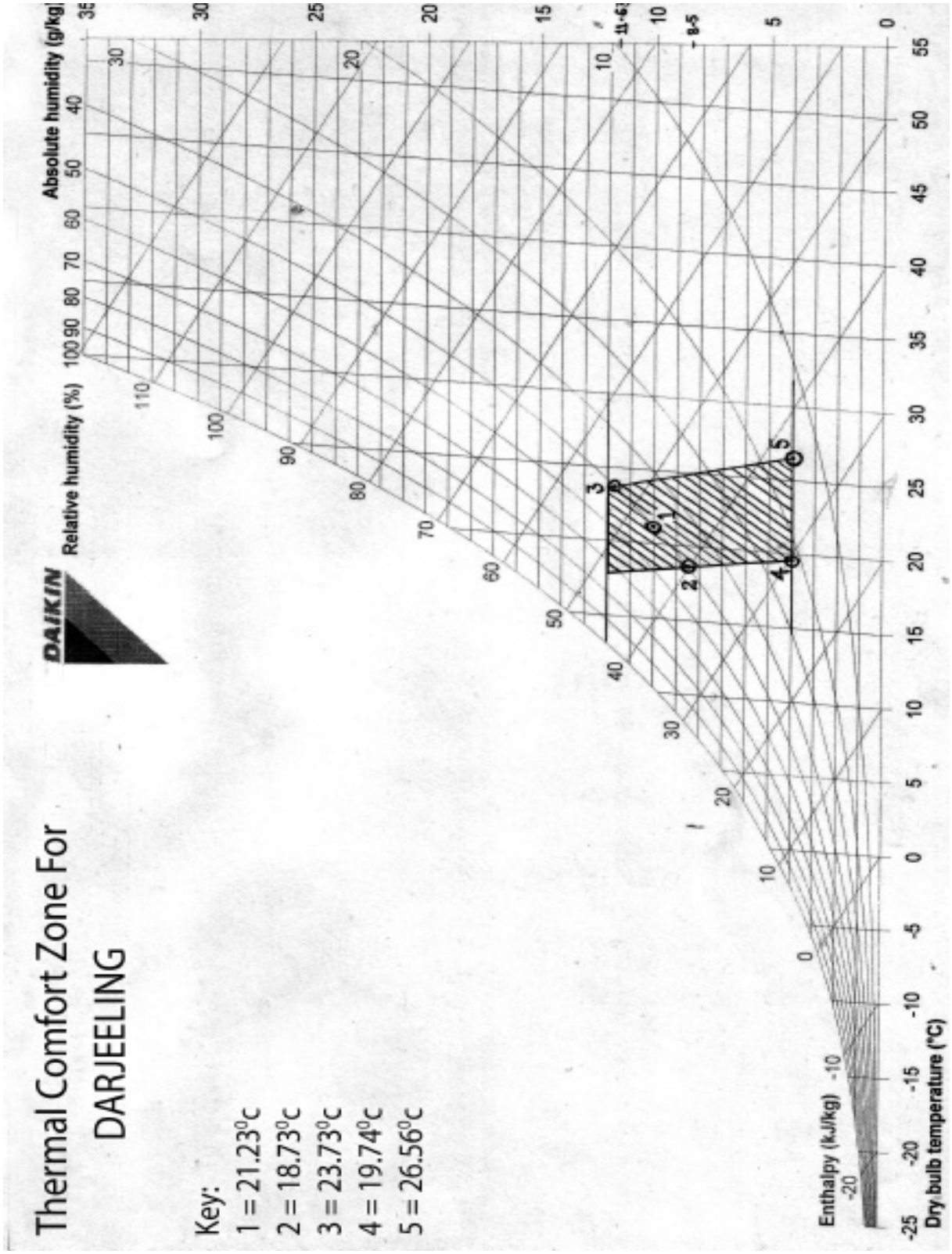
The Thermal Comfort zone for Darjeeling is plotted below: The graph was prepared by the author himself



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Situation of Solar Radiation, Sky Condition & Sky Clearance Factor in Darjeeling

- Solar Radiation is largely diffuse during the most part of the Year. The direct component of the solar radiation is higher in the spring (late Feb till Early May)and during the autumn (late Sept till late Nov).

- Sky Condition is mostly overcast due to various reasons…. like the prolonged monsoons, vicinity to the Bay of Bengal, and the region being lying on the windward side of the Himalayas. However the sky remains more or less clear during the winter months and the spring.

- Sky Clearance factor represents the mean period of the day, expressed as percentage of the total, for which the sky is clear with bright sunshine. An approximation of the total radiation for any month, at a given place can be obtained by the sky clearance factor.

Sky clearance factor

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sky Clearance Factor (%	55.37	66.61	57.5	50.02	45.06	23.14	28.6	35.72	40.58	57.16	64.12	69.95

Source: NASA - Retscreen Software.

Now, the solar radiation for different months and the average solar radiation in the months of July are graphically represented below:

Average Solar radiation (W/m2) for Darjeeling for December; where ig= global irradiance; and id= diffuse irradiance

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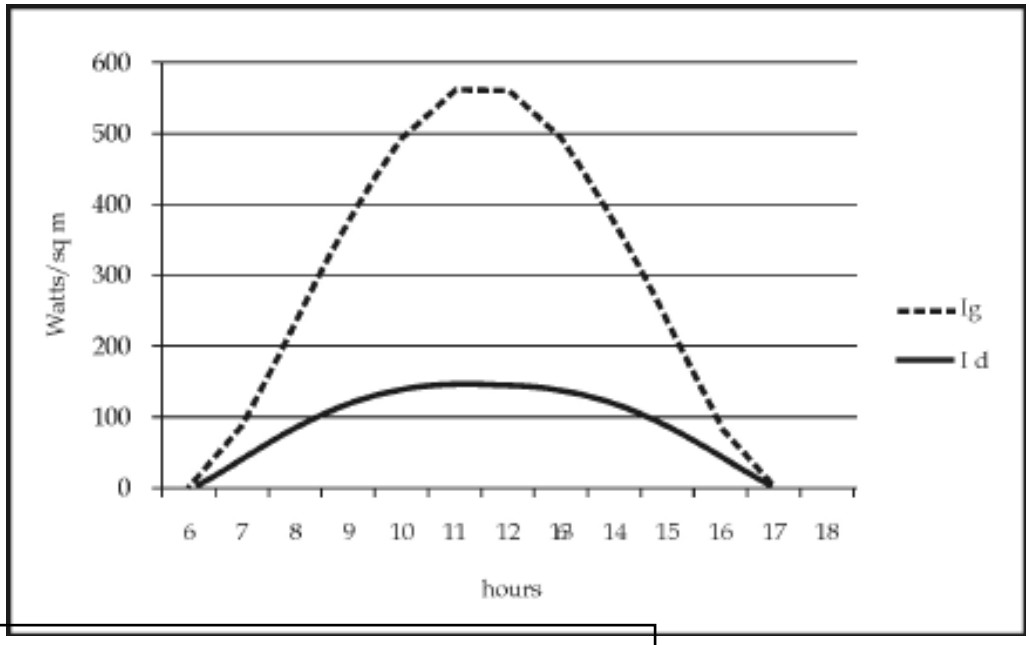
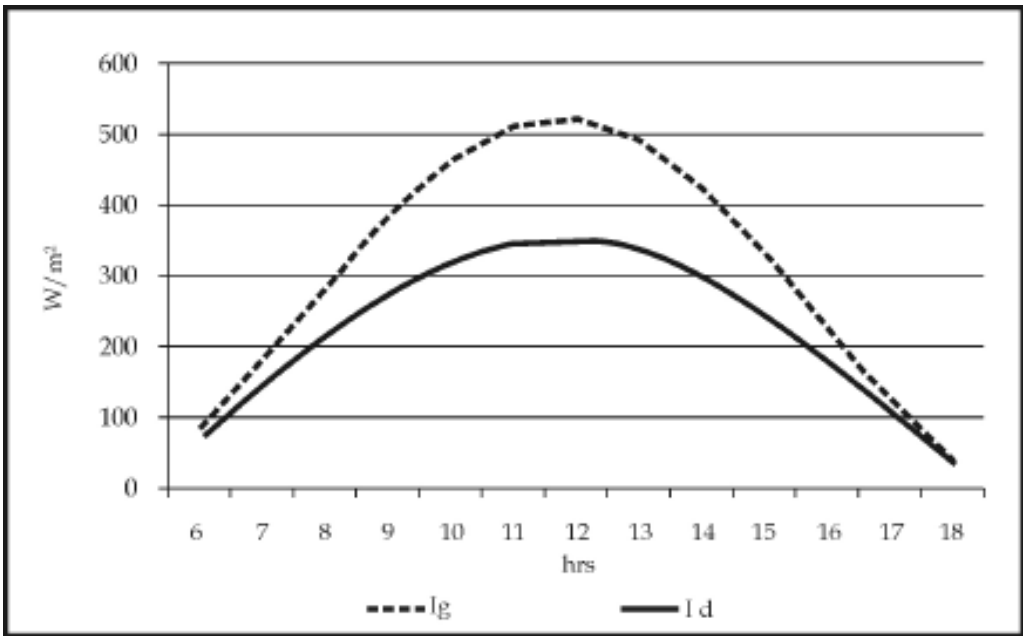
Solar radiation for different months for Darjeeling



Average Solar radiation (W/m2) for Darjeeling for July



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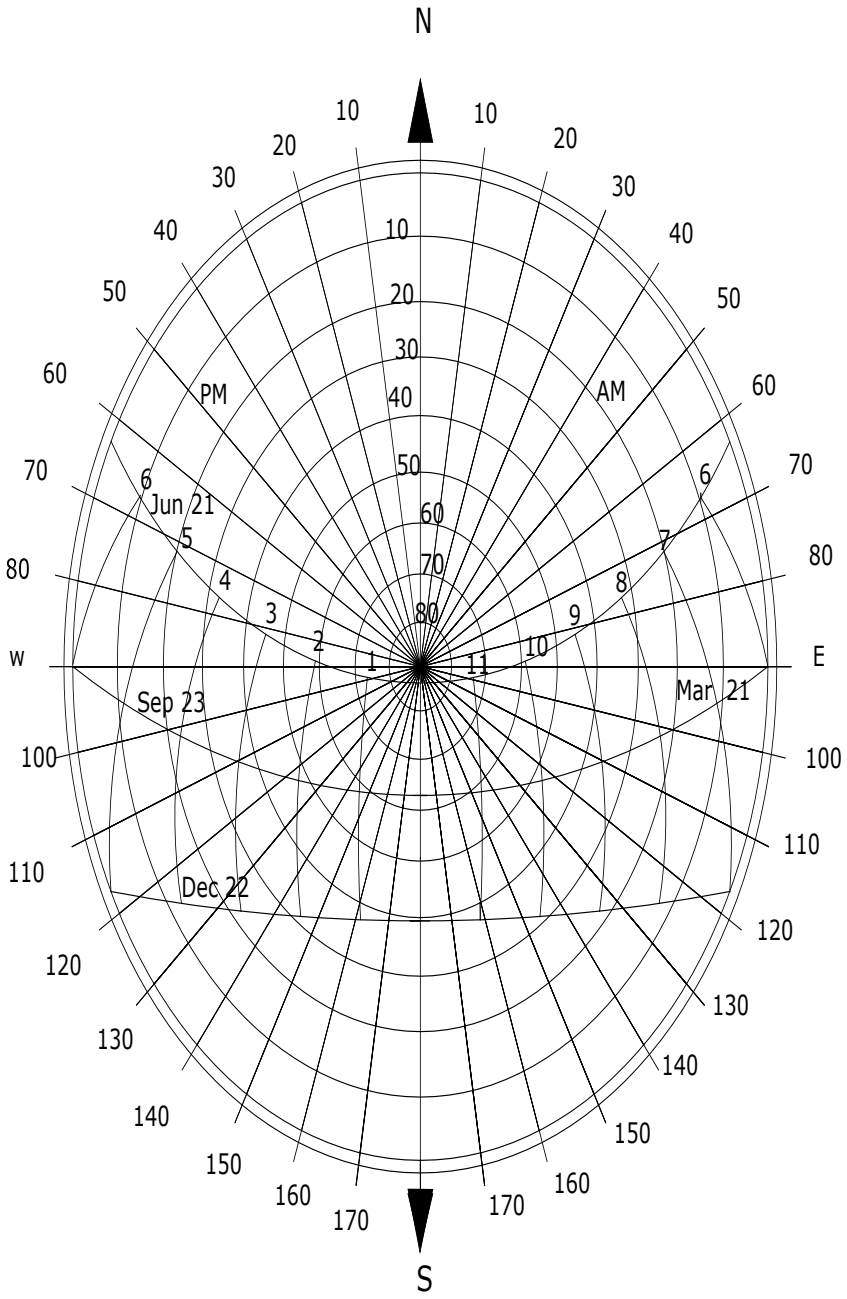
Solar Chart for 27.1° N latitude (Darjeeling).



SOLAR CHART FOR 27.1 DEGREE NORTH LATITUDE

Solar Chart for 27.1° N latitude.[4] This chart shows the sunrise and sunset time in the region at certain important geographical dates, i.e. March 21st, June 21st, Sept 23rd and Dec 22nd. The chart also shows the solar angle at various hours and the respective day length for these days.

4 G.N. Tiwari, *Solar Energy: Fundamentals, Design, Modelling and Applications,* Narosa Publishing House, New Delhi; P Suhas Sukhatme & J.K Nayak., *Solar Energy: Principles of Thermal Collection and Storage,*Tata McGraw Hill Publishing Company Limited, New Delhi; J.K Nayak., R.Hazra & J.Prjapati, "Manual on Solar Passive Architecture, Energy Systems Engineering", IIT Bombay, Mumbai and Solar Energy Centre, MNES, GOI, Richard J. Williams, Passive Solar Heating, Ann Arbor Science, R.L Shawney, notes on Solar Energy Utilization, 2010.

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Energy Load Calculation:[5] Based upon the above data, simulations were done to find the yearly energy (electrical) requirement for heating the building, considering the various factors like the occupancy, periodic fluctuation of heat flow through the wall considering the sol-air temperature, etc.

Conclusion

A process of determining the extent of heat dissipation and temperature conditions inside a building in Darjeeling has therefore been innovated. But since heating a building depends on several factors, some passive heating mehods have also been highlighted. Finally, some passive heating methods were suggested for the upcoming building like the use of hollow blocks, double panelled windows on the northern envelope of the building, glazed wall on the southern envelope, unglazed transpired collector, etc with the design, cost and savings and the payback.

5 M. Tech Energy Management notes on Energy Conservation in Buildings, School of Energy & Environmental Studies, Devi Ahilya Vishwavidhyalaya, Indore, 2010.