SUSTAINABLE BUILDING DESIGN FOR KERALA STATE WITH SPECIAL EMPHASIS ON ENERGY EFFICIENCY

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF ARCHITECTURE

By

SUNIL EDWARD

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Energy efficiency is to be viewed as a primary mechanism, to limit the environmental damage caused to our planet by our increased energy use, (which) now threatens the very survival of... people on earth through global climate change. Energy efficiency is no longer an optional extra in design- it has become a basic requirement for designing professions.

-Ar. Susan Roaf, RIBA.*

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* from the introduction of her book titled 'Energy Efficient Building' published by Blackwell Scientific publishers, London 1992.

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **SUSTAINABLE BUILDING DESIGN FOR KERALA STATE WITH SPECIAL EMPHASIS ON ENERGY EFFICIENCY** in partial fulfillment of the requirement for the award of the Degree of **MASTER OF ARCHITECTURE** submitted in the Department of Architecture & Planning of the University is an authentic record of my own work carried out during the period from July 1998 to December 1998 under the supervision of Prof. P.K. Patel.

The matter embodied in this thesis has not been submitted by me for the award of any other degree.

Roorkee
15th December 1998

(SUNIL EDWARD)

CERTIFICATE

This is certified that the above statement made by the candidate is correct to the best of my knowledge.

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Roorkee
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ABSTRACT

This thesis examines the possibilities of solving a share of energy shortage in the south Indian State of Kerala by appropriate intervention through architecture. Since almost 40% of the State's energy use is consumed by the domestic sector, any saving in this area would have a substantial impact on the State's energy crisis.

In doing so, it identifies two basic areas where energy efficiency can be achieved in building construction, namely:

1. By reducing the need of energy intensive active means of thermal comfort altogether, if not completely at least partially, by the integration of passive systems into the building design which are suitable for the warm-humid climate of Kerala and
2. By constructing the buildings with low energy and locally available materials.

The traditional vernacular passive design techniques, practices and the materials used are documented and analyzed through selected case studies and compared to the conventional buildings to understand the underlying principles and the pros and cons of both types.

Furthermore, the most used construction materials of Kerala are identified and analysed for their environmental and energy efficiency properties to find out the potential low energy and locally available materials of the State.

Thesis arrives at the proposition that the architectural features in the traditional domestic architecture of Kerala, as evident from the case studies, was the result of conscious designing and constructional practices for achieving thermal comfort.

In the end it proposes some guide lines, or thump rules, to any architect/ builder for designing/ constructing a better energy efficient building on this particular geographical area.

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GHGs	:	Greenhouse gases
GWh	:	Gigawatt hours
kcal	:	Kilocalories
kgoe	:	Kilograms oil equivalent
kWh/yr	:	Kilo watt hours per year
MJ	:	Million joules
MNES	:	Ministry of Non-conventional Energy Sources
Mtoe	:	Million tonnes oil equivalent
mu	:	Million units
MW	:	Megawatts
OCED	:	Organization for Economic Cooperation and Development
OPEC	:	Organization of Petroleum Exporting Countries
toe	:	Tonnes of oil equivalent

CHAPTER 1
INTRODUCTION.

1.1 Introduction.

One of the greatest challenges facing the next millenium is to enforce a well-integrated and environmentally sustainable solution to the problems in the energy sector. In spite of many years of studies after the energy crisis, involving research and experiments, success has been often elusive or limited to confined areas.

It reflected in the architecture/ construction sectors also, with considerable technical developments taking place in the recent years, and more importantly with the emergence of a new branch called the 'energy efficient buildings'. This development has made it popular among architectural circles to take a fresh look at the building design with a more open eye towards sustainable development and energy conservation.

Furthermore, recently human comfort had become a more important design factor in deciding the form of the building, than any particular 'style' or the exterior decorations, as was the case earlier. The concept of 'low energy' building (building designed to minimize the energy consumption) has already attained much popularity in the western countries. The reason for all this is the understanding that the conventional energy sources are all finite and will perish one day sooner or later and the total dependency on these limited resources as the sole source of energy, is not a viable proposition.

Also now with a clear understanding that the production, or conversion of energy into useful form, (mainly electricity) is polluting the environment in a drastic way, by the unfavorable alteration it causes to our surroundings (air, water and land). So even if there is enough conventional sources of energy for, say another 50 or 100 years, the question is should we go for the conventional sources of energy for that long, that now we know the bad side effects of it.

We are in the threshold of entering into a new century. It is extremely essential now, that the architects should look into the future and see what they can do as building designers to make their contribution to the destiny of our planet. It is the duty of architects and builders to develop buildings that will align themselves more strongly with the environment and depend less on conventional energy for its construction and sustenance. These types of buildings are now generally grouped under the broader headings such as energy efficient buildings or environmentally sustainable buildings or sometimes simply as solar buildings.

But when we hear of a solar building the picture that comes to our mind is a building with glass walls or roofs, with its main intention to heat up the indoors passively. One of the reasons for this is that most of the research that has gone into this field was done in European countries, UK, Australia and parts of USA where heating the indoors was the main necessity of the climate, than space cooling.

Even in India most of the work is done from the north Indian places like Delhi and Roorkee (CBRI) where again concentration was on heating. It's also a fact that heating consumes more energy than it takes for ordinary cooling and so it obviously needs more attention.

This being so, then, is this energy efficient architecture relevant or viable in a warm- humid climate, like the south Indian State of Kerala for example, where it is the summer heat and not winter cold that is to be tackled through out the year ?. Can we use sun's heat to power cooling or induce forced ventilation inside ?. What should be the criteria's for passive design for energy efficiency in this region ?. What are the materials that are environmentally sustainable and low in energy input ?.

These are some of the questions of which answer can guide an architect to design sustainable low energy buildings in this climate. My intention through doing this thesis is to study, analysis and try to find the answer to these questions and to frame some policy guide lines, or thump rules for the help of architects and builders for designing and constructing sustainable buildings in Kerala State.

1.2 Sustainable Development And Energy Efficiency.

Sustainable development is envisaged as a holistic concept of development which involves raising the quality of life of the present generation with out sacrificing the right of the future generations to a similar quality of life. In other words sustainable development is the effective utilization of energy, natural resources (like land, water, etc.) and it also includes the effective recycling of wastes. [Figure 1.1]

Energy efficiency is therefore actually a part of the broader sustainable development paradigm. To be more precise, an energy efficient building doesn't necessarily have to be a sustainable building but a sustainable building has to be energy efficient. So, although I concentrate more on energy efficiency, the purpose of bringing in the larger sustainable paradigm is that, the recomentational outcomes of this study to make the buildings more energy efficient, should take care of the other aspects of the sustainability also, to make the final proposals, or guide lines, a real viable base for the future development activities.

It's true that any construction implies an intervention and alteration of natural landscape. Stone boulders mean a hill flattened, bricks mean earth excavated and wooden logs mean a tree cut somewhere. It will be, of course, almost impossible to do any construction activity with out this intervention. But understanding the finiteness of the natural resources and the recurring implications of its consumption, all viable proposals for energy efficient development should also be environmentally sustainable.

1.3 Energy And Building Design; Needs For The Study.

Energy occupies a central place in our lives. Today by pressing a button we heats or cools our living space, by turning a facet we gets water- even hot water, but while doing all this we do not understand that we are using the limited sources of energy for this luxury. But still planning for the proper use and development of energy was given less importance until about a decade ago; then energy shortage usually meant increasing the supply of energy from various sources.

But after the oil shock of the 1970's this view has changed when the energy supply has become scare, expensive and unreliable. This will be more evident if we just look at the price of crude oil per barrel, in early 1973 it was only around 10 US dollars but by 1981 it shoot up to around 50 US dollars, almost 5 times. Today, although it has come down to about 14 US dollars per barrel, it is an accepted scarce material.

It can be seen that, if we analyze the sector-wise energy consumption of 3 major consumers of commercial energy in India; '52% of the total energy used is consumed by the industrial sector, 23% by the transportation sector and only 11% by the residential sector'. [1] But it is to be noted here that this 11% does not include the energy used for production and processing of building materials, transporting raw materials to factories and finished materials to site and the energy used for construction activities etc., which is accounted with the industrial and transportation sectors. So the actual total energy consumption by residential sector would be much higher.

There are various areas where conservation of energy can be achieved. But if out of total energy produced, a substantial part of it is consumed by the buildings, then an effective energy conservation system in the building design and construction will have a major impact on national energy situation. It is claimed that just the renovation of a

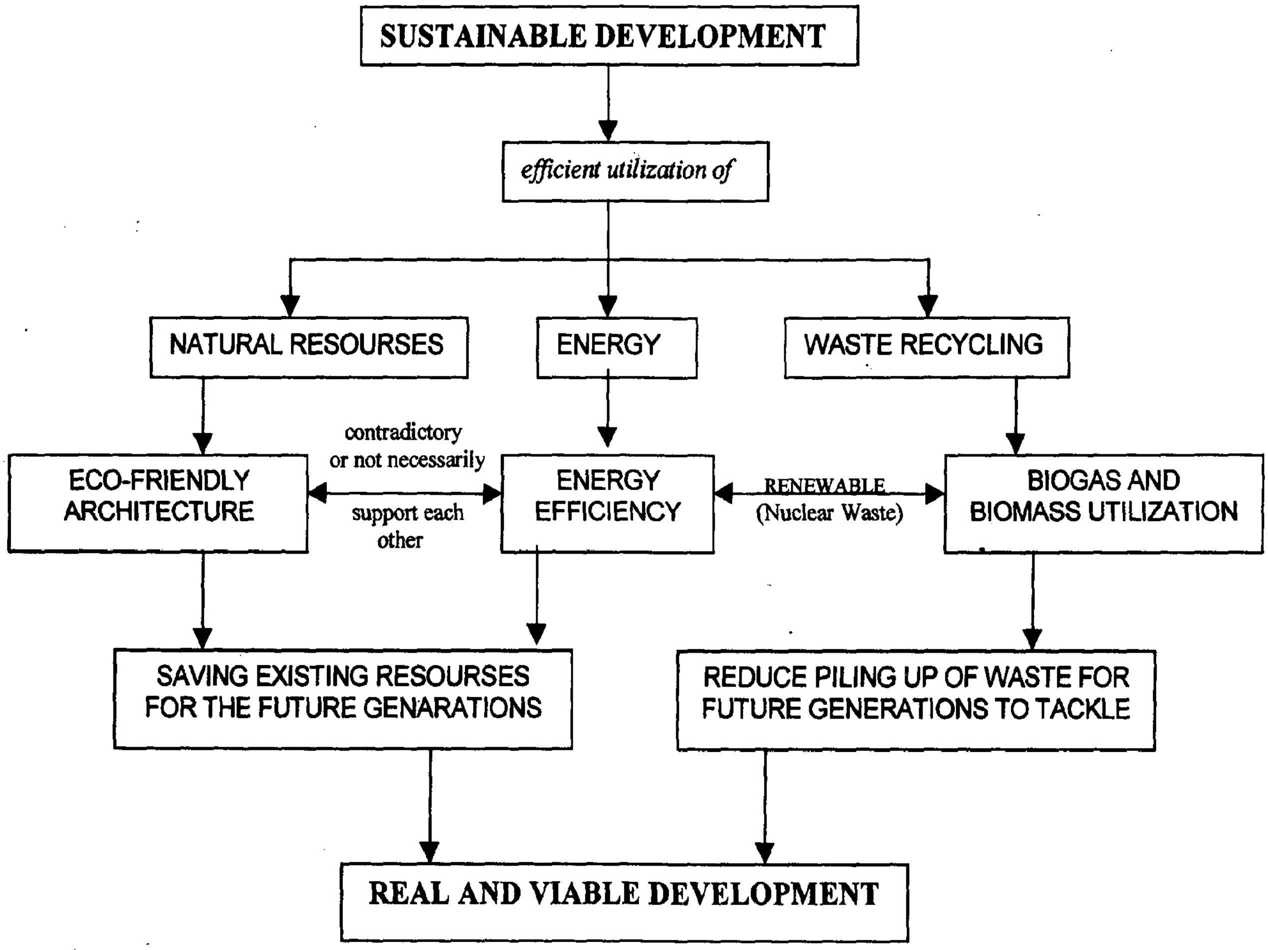


Figure 1.1: Sustainable Development Concept

building can save up to 30% of its energy consumption and a properly planned building will raise this saving by 50%.

'The energy consumption in buildings varies over a wide range, for building of similar use and type. A day lit and naturally ventilated building which is occasionally conditioned will have an annual energy cost as low as Rs. 60/sq.m/year (domestic building) to Rs. 200/sq.m/year (commercial building). On the other hand fully conditioned building with poor services design and control could cost more than Rs. 600/sq.m/year (domestic building) to Rs. 1000/sq.m/year (commercial building)'.[2]

So looking ahead, factors of increasing energy demands, the finite nature of conventional energy resources, the environmental problems and the burden it places on national economy, makes the dependence on processed fuels less and less viable. There is, therefore, an urgent need now to use available and underdeveloped resources in a more efficient and sustainable manner. The 'energy efficient building' is one major area which response to this need.

1.4 RESEARCH DESIGN

1.4.1 Aims and Objectives.

This investigation is an attempt to study how buildings can be designed and constructed in the warm-humid regions to conserve energy, natural resources like land, water, trees etc. and cause minimal disturbance to the natural environment by the construction and its associated activities. It concentrates on the various methods of energy conservation in building.

The objective of this research is to prepare a set of guidelines or thump rules for the help of architects and builders for designing and constructing sustainable and energy efficient buildings in warm-humid regions.

1.4.2 Steps

The following steps have been adopted for this research:

- Study the state-of-the-art of sustainable development and energy efficiency in buildings.
- Analyze the climatological data of warm-humid regions to understand thermal comfort requirements and the various principles of both active and passive cooling systems.
- Analyze the traditional vernacular architecture of warm-humid regions to find out the various underlying principles, construction techniques and materials used for thermal comfort before the active systems of thermal comfort became popular.
- Conduct a comparative analysis of traditional and conventional buildings through case studies in terms of passive design terminology and to draw inferences.
- Classify the building materials according to the energy used for its production and to analyze the contribution of different building materials to thermal comfort.
- Conduct feasibility analysis for identifying the appropriate locally available and low energy materials of construction to conserve energy.
- And finally to propose a realistic solution, for building a sustainable and energy efficient building, in warm-humid climate.

1.4.3 Scope.

The present investigation has ample scope. Some important of these are listed in the sequel. They are:

1. It would pave the way for understanding the thermal comfort requirement of this particular climate and can be used as a guideline for any architect working in this climate.
2. It would clearly identify and define the parameters which are highly responsible for thermal comfort conditions.
3. If the proposed guideline is implemented/ adopted by the architects or builders it would pave the way for solving the energy problem of the region in a drastic way.

1.4.4 Methodology.

The methodology followed for this research is graphically represented in the flow chart given in Figure 1.2.

1.4.5 Data.

Two types of data have been used for this investigation. They are:

1. Secondary data: This includes a literature survey done mainly on three areas. First one was on today's energy scenario, to get an insight & to know the state-of-the-art of the situation. Secondly on the study area to get data on its climatic needs and materials which are locally available. And finally on the energy content of materials to understand low energy materials.

   It was obtained from relevant published literature, unpublished documents which were available from authentic sources and also the climatic data published by meteorological department.
2. Primary data: The investigator has conducted case studies of traditional and conventional buildings, and the results are used.

1.4.6 Limitations.

1. The present investigation focuses only on residential buildings because of the limited time frame available. But the recommendations may be effectively implemented on to other types of buildings also after considering the relevant parameters, to conserve energy.
2. Of all forms of conventional energy, the one we are most dependent on is electricity. Quantitatively it is the most used form of energy in any building for thermal comfort and illumination needs. So any efficient energy conservation system must try to tap this vital form of energy to its maximum, either by reducing the need for it to run active mechanical systems for thermal comfort altogether, by passive methods, or by using sustainable sources of energy to power these mechanical systems. The former one will come more in the preview of an architect than later. So the investigator concentrates more on the ways to eliminate the needs for active mechanical systems, if not completely at least partially, for thermal comfort needs.
3. India is a vast country which extents between 8 deg. N to 36 deg. N latitudes and embraces a verity of local climates. It is usually seen divided as two climatic zones, with the peninsular region as the tropical zone and the rest of the country, north of it as the Temperate Zone. But CBRI, Roorkee had more accurately divided India into six climatic zones for the purpose of design of buildings based on climatic and environmental considerations. 'Each of these has its own special environmental and physical characteristics and each of these should be considered in planning of the building'.[3] The design criteria for energy efficient and environmentally sustainable buildings would be different for different regions, according to the intensity and direction of sun & wind, temperature, humidity etc. and the abundance and properties of locally available natural resources like soil, water, trees etc. The present

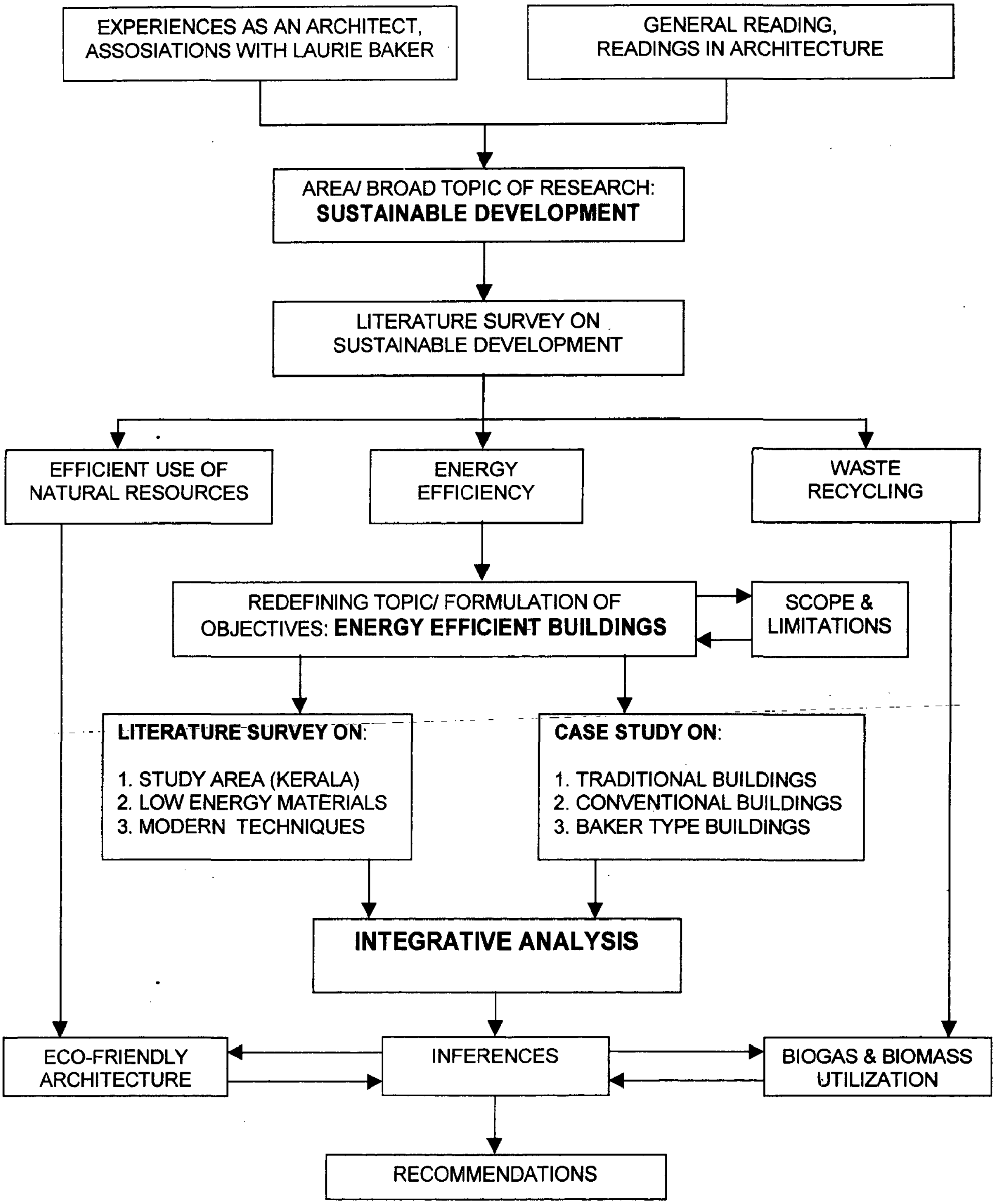


Figure 1.2: Methodology flow chart

investigation confines to Kerala State since some homogeneous characteristics are found here, which differ from other warm-humid regions. The recommendations may be implemented in the rest of warm-humid regions by taking into consideration the relevant parameters of that area.

CHAPTER 2
PROFILE AND CLIMATE OF KERALA STATE.

2.1 Introduction.

Kerala is a small state, ranking 18th in area and 12th in population (1991) of Indian union. It is tucked away in the extreme South West corner of Indian sub-continent. It is a narrow strip of land measuring about 560 km in length and 30 to 120 km in width. It is boarded by Karnataka State in North, Tamilnadu State in East & South and the Arabian Sea in West. It lies between 8'11" to 12' 48" north latitudes and 74'52" to 77'22" east longitudes. [Figure 2.1] The total area of the State is 38,863 Sq.km. It is also the most densely populated State.

On the eastern border is the Western Ghats, nearly 590 km long, which rise to an average height of 900 meters, with a number of peaks well over 1800 meters in height. The highest point is Anamudi (2817m). Physiographically, the state is divided into three natural divisions, the high lands, the midlands and the lowlands. The highlands are the hilly areas which slopes down from the Western Ghats. This is the area of major plantations like tea, coffee, rubber, cardamom and other spices. The midlands, lying between mountains and lowlands, are made up of undulating hills and valleys. This is the area of intensive cultivation; cashew, coconut, banana etc. are grown in this area. The lowlands or coastal area, which is made up of river deltas, backwaters and the shore of Arabian Sea, is essentially a land of coconuts and rice.

The name Kerala is believed to have been originated from the vernacular word 'Kera' which means coconut. Thus Kerala means the "Land of Coconuts". It is a land of rivers and backwaters. Forty-four rivers (41 west flowing and 3 east flowing) cuts across Kerala with their innumerable tributaries and branches, but these rivers are comparatively small and being entirely monsoon-fed, practically turn rivulets in summer, especially in upper areas.

A unique feature of high land is the great Palghat Gap. The gap is a complete opening in the western ghats having a width of 32.2 km, during January and April every year hot land wind rushes from the east into the Palghat district through this gap. Similar to this is the Archen Koil Gap or the Aryan Kava pass which is in the Pathanapuram Thaluk of Quilon district and both these gaps gives an easy access to rail and road traffic across the State.

2.2 The Climatic Conditions

The climate of State is of warm-humid type, one of the prominent climatic zones of India, [Figure 2.2] with seasonally excessive rainfall and hot summer. Warm-humid climates are found in a belt near the Equator extending about 15 deg. to north and south. The State enjoys an equable climate with high temperatures almost through out the year. There is very little seasonal variation through out the year, the only punctuation being that of periods with more or less rain and occurrence of gusty winds and electric storms.

The mean monthly temperature ranges between 24 deg. c and 31 deg. c. The rainfall is also uniformly high as there is precipitation from both the monsoons. The rains start with the Southwest monsoons in June which lasts to September and followed by the Northwest monsoon from October to December.

The period from March to end May is the uncomfortable hot season coupled with high humidity. The wind over the state is seasonal, with westerly component during the day and easterly component during night in most parts. Temperature and humidity are always on the higher side.

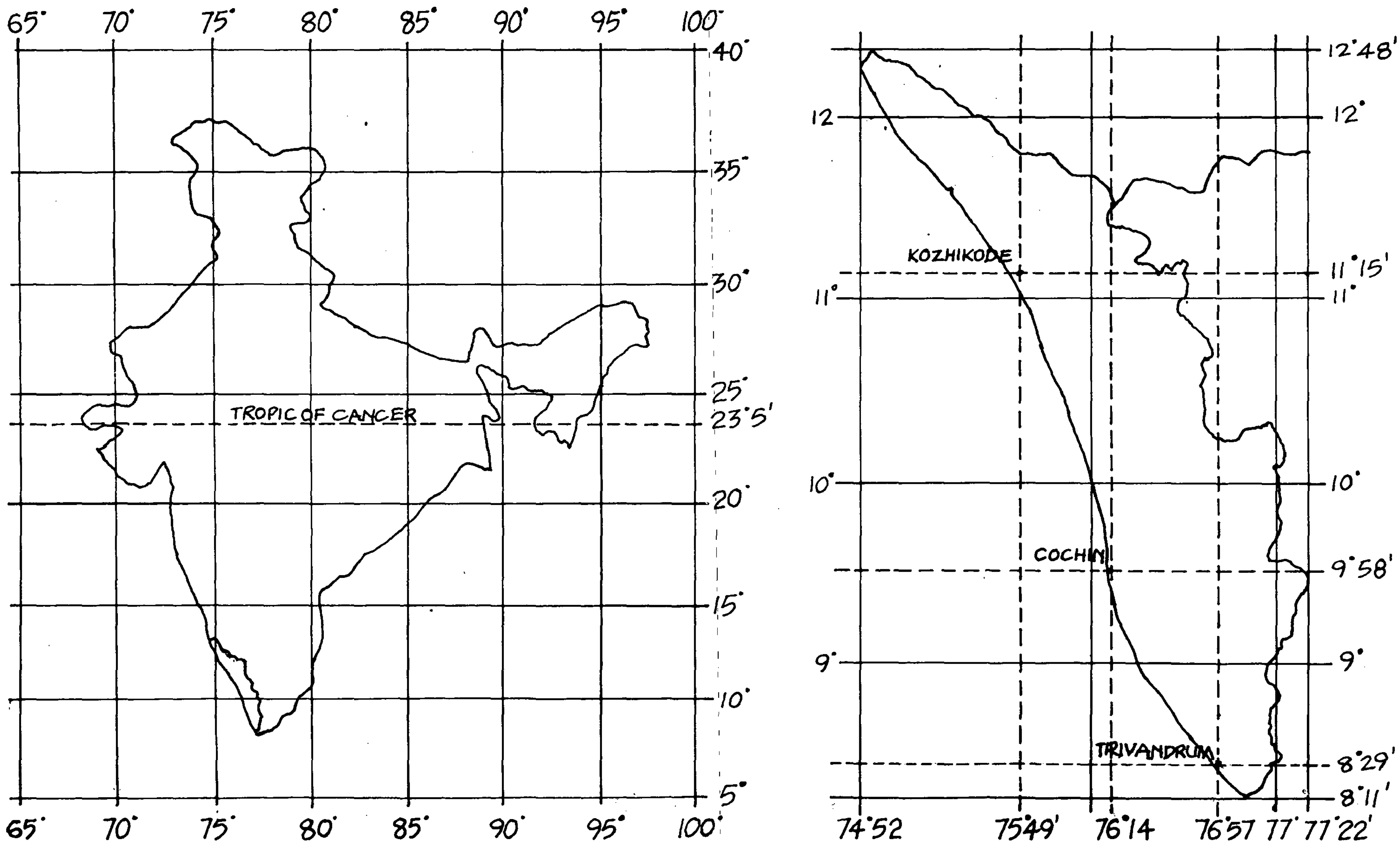


Figure 2.1: India & Kerala: Position of Latitudes & Longitudes

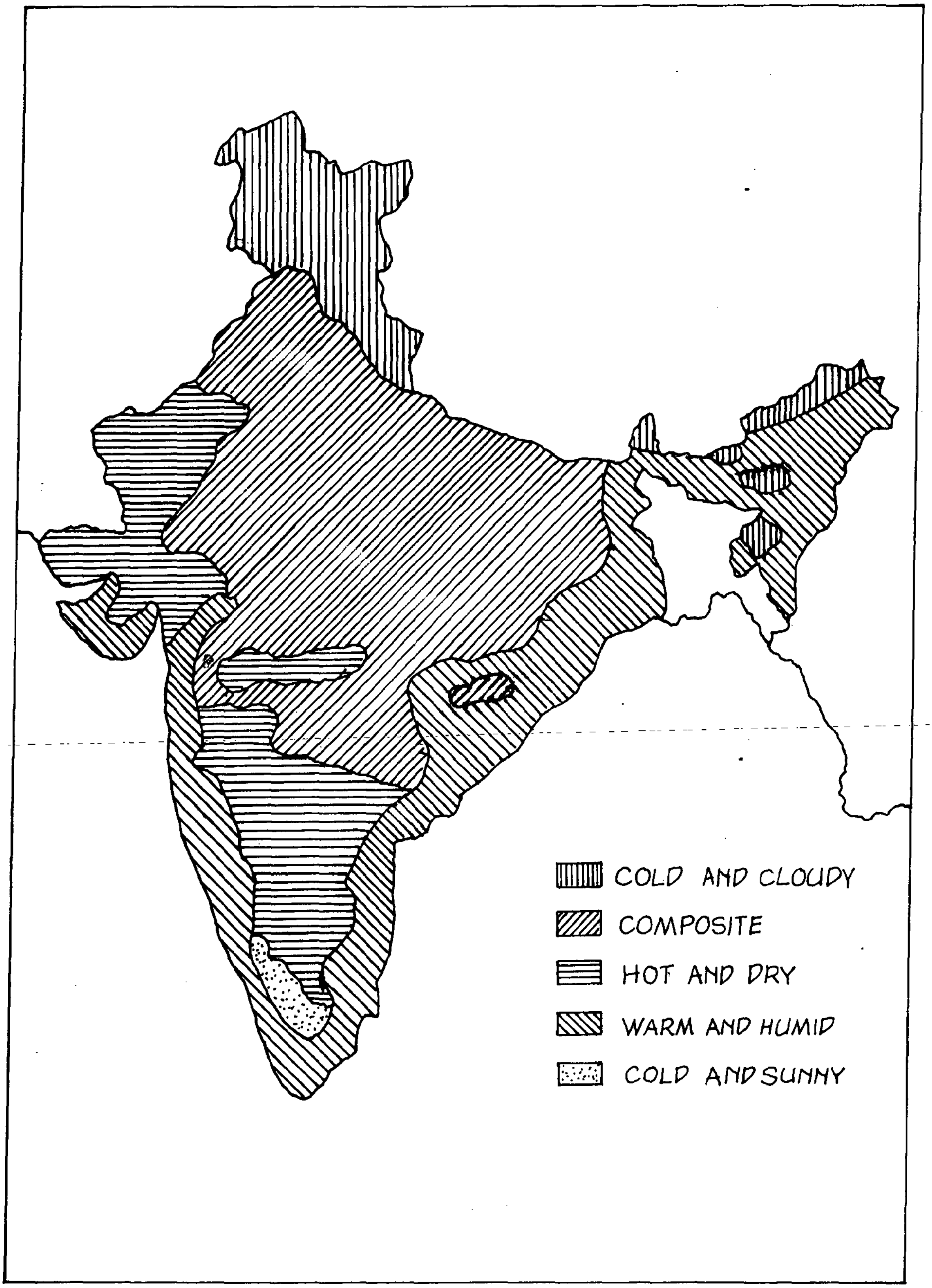


Figure 2.2: Climatic Zones of India (Source: CBRI)

2.2.1 Winds.

The winds over the State are seasonal only in the region of Palghat Gap where winds are predominantly from the east in the period from November to March and from west in the rest of the year. In other parts of the State flow of wind is mainly governed by differential heating of land and water mass together with mountain wind. Only during July, August and strong monsoon period, prevailing conditions do not permit the diurnal cycle of winds to exist. With these exceptions, winds have westerly component during the day and easterly component during the night throughout the year.

In general winds are quite strong during afternoons when the thermal circulation is best developed and weak during night. Table 2.1 gives the monthly mean daily wind speed in km per hour for Kozhikode, Cochin and Trivandrum. The predominant wind direction in the morning and evening are given in Table 2.2 and 2.3.

2.2.2 Temperature

Day temperature are more or less uniform over the plains throughout the year expect during monsoon months when these temperatures drop down by about 3 to 5 degree C. Both day and night temperature are lower over the plateau and at high level stations than over the plain. Day temperatures of coastal places are less than those in interior places. Both the diurnal and annual ranges of temperature are quite narrow.

Mean maximum temperature is minimum in the month of July when the State receives plenty of rainfall and the sky is heavily clouded. It is then an average of 28.5 deg. C. for the State as a whole in July, varying from 28 deg. C. in the north and 29 deg. C. in the south. Table 2.4 gives the mean daily maximum and Table 2.5 gives daily mean minimum temperature of three major towns.

2.2.3 Humidity.

Relative humidity remains always high at about an average of 75% for most of the time, varying from 60-95%. Table 2.6 gives the mean relative humidity at 0830 and 1730 hrs. IST for three major towns of the State. Because of closeness to the sea the humidity is always higher. It rises even further to above 80% in the monsoon period.

2.2.4 Rainfall.

Precipitation is high throughout the year, generally becoming more intense for several consecutive months. The total annual rainfall in the State varies from 380 cm. over the extreme northern parts to about 180 cm. in the southern parts. The '*Edavappathi*' or the south west monsoon (June- mid October) is principal rainy season when the State receives about 73% of its annual rainfall. Monsoonal rainfall as percentage of annual rainfall decreases from north to south and varies from 85% in north to 54% in south.

Rainfall in the *'Thula Varsham'* or the north east monsoon season (mid October to December) contribute the rest. Table 2.7 gives the mean monthly and annual rainfall and Table 2.8 gives the monthly and annual number of rainy days.

2.2.5 Special Characteristics. [4]

If we analyze the sun-path diagrams for all the latitudes closely, we can see that at the equator the sunrays come from northern side for exactly half the year and for the other six months the sunrays come from southern side. And the regions north of tropic of cancer will not get much sun from northern side and similarly the regions south of tropic of Capricorn will not get much sunlight from the southern side. [Figure 2.3]

Table 2.1 Mean Wind Speed in Km.p.h

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kozhikode	9.4	11.4	12.3	12.6	12.5	9.8	9.2	8.9	8.7	8.8	8.1	8.3	10.0
Cochin	8.0	9.3	10.6	10.7	10.9	9.1	9.6	9.9	9.1	7.8	6.7	7.1	9.1
Trivandrum	5.1	5.9	6.6	7.8	9.2	9.6	10.9	11.2	10.4	7.3	5.5	4.8	7.9

Table 2.2 Predominant Wind Direction * in the morning and during day

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kozhikode	E	E	E/NE	NE/E	NE/NW	NE/E	Var	NW	NW	E	E	E
Cochin	NE/E	NE/E	NE	NE	NE/E	E/NE	Var	Var	NE/E	NE/E	E/NE	NE/E
Trivandrum	NE	NE	NE/E	N	N/NW	NW/N	NW	NW/N	NW/N	N/NW	C/NE	NE

Table 2.3 Predominant Wind Direction* in the evening and during night

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Kozhikode	W	W	W/NW	W/NW	W/NW	W/NW	NW/W	NW	NW/W	W/NW	W	W
Cochin	NE/E	NE/E	NE	NE	NE/E	E/NE	Var	Var	NE/E	NE/E	E/NE	NE/E
Trivandrum	SW	SW	SW	W	NW/W	NW	NW	NW	NW	NW/W	SW/W	SW

* Wind 'from' this direction to opposite side (i.e. 'E' means wind from east towards west)
Var: Variable C: Calm (The next predominant direction is also given when calm is mentioned)

Table 2.4 Mean Maximum Temperature (degree centigrade)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kozhikode	Max	31.7	31.9	32.6	32.9	32.5	29.5	28.2	28.7	28.3	30.4	31.1	31.6	30.9
Cochin	Max	30.6	30.7	31.3	31.4	30.9	29.0	28.1	28.1	28.3	29.2	29.8	30.3	29.8
Trivandrum	Max	31.3	31.7	32.5	32.4	31.6	29.4	29.1	29.4	29.9	29.9	30.1	30.9	30.7

Table 2.5 Mean Minimum Temperature (degree centigrade)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kozhikode	Min	22.0	23.1	24.7	25.8	25.6	23.8	23.3	23.6	23.7	23.8	23.4	22.2	23.7
Cochin	Min	22.2	24.3	25.8	26.0	25.7	24.1	23.7	24.0	24.2	24.2	24.1	23.5	24.4
Trivandrum	Min	22.3	22.9	24.2	25.1	25.0	23.6	23.2	23.3	23.3	23.4	23.1	22.5	23.5

Table 2.6 Mean Relative Humidity (%) at morning (M) and evening (E)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kozhikode	M	74	76	74	75	81	90	92	92	88	85	80	75	82
	E	64	66	69	71	76	85	89	86	82	78	72	64	75
Cochin	M	68	72	74	75	81	88	89	88	84	83	78	71	79
	E	64	68	70	74	78	84	87	86	84	80	74	66	76
Trivandrum	M	77	79	80	81	84	90	89	88	86	87	87	80	84
	E	63	63	66	73	77	82	81	78	77	80	78	69	74

Table 2.7 Mean Rainfall (mm)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kozhikode	10.4	7.6	20.0	92.4	254.1	944.5	1117.4	599.2	262.4	290.2	163.7	34.2	3796.1
Cochin	16.8	22.6	51.6	129.5	308.4	796.1	785.3	518.0	293.9	359.7	212.6	54.2	3548.7
Trivandrum	24.1	18.9	45.7	117.2	201.9	351.1	222.0	149.3	137.6	283.2	213.0	69.9	1833.9
All Kerala	18.1	17.3	42.9	111.6	244.9	676.3	695.5	417.2	234.6	305.2	187.9	49.5	3001.0

Table 2.8 Average number of rainy days (days with rain of 2.5 mm or more)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kozhikode	0.7	0.4	1.3	5.5	9.9	24.5	27.2	22.0	14.0	12.6	7.5	2.0	127.6
Cochin	0.8	1.1	2.9	7.2	12.0	25.1	25.7	21.8	15.1	14.9	9.9	2.7	139.2
Trivandrum	1.7	1.2	2.8	6.8	9.0	17.0	14.6	10.0	8.4	12.5	10.3	4.0	98.3
All Kerala	1.1	1.0	2.5	6.4	10.2	22.6	23.5	18.9	13.0	13.6	9.0	2.7	124.5

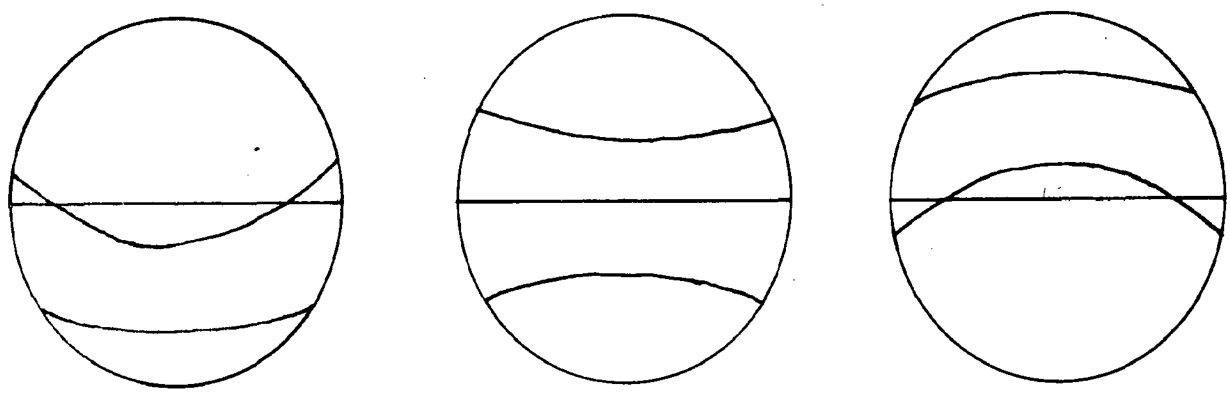


Figure 2.3: Sunpath Diagram at 40 North, Equator and 40 South Latitudes

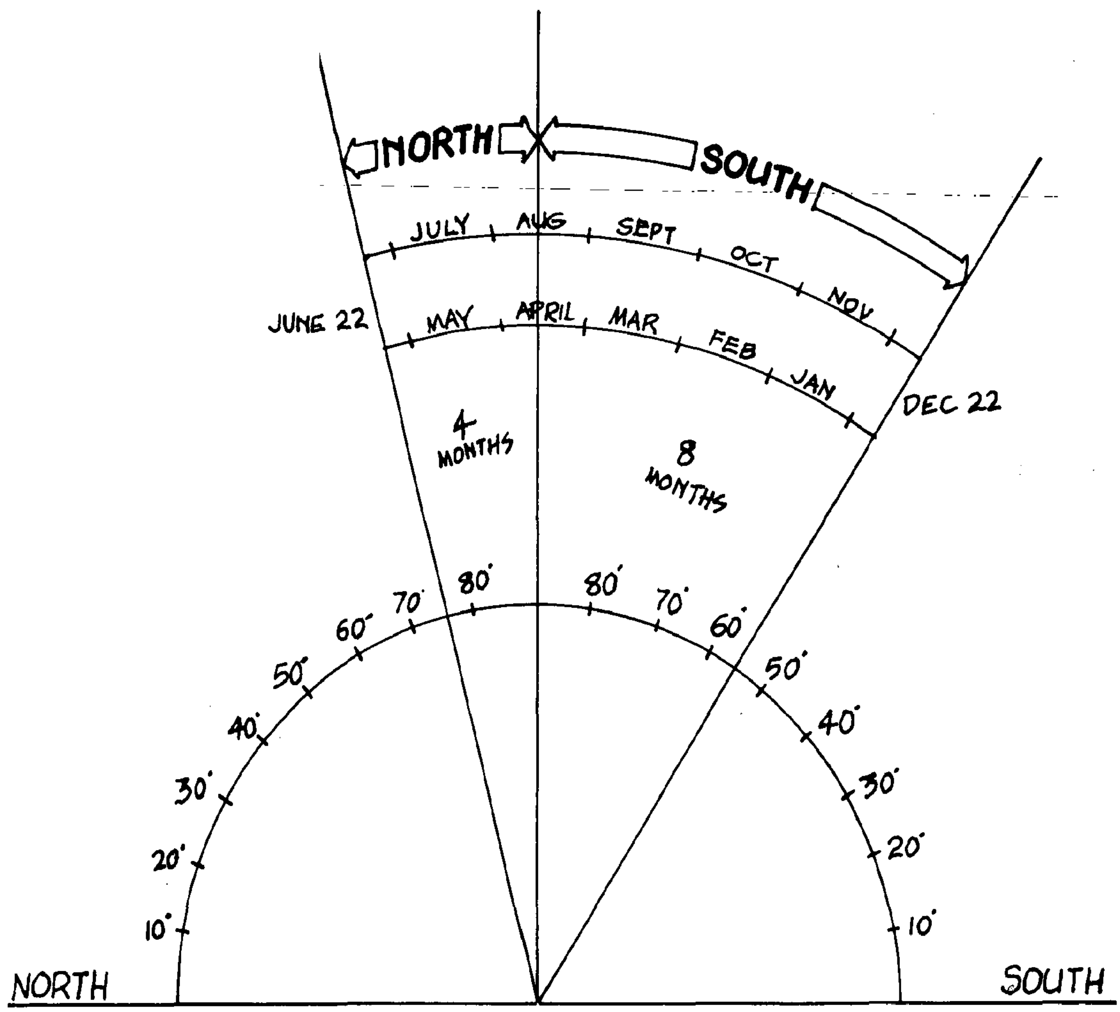


Figure 2.4: Section through Sunpath Diagram at 9 North latitude

This is because of the diurnal movement of the sun, which intern happens due to the tilt of earth's axis by 23.5'. But the places in between the tropics, gets both southern sun and northern sun. The region south of equator, but north of tropic of Capricorn will get more northern sun and less southern sun. And similarly the region north of equator but south of tropic of cancer gets more southern sun and less northern sun.

Kerala which comes between 8'11" to 12'48" north latitudes, so get both northern and southern sun. In fact Kerala gets some seven and half months of southern sun and four and half months of northern sun. But what needs more attention is the fact that even in the months of April and may, comparatively hotter months, Kerala is exposed to the northern sun. It is evident if we take a section of solar chart at 9' N latitude. [Figure 2.4] Solar charts for Kerala are given in Appendix I.

So in Kerala it is very important to protect the northern facade also with sunshades, which can be logically avoided in northern India. Because northern sun is not at all a possibility here. But of course 'sun'shades are not just to protect sun only and so it is used there in north facades also for other reasons. But in a hypothetical condition where it is used only for protection from sun, it can be avoided on the northern facade in regions lying north of tropic of cancer.

Therefore while designing and constructing buildings it should be kept in mind that in the months of April and May, comparatively hotter months, Kerala is exposed to northern sun.

2.3 Thermal Comfort Needs.

Passive systems for any building should be designed considering all the criteria's needed for thermal comfort of that particular geographical area, which are completely defined by its micro climate. Of course the climate of any place is defined by the solar radiation it receives (both intensity and direction), temperature, humidity, rainfall, air movement, vegetation etc. which all varies from place to place and latitude to latitude. So needless to say that the passive systems needs for Kerala's climate will be different from that of other parts of India.

The most prominent characteristics of Kerala's climate are the hot, sticky conditions and continual presence of dampness. The temperature remains moderately high, between 21 and 32'c, with little variation between day and night and it seldom exceeds normal skin temperature. Humidity is also high during all seasons varying from 60 to 95%.

Heat is being continuously produced in the human body, most of the bio-chemical process involved in tissue-building, energy conversion and muscular work produce heat. And of all the energy produced in the human body 'only about 20% is utilized, the remaining 80% is 'surplus' heat and must be dissipated to the environment' [5] because the deep body temperature must be kept balanced and constant and also if there is any simultaneous heat gain from the surroundings to the body that also must be dissipated. The body does this by conduction, convection, radiation and evaporation.

Human comfort occurs when the heat flows in the human thermal system are balanced. The internal body temperature of human being is within the narrow range of 36.5'c to 37.5'c (98.4'F) and skin temperature is about 30-35'c. One mode of heat loss is evaporation, the evaporation of moisture into exhaled air and the evaporation of moisture from skin. If the rate of heat loss exceeds the rate of heat production and gain, we begin to feel cool.

Evaporative cooling takes place when the water changes from liquid to vapor. But the limit of temperature reduction by this process can be only up to the air's wet-bulb temperature at the beginning of this process, which means direct evaporation cannot cool below the wet-bulb temperature.

In Kerala where this temp difference is less because of high relative humidity of the region. The air we live is a mixture of dry air and water vapor called moist air. Although the amount of water vapor in air is very small, its effects are great. The rate at which our body can use evaporation for cooling is directly determined by the relative humidity- a measurement of this water vapor content- around us. If there is more relative humidity the evaporative cooling would be naturally less.

So in Kerala where the air temperature is continually very near to skin temperature, bodily heat loss to air by convection or conduction is negligible. As far as evaporation is concerned, even the evaporation of small quantity of moisture from the body would form a saturated air envelope, because of high humidity already present, which prevents any further evaporation and there by blocking this last resort of heat dissipation.

But this saturated air envelope can be removed or carried away by air movement and some degree of comfort can be achieved by encouraging out-door breezes to pass not only through building, but across the body surface of occupants. This is, in fact 'the only way of ameliorating thermal conditions'. [6] So all possible steps should be taken to ensure that every possible breadth of air movement will reach our body, to remove this body heat - this is the same reason why we feel more comfortable under a fan. The orientation of room and positioning of windows play a key role in channeling wind through the building. Maximum effort should be given to get cross ventilation so as to let air pass through the room, at body level.

In Kerala with 60-95% relative humidity there fore evaporative cooling is not much beneficial under normal air velocity inside the room. But evaporative cooling can be increased if the air movement inside the room is increased. This can be done only by proper cross ventilation at body level.

2.4 Inferences.

So the objective for any passive technique, to achieve thermal comfort in Kerala, must be basically by two ways:

1. Reduce heat gains into the building by cutting off solar radiation as much as possible from falling into building through windows and also on the exterior envelope (there by avoiding/reducing heat to built up indoors).
2. To produce more possibilities to let wind/air pass through the building, those too at body height of occupants (there by increasing heat dissipation from body through evaporation).

CHAPTER 3
ENERGY SCENARIO

3.1 Introduction

Energy is the basis of human life. There is practically no activity in today's world which can take place without invoking the transfer of energy in some way or other. When we cook our food, or sitting comfortably under a fan, or while driving our cars and scooters, or even while sipping a coffee, some fuel is burned somewhere to make it happen, but only we never realize this.

Earlier we didn't even bother about it. But in October 1973, when oil producing Arab states announced that they would cut down the output of oil from oil wells in middle east, people every where suddenly realized how vital oil has become in their daily life. The crisis increased when the 13 member OPEC increased the price of oil tremendously. The cost of one barrel (156 liters) increased from around 10 US$ IN 1973 and went to a peak of around 50 US$ in 1981. [Figure 3.1] The television and newspaper people coined a catch phrase to sum up the situation: "The energy crisis". Although today the price has come down to around 14 US$ the crisis taught one thing to the world; the value of energy.

It reflected in the construction sector also as it was recognized that energy use in buildings was a significant proportion of a developed country's energy consumption. It is almost '40% in USA, 30-35% in OCED countries and 10-18% in underdeveloped countries'. [7] This knowledge produced a new interest in the 'energy efficiency' aspect of building design.

The word 'energy' derived from the Greek *energeia: en* means 'in' and *ergon* means 'work' [8]. So the word would mean something like 'in work'. Actually it's very difficult to define energy precisely. In school we learn that energy is the capacity to do work or energy is what's used when work is done. It means that no work can be done with out some energy being used.

All energy, well almost all energy, comes from the sun. When we lift a book we use energy which comes through our muscles and it got there from the food we eat and which got into the food from some plant cell we consumed (by direct consumption in vegetarian food, and by indirect consumption in non-vegetarian food). And the plant cell got it, or rather processed this by converting the solar energy into chemical energy by the process of photosynthesis. So the food is nothing but the radiant energy of the sun stored up in plant cells as chemical energy. This is true for almost all energy sources.[Figure 3.2]

3.1.1 Conventional Sources of Energy.

Primitive man had only his own muscles to help him convert this energy into useful work. In fact in the beginning of history he had only two sources of energy; one was the radiant energy of sun light, which gave him warmth and the other the food he ate, which again, as we saw got it from the sun.

When he discovered fire, all he managed to do was to find a quick method of converting this chemical energy stored in the cells of woods to heat energy. He then found various uses of this heat energy and was dependent on it for a very long time. Actually in 1698 when Thomas Savery, an English man, patented the first steam pump it was powered by wood fire.

In 18th century man discovered coal, 'which is the buried remains of timber forests, millions of years old. When he discovered coal and later oil and natural gas, all he had done was to find new stores of chemical energy. When we burn coal we are only releasing the stored chemical energy, which originally came there from the sunlight'.

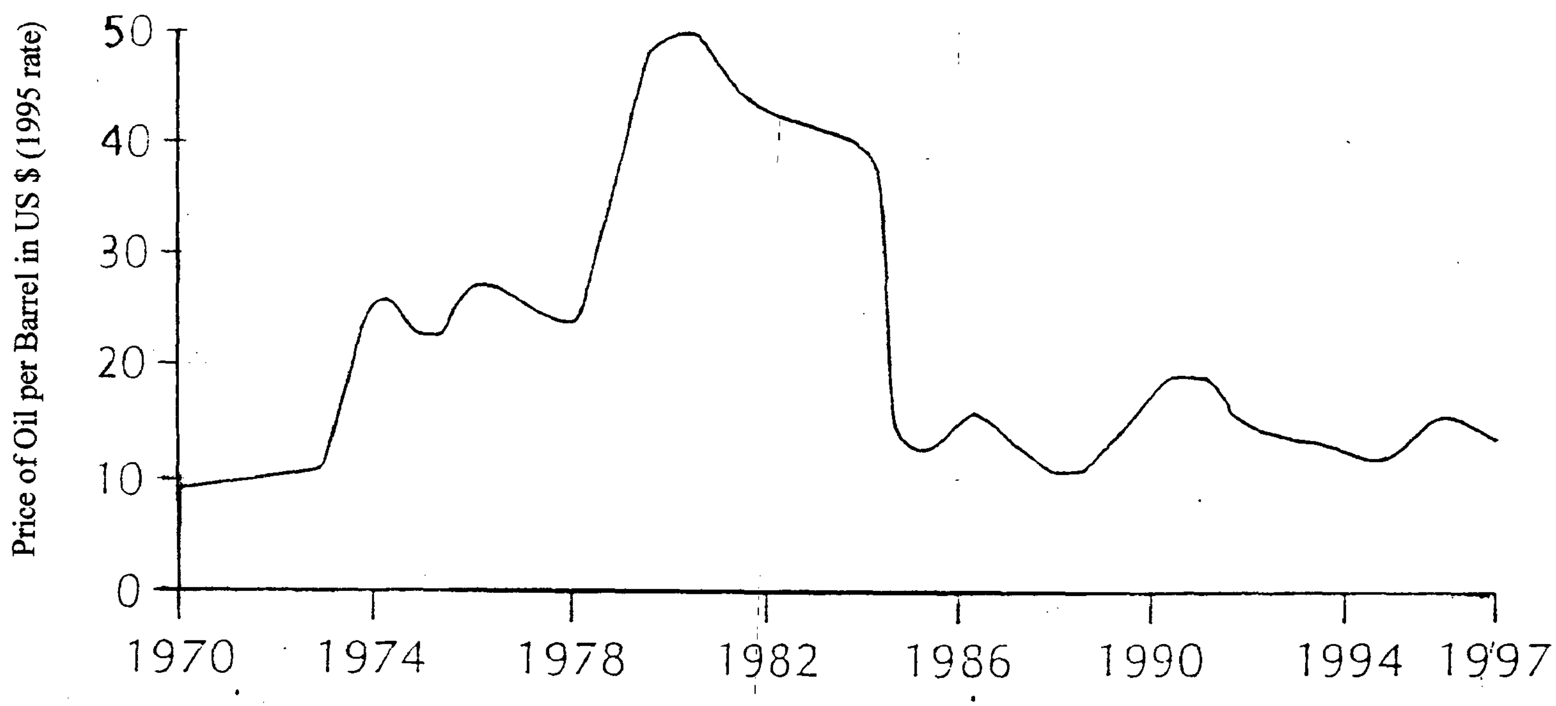


Figure 3.1: International Oil Prices (Source: TERI)

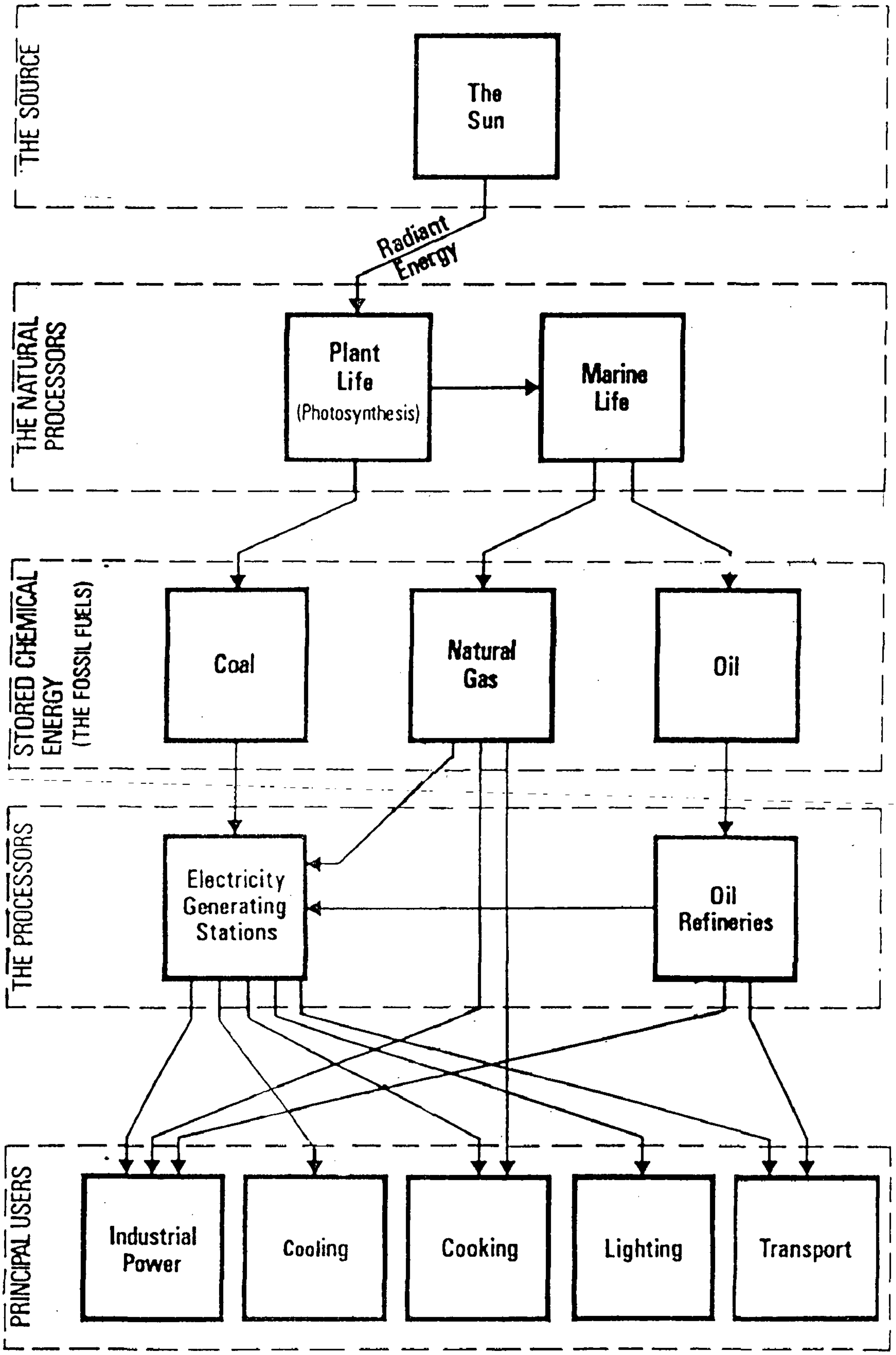


Figure 3.2: Energy Use in Life for Warm-humid Regions

'Oil is again much the same, plant life of prehistoric age stored radiant energy from the sun; marine organisms used these plants as food and the chemical energy not used by these for its sustenance remained in their dead bodies which were buried, layer upon layer, over an immense period of time. It is the remains of these early living organisms which has rotted down eventually to form mineral oil, with its chemical energy preserved'. [9]

Now when he had new stores of stored chemical energy, soon he found new ways of making use of it. The production of coal gas was one, and with the aid of the gas 'mantle' the chemical energy of gas could be turned into the radiant energy of light. Gas lighting became popular and soon he started to use it to bring light to his house and other places.

Then man found how he could convert heat energy into mechanical energy by means of the steam engine. He improved the wood powered early steam pump and coal proved to be more efficient fuel and before long the coal-fired steam engine was being used not only to pump water but also to drive the railway locomotive and to power the machines which were needed more and more in man's new factories. And the Industrial revolution swept the world and the use of fossil fuels (a collective term used for coal, oil and natural gas) increased drastically.

It would be more evident from if we look at the figures. 'During the first 200 years coal mining worldwide rose to a little over 750 million metric tones each year. It then took 40 years for this output to double, and only 30 years more to double once again to a remarkable 3000 million metric tones'.

'In the case of oil, production accelerated even faster. Within 1 year, the first oil well proved a commercial success 74 more was drilled. By 1914 the annual production in US alone was 60 million metric tones, within 25 years, in 1939 it multiplied by 4 and by

1970 it became about 686 million metric tones. And this was only one-third of world production'. [10]

'The case of natural gas, from the modest start with the heat equivalent of gas obtained from underground in US in 1910 was, about 1000 trillion BTU. By 1945 it has grown tenfold and by 1973 it was 20,000 BTU'. [11]

Of all forms of energy the one we are dependent most today is electricity. In 1791 Alessandro Volta, an Italian physics professor, invented the electric battery. It was a device, which converted chemical energy into electrical energy. It sparked off a great deal of research in the new science of electricity and within a hundred years the electric motor and the dynamo was invented. Now electrical and mechanical energy were interchangeable, and heat energy could be converted into electrical energy by using it to power a steam turbine which turned an electric generator. The demand for the fossil fuels increased further.

Soon man developed hundreds of new ways for making use of this new form of energy. He used electricity to light his house and to bring thermal comfort to him by electric fans and later fans were replaced by air conditioners. But this caused a subconscious change in his approach to building construction. Earlier his traditional vernacular houses were to be designed to give thermal comfort and illumination to the occupants inside. And now with the electric fans, air-conditioners and electric lights, he choose to ignore the traditional concepts in house design in his belief that the coal and oil will always be there to give him the comforts.

And by the time he realized his mistake, after the oil shock of 1970's, the traditional concepts were almost forgotten and what has managed to crept through were already being labeled as superstition and non viable.

3.1.2 Non-Conventional Sources Of Energy.

The figures of fossil fuel consumption given above are so enormous that reasonably one wonders how long these will last. Estimates, mostly 'guess'timates, vary widely, but it is certain there is enough coal to last us several hundred years. But situation is different in case of oil and natural gas, many believe that all our reserves will be over with in 20 or 30 years, although many new oil fields have been found.

The reduction in oil production imposed by the Arab oil-producing states in 1973 only brought the so called energy crisis into the lime light and research had been directed to the task of finding alternatives. These researches had brought out a number of other sources of energy. [Figure 3.3]

1. The Fossil fuels: We already saw that although coal may last for some several hundred years, the situation of oil and natural gas is very different. Many believe that all our reserves will be exhausted within 20 or 30 years.

2. The Biological Materials: This includes the wood, animal dung, methane gas, peat etc.. But they have but a limited use and can not be used for large-scale power production. And further though it can be used for room heating, it's not possible with today's technology to use it to cool rooms.

3. The Solar Radiation: This is by far the virtually unlimited supply. About 2 million TW (a tera watt is a million million watts) of solar energy fall at all the time on our planet. An average of 1kW of heat falls on every Sq.m of earth, which can be effectively used directly for water heating (but of course it has limited application in warm-humid climate)

Another major use is through solar cells, which directly converts radiant energy of the sun into electrical energy. Like the solar panels of a satellite to produce the electrical energy needed for its use, in theory it can be used in land also in large scale 'solar farms' to produce enough electrical energy needed for our use.

This would be one which can give totally 'free' and 'pollution less' energy. But with present day technology the main problem is the immense capital cost associated with this. (Solar energy is free but the equipment to convert it to useful form is very expensive).

4. The Wind Power: This is obtained by rotating a small generator with the movement of wind. This technology is already in wide use. There is, however, a problem of finding the right places where sufficient wind flow is there to make the rotation possible.

But the energy of all the winds that blow steadily over the earth can never provide more than a fraction of modern world's need.

5. The Hydroelectric Power: The theory behind this is that, an ordinary electric motor can also be used the other way to convert mechanical energy into electrical energy. When first electric generators where put to use, steam engine was used and coal was the fuel. Then a German engineer thought, why can't it be powered with a water wheel, the result would be, in theory, free electricity.

His idea was demonstrated, though little noticed then, at the 1882 Munich exhibition, where an electric motor was kept continuously running. But today it is the most popular way of producing electricity across the world, water held by big dams is allowed to flow and water's potential energy is converted to electrical energy in a major way.

Some of the problems associated with hydel projects are that it would submerge a lot of fertile cultivate land, life of the dams are reduced by silt fill, it will make the area more prone to earthquakes, the resolution of problems associated with land acquisition,

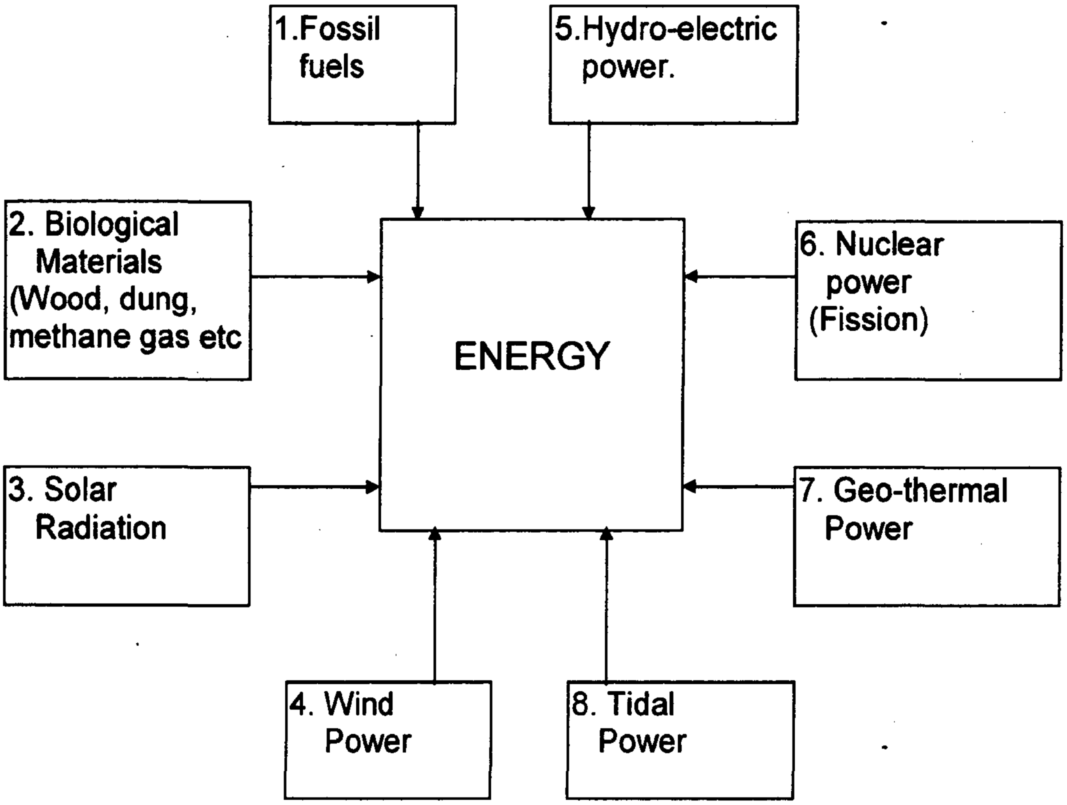


Figure 3.3: Different available sources of energy

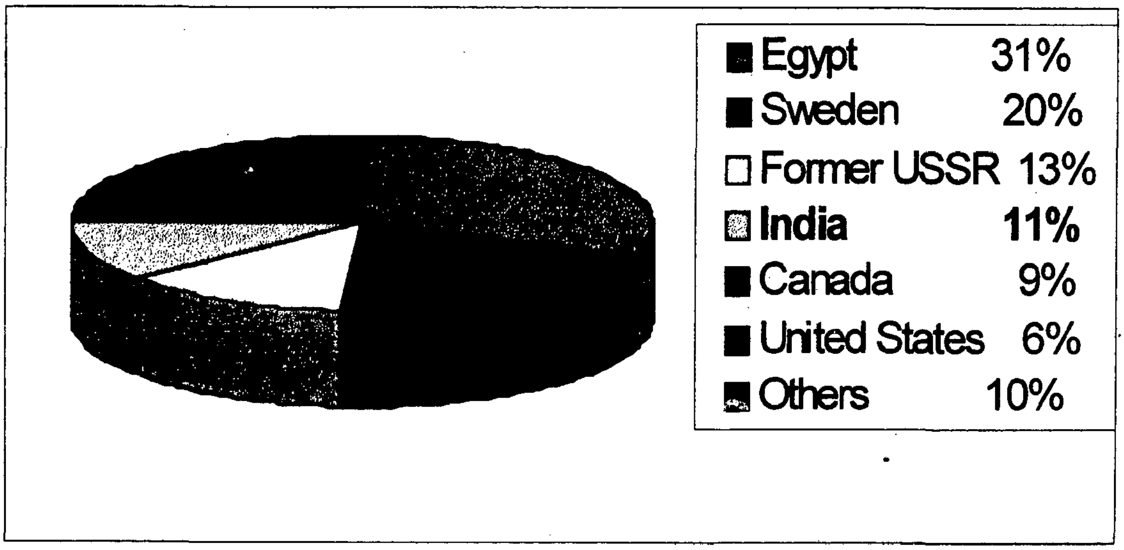


Figure 3.4: Global Nuclear Fuel Share

resettlement and rehabilitation, the inter state issues and the environmental and forest clearances etc.

6. The Nuclear Power: This is obtained from the energy stored in the atom. India has immense potential in nuclear energy use because we have fourth place in the world store of nuclear fuel. India has 11% of Uranium/ Thorium oxide store, the current nuclear fuel of the world. [Figure 3.4]

But the main problem associated with this is that the nuclear reactor fuel does not 'vanish' as it 'burns'. Even after removal of all remaining Uranium (or plutonium) from spent fuel rods, a considerable amount of 'highly radioactive ash', which lasts so for at least 100 years, is left which has to be disposed off somewhere.

The question of this disposal presents a serious problem. It is estimated that by the year 2000 AD, the nuclear power stations around the world would be producing 2,00,000 cubic meters of radioactive waste every year. Although production of electricity from by fusion (of hydrogen) is supposed to be cleaner, scientists generally agree it is not going to happen in the near future.

Also in a place like Kerala where the density of population is very high finding a proper place for implementation of a nuclear power scheme would be even more difficult.

7. The Geo-thermal Power: This is obtained by tapping the heat generated all the time in the core of the earth. This type of power production was started in 1904 in Italy. Now other than Italy, New Zealand and California also uses it in a substantial way. And more research is currently going on in California and it is confidently believed that it will soon be feasible to build geothermal power stations almost anywhere in the world.

8. The Tidal Power: Tidal power is obtained by converting the energy of motion of the ocean's water into electrical energy, by using a special form of turbo-generator. Tidal energy is 'free' and non-polluting and it could, in theory, produce half of our total energy demand.

But there are relatively few sites where the tides are high enough to make the investment worthwhile, for a tidal power station is very expensive, and it is inefficient if the tidal rise and fall is low.

3.2 Is The Energy Crisis Over?

It can be argued in the light of these alternative sources energy, which are available in quantities immensely greater than our foreseeable need, that if they are made use of then there is no energy crisis today. And if we are temporarily short of energy it is the fault of our planners who have failed to direct the research in the directions needed of the time.

And also, another line of thought can be, the 'energy crisis' which has been caused artificially by the action of some major oil producers is equally artificial because unlimited supplies of non-conventional energy lie around us.

Does this all means that the energy crisis is over now ? Well, the answer is no. Because most of this alternate sources comes with a tag attached; immense capital cost, not enough availability, makes solid radioactive waste byproducts, etc. And also the energy crisis taught us some important lessons:

1. The conversion of energy into electricity or motor power is highly polluting.
2. It places a heavy burden on our economy, which makes the total dependence on processed fuels less and less viable.
3. The conversion produces a lot of byproduct waste, dumping of which will be a major problem sooner or later.

4. Carbon, one of the byproducts of fuel conversion is increasing in the atmosphere in a very alarming rate and it has become important to free the world from fetters of carbon.
5. Recurrent tanker oil spills often cause major ecological disasters and ruin fisheries.
6. And above all the Global warming; the green house gas emissions which are accumulating in the worlds atmosphere because of the fossil fuel conversion, is threatening to overheat the earth.

The 'Global warming' is one of the most prominent problems facing humanity today which even has the potential to wipe out humanity. [Figure 3.5] Scientists are giving repeated warnings against this: 'The year 1998 is all set to be the hottest year of this millennium, the latest global temperature measurements show. Thousands of readings from satellites and weather stations across the globe have confirmed that the world has been warmer this year than at any time since 1880'. [12]

The principal reason for this is the increasing quantity of green house gases in the atmosphere. 'Although acid emissions have drastically reduced in most industrialized countries, they are increasing in developing countries, especially those such as China and India, which have ample domestic resources of coal and use this to fuel their much needed growth'. [13] The main concern is over carbon mono and dioxide, chlorofluoro carbons, methane, sulphur dioxide, nitrogen oxide, various hydrocarbons, fly ash and suspended particles.

Usually the input of solar energy to the earth is balanced by an equal output of infra-red radiation towards outer space. But the increased presence of greenhouse gases brings about a larger number of absorptions and re-emissions of infra-red photons into the atmosphere and the net result is an increase in temperature on the earth's atmosphere. Carbon dioxide is by far the most important of these gases. Now with the scientific progress today it has been able to measure quite accurately the concentration of carbon dioxide in the atmosphere. [Figure 3.6]

So in the light of all this today the question is not how long the fossil fuels will last. But even if the conventional sources of energy lasts for say, 50 or 100 years to come, should we go for it now that we know the bad side effects of it.

3.2.1 Transition To Alternate Energy- Problems.

But the current process of economic growth of a nation is so intensely linked to the use of fossil fuels, which are the biggest source of green house gas emissions. Higher the consumption of conventional energy sources, higher is the GNP.

And another alarming sign is that after 1981 the prices of oil has started to come down and now the price of oil is falling to an all time low. These means that the transition to solar or other sustainable power sources may be delayed even further, although scientists are working on it.

Our experiences in resent times, like the Pokaran II for example, has shown that our scientists- researchers can also find a solution to any problem. If we are temporarily short or lagging behind other developed countries in the development of alternate sources of energy it is the lack of our planners who have failed to direct the research in the right direction at the right time.

Looking at the overall national policies, it can be seen that it is unlikely to happen soon. For example if we just look at the 1998/99 Union Budget's planned allocations of funds in the development of alternate energy sources the picture would be more clear. It is no surprise that in a country competing for nuclear weaponisation the allocation for the department of atomic energy should almost double from Rs 1391 crore in 1997/98 to Rs

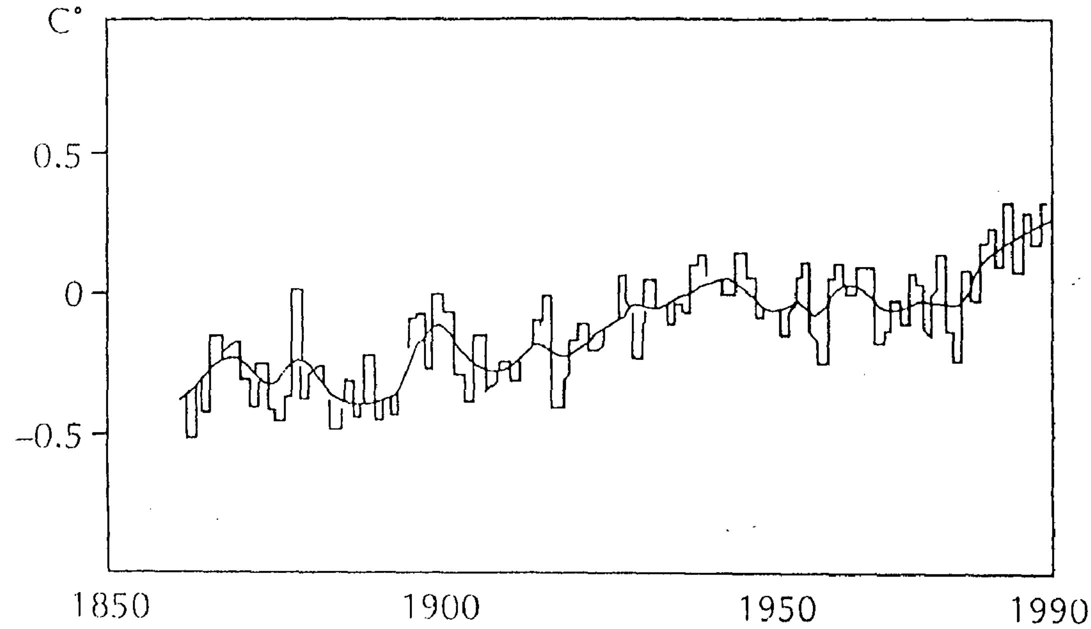


Figure 3.5: Variation of Global Average Temperature (Source: TERI)

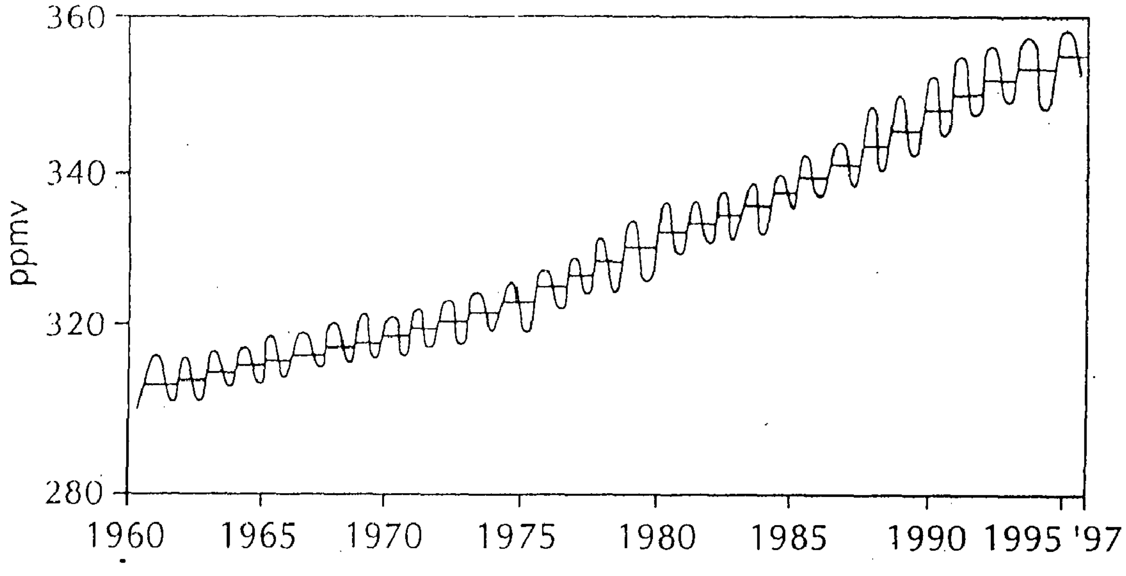


Figure 3.6: Carbon Dioxide Concentrations in Atmosphere (Source: TERI)

2608.06 crore in 1998/99, but experts are skeptical how much of this money would be channalised towards the benevolent use of nuclear energy.

But compared to this increase in fund, the Ministry of non-conventional energy sources has been practically neglected. The total plan and non-plan expenditure budget for 1998/99 has been increased by just four crore, (Rs 407.62 crore in this area against Rs 403.02 crore in 1997/98) at a time when more and more countries all over the world are pooling more resources for research and development of non-conventional energy.

Other than the Indian Renewable Energy Devolopment, whose funds have been hiked from Rs 408.17 crore in 1997-98 to Rs 516.68 crore in 1998-99, all other departments and programmes have been sacrificed to meet the challenge of sactions induced cash crunch.

Allotments to the solar energy programme have gone down from Rs 56.57 crore to Rs 48.90 crore. Allotments for biogas programme have gone down from Rs 66.65 crore to Rs 62.34 crore. Allowtments for biomass programme have gone down from Rs 13.05 crore to Rs 12.15 crore. So it all shows that there is going to be 'an energy crisis' sooner or later.

3.3 What Is The Solution ?

Let's see how the other countries are trying to solve this problem. We have already seen that they have started to pool more and more money into the devolopment of alternate sources of energy. But other than that they have all come up with new laws to be enforced on the energy usage.

Today all thinkers agree on one solution which could provide one significant contribution to the energy shortage; Control of wastage of energy or the use of available energy in a more efficient and sustainable manner: **The Energy Conservation**.

BUT WHERE ?

As stated earlier, if we analyze the sector-wise energy consumption of 3 major consumers of commercial energy in India it can be seen that; 52% of the total energy used is consumed by the industrial sector, 23% by the transportation sector and 11% by the residential sector. But it is to be noted here that this 11% does not include the energy used for production and processing of building materials, transporting raw materials to factories and finished materials to site and the energy used for construction activities etc., which is accounted with the industrial and transportation sectors. So the actual total energy consumption would be much higher.

If we analyse the sector wise energy consumption, it can be seen that the energy use in buildings was a significant proportion of a developed country's energy consumption. 40% in USA, 30-35% in OCED countries and 10-18% in underdeveloped countries.

There are various areas where conservation of energy can be achieved. But if out of the total energy produced a substantial part of it is consumed by the buildings, then an effective energy conservation system in building design and construction will have a major impact on national energy situation.

It is claimed that just the renovation of a building can save up to 30% of its energy consumption and a properly planned building will rise this saving by 50%. So the 'energy efficient building' is one major area which response to this need.

3.4 Energy Efficient Building

Now if we analyze where all does the energy goes into a building, it can be seen that it happens in two stages: The Construction stage and The post Construction Stage.

But there is also another stage which influence this: The Pre-Construction Stage or the design stage.

The Pre Construction Stage is actually the most important stage because all the major design decisions are taken and material choices are made in this stage.

The Construction Stage or the implementation stage is where energy is physically used, mostly as solid energy content in the building materials. In this stage energy is also used for actual construction; as human energy and also as electricity etc.

The Post Construction stage or the period after the building becomes the abode of its occupants, energy is used by the occupants for lighting, cooking, thermal comfort and also to run other electrical appliances. Electricity is the main energy used here.

United Nations ECE energy series defines energy efficiency as the "capacity to produce better results with a minimum expenditure of energy input" [14]. A building is said to be energy efficient, when it is built of materials which consumed less energy for its making, and transported to the site from a minimum distance (thus reducing the energy spent on transporting); or the energy input gone into the construction is less. And also one where the energy input needed to the sustenance of the building, like to keep the occupants in thermal comfort, to meet their illumination needs, cooking needs, etc. Are minimum and it is also cost efficient.

So the design criteria's for a truly energy efficient or low energy house would be in:

1. Minimizing the solid energy content of the building, through appropriate selection of low energy content materials.
2. Minimizing the energy requirement from conventional sources for thermal comfort and services by passive techniques.
3. Integration of solar energy into design.

4. Integration of biogas for waste recycling into planning.
5. Integration of biomass into landscape.

An architect can contribute to this basically by two ways;

(a) incorporating passive systems of thermal comforts into design and

(b) by constructing the building with low energy materials.

3.4.1 Passive techniques

Donald Watson in the introduction of his famous book 'Climatic Design' says, "Climatic design is the one approach by which to reduce the energy cost of a building comprehensively; the building design is the first 'line of defense' against the stress of outside climate. In all climates, buildings built according to climatic design principles reduce the need for mechanical heating and cooling by using 'natural energy' available from the climate at the building site" [15].

Today mechanical fans and air conditioners, which consume a lot of energy, are often required in many buildings in any warm- humid regions simply because of its improper window locations or the lack of proper shading, which practically makes the building a solar oven in summer.

Even during the months when it is quite comfortable outside, an improperly designed building can be very uncomfortable due to the designer's lack of proper understanding of climatic design principles and practices. So its essential for all architects working in any particular climate to understand how a building can take the advantages of sun, breeze, vegetation, etc. and creates a unique micro-climate of its own.

Basic design goal of any residential building is to create a comfortable living environment to carry out desired functions, and one of the most important factor which contributes to this comfortable living is the thermal comfort inside the building. But usually while designing/ constructing the building, the thermal comfort factors are often overlooked or neglected and on the end we all depend a lot on mechanical systems for this comfort, like fan, A/c etc., which consumes a lot of energy (electricity). In Kerala, as in many other parts of India, where the energy crisis is on the higher side, its high time to re-evaluate this factor and give more weightage to the techniques of achieving this goal with out such mechanical equipment.

Architects/ students of architecture must be understood the importance of passive systems- the term used for the techniques for achieving thermal comfort, if not completely at least partially, with out the input of energy- and must realize that passive systems should be an integral part of any building design and not an addition.

3.4.2 Low energy materials.

In conventional houses, we stay in comfortably only because some fuel is burned somewhere to give us energy to run our fans and A/c's to keep us in thermal comfort. Not only that energy is used for this, but also the fan and A/c itself, as a machine made of iron and steel was produced by a high consumption of energy to convert iron ore into, say a fan. Energy is thus used to make almost all component of a house, whether its brick, cement, ceramic tiles, glass, aluminum or anything.

Attempts at reducing energy use in buildings have mostly concentrated largely on the energy use by the building's occupants to cool, heat, ventilate, light, operate equipment and so on. Design strategies evolved have consequently focused on energy used after the building has been built. Such strategies have virtually ignored the energy required to produce the buildings and constituent parts, to get them to site and assemble them.

But in a building the energy content in the building's fabric and its services will itself comes to a substantial amount. The building industry is one of the largest consumers of highly energy intensive materials. The increasing population and consequent need for dwelling units will increase this even further.

3.5 Energy Scenario in India

India's energy sector continues to grow with the growth of economy especially in the last 5-6 years and along with this our dependence on oil imports also continued to grow. [Figure 3.7] As a result today we face an acute energy shortage. The extent of India's energy poverty can be understood by the fact that the per capita electricity consumption in India is only 314 kW as against the global average of 2112 kW and that also with only about 42% of households in India have electricity connection.

This low per capita consumption does not mean the consumption of Indian urban population is very less compared to world use. But this is mainly because there is a great disparity between consumption of urban and rural areas. Urban areas consume 80 % of the total energy used, with only 20 % of the total population, and rural areas consume the other 20% although they constitute 80 % of the population. Being the second largest populated country, the huge denominator will pull down the per capita consumption although the energy used in urban areas are on the higher side.

The commercial energy consumption in India has grown at a rate of 6% per annum during last decade, although the per capita commercial energy consumption is only 9 GJ as against world average of 90 GJ. In this, although the share of industry is declining gradually, it still continues to be the largest commercial energy-consuming sector, accounting for almost 50% in 1994/95.

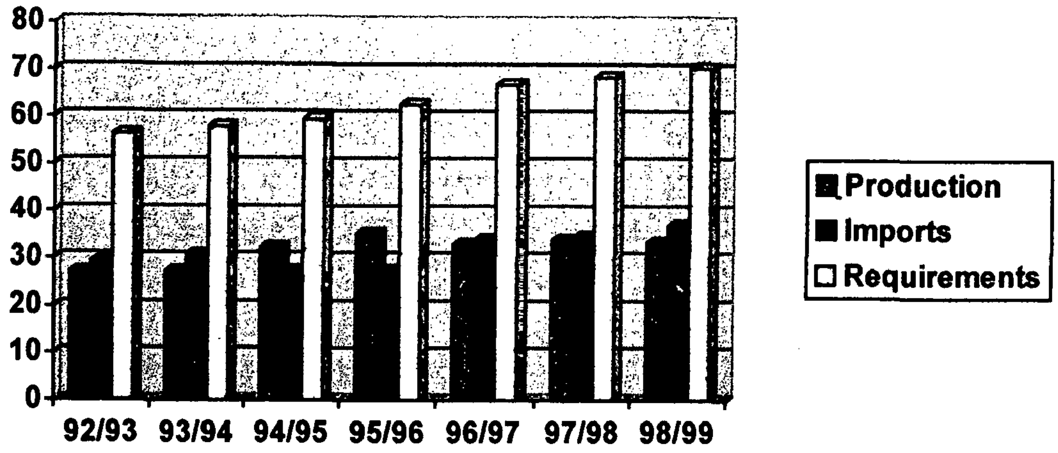


Figure 3.7: Crude Oil, Production, Imports and Requirements in India in million tonnes (Source: The Hindusthan Times, 27.10.98)

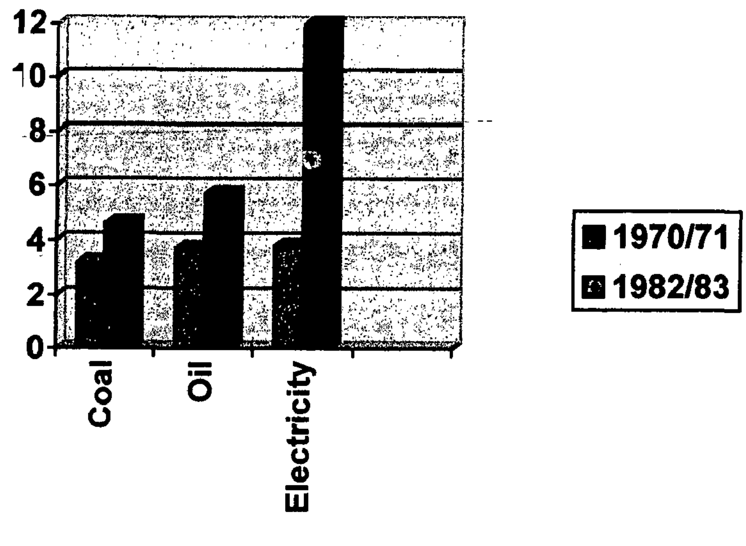


Figure 3.8: Increase in Consumption of Various Energy Sources [source TERI]

Although energy is an essential and crucial input for economic growth, there is recently a new view coming up, opposing the accepted world view, that energy consumption cannot be considered as the only measurement of economic growth of any country- and exceptionally India. Because the Indian people by their very culture practice 'conservation' in all aspects of their day to day life, and it will be reflected in their use of energy also.

For example most Indians will not go into starting heating the room for thermal comfort until he will not be able to protect himself from cold by putting on two sweaters. But most westerners start heating the entire residence/ offices according to the readings of thermometer falls. It has been estimated that India would require about 400 million tones of coal, 100 million tones of petroleum and about 100,000 MW of power every year up to 2000 AD.

COAL: Is the most abundant source of commercial energy in India, as on 1 Jan 1995, total coal reserves is assessed at 200 bt out of which 68 bt are proven reserves.

The production of coal increased rapidly after nationalization of coal mines, from 72.9 mt in 1970/71 to 270 mt in 1995/96, making India fourth largest coal producer in world. Electricity sector is the single largest consumer of coal, followed by the iron & steel sector and the cement sectors. [Table 3.1] Cement sector alone consumed about 12.4 mt in 1994/95.

It is to be noted here that almost 60% of the coal are used for making electricity. On industrial sector, the production of steel & cement alone consumed almost 20%.

PETROLEUM AND NATURAL GAS: Production of crude oil in India increased from 8.5 MT (million tones) in 1975/76 to 32 mt in 1994/95 and that of natural gas from 2.4 b.Cu.m to 19 b.Cu.m in the same period (net natural gas production 17 b.Cu.m 94/95). Along with this the consumption level has also been increased tremendously and

	91/92	92/93	93/94	94/95	% of 94/95
Total Availability (Production + Import)	228.9	241.8	256.0	269.2	**100**
Electricity	126.8	138.6	154.4	160.9	**59.7**
Other Industries	40.5	38.7	39.5	46.7	**17.3**
Steel and Washery	34.0	37.3	37.6	38.6	**14.3**
Cement	10.8	11.7	11.1	12.4	**4.6**
Colliery consumption	4.1	4.0	4.7	3.7	**1.3**
Paper	2.7	2.6	2.9	3.2	**1.1**
Cotton	2.0	1.9	1.8	1.8	**0.6**
Brick	1.8	1.7	1.5	1.0	**0.3**
Railways	5.1	4.3	2.0	0.7	**0.2**
Making soft coke	1.0	1.0	0.4	0.3	**0.1**
Jute	0.1	?	?	?	**?**
Total Consumption	228.9	241.8	256.0	269.2	**100**

Table 3.1 Sector wise consumption of raw coal in million tones

today we depend heavily on imports for our needs and the economic implications of this import has become a series blow to our economy.

The total crude oil requirements of the country in 1998/99 were 70.3 mt, out of which our integenious production was only 33.3 mt. The import of crude and petro goods was 54.2 mt in 1996/97 and 54 mt in 1997/98 while our indigenous production on the same period was 32.901 mt and 33.862 mt respectively. [16]

The import bill of crude oil in 1995/96 was Rs. 25, 000 crore, which is almost one-fifth of countries export earnings. The oil import bill for the year 1998/99 is estimated to be at Rs 33,252 crore, out of which Rs 17,212 crore will be spent to procure crude oil and Rs 16,040 crore has been kept for importing petroleum products. [17] The Petroleum Ministry proposes to import 25.75 mt of crude oil during 1998/99 as against 21 mt in 1997/98. [18]

It is believed that the process of economic development in our country will get accelerated in the 21st century, resulting in a high energy requirement in all sectors of our economy and our increased dependence on external sources of fossil fuels. The percentage of foreign exchange earning spent on oil imports is also accelerating to an alarming situation. The only refinery in Kerala, the Cochin Refineries Ltd. (CRL) now has a capacity of 7.5 mt which it plans to expand to 13.5 mt. [19]

An architect can contribute drastically to the saving of these scarce fuels by choosing low energy materials for construction, by advocating the locally available materials and also by incorporating passive techniques to design.

3.5.1 Electrical Energy

Of all forms of energy the one we are most dependent on is electricity, especially for thermal comfort requirements in a warm-humid region. But the power supply in India is still characterized by high-energy shortage and peaking, although the electricity consumption has gone up tremendously in the recent years.

This will be more evident if we just look at the change in energy consumption of various sources in domestic sector in the period from 1970/71 to 1982/83. [Figure 3.8] On this period the consumption of coal recorded a 45% increase (from 3.2 mt in 1970/71 to 4.6 mt in 1982/83) and that of oil recorded a 55% increase (from 3.7 mt to 5.7 mt), but the consumption of electricity has gone up by a tremendous 211% on the same period (from 3.8 twh in 1970/71 to 12 twh in 1982/83). [20] The official estimates of ministry of

Petroleum and Natural gas (MoPNG) on electricity consumption in residential sector also shows this. In 1980/81 it was 9247 gwh and it became 31982 gwh in 1994/95. [21]

In 1994/95 all India energy deficit was 7.1%. Although the per capita consumption of electricity in India in 1996/97 was only 300 kWh/yr. compared to the developed world level of 2400 kWh/yr., the demand is increasing at a very fast rate of 10% per year from 1950 to 1996.

As of 31.3.96 we have commissioned 83,288 MW of electricity of which more than 60% was done after 1980. On this the share of hydropower is 26%, while thermal power enjoys a 72% and the balance 2% is shared mainly by nuclear power. The share of hydropower was 43.4% in 1970/71, one of the reasons for its decrease to 26% is that the gestation period of hydro project is longer than that of thermal project. On nuclear power sector, as on 31st March 1995, we have a total installed capacity of 2225 MW, (2.7% of total installed power capacity) and gross generation in 1993/94 was 1.6% of total generation.

The rest, almost 3/4 th, is generated from thermal & nuclear plants mostly; both of which have high environmental cost. Hydropower also have this like summerging of fertile land being just one, but compared to thermal and nuclear power the pollution factor is absent. But the government will have to invest Rs 132,000 crore in 22,000 MW of hydel projects over the next 10 years to maintain the current hydel-thermal ratio of 25:75. The present ratio of 25:75 itself is well below the prescribed 40:60. [22]

Although in few north-east States of the country the production of power is what would be called a surplus situation, it is not the overall situation, especially in south India. It should be also mentioned here that whenever it was tried to sent power from east to south some problems- like higher price asked by donor State- have always emerged.

Looking overall the picture of electrical energy is still not very appealing. Even though according to a report by Planning Commission, the country's inefficient State Electricity Boards made a combined commercial loss of Rs 10,000 crore in 1996/97, [23] the possibility of adequate and reliable power supply is still a distant dream in India.

3.5.2 Energy Scenario in Kerala

Kerala, one of the smallest states of India is one of the poorest too. Although it is very advanced in health and the quality of life & literacy, it has a low per capita income and a high population density. The per capita consumption of electricity is also low, in fact lower than national level, but it is increasing in a fast rate. [Figure 3.9] But the power generating capacity in Kerala is not coping with this consumption increase, although today all 1291 villages are electrified, for 49.23 lakh consumers.

Although Kerala has forty-four rivers to its credit, it is a mis-consumption that the state has immense hydro-power potential. As stated earlier Kerala gets an average rain of 3000 mm, this means about 12,000 crore.Cu.m rain every year and about 60% of this, some 7000 crore Cu.m runs through its rivers.

But for producing hydro-power just more number of rivers are not enough, it has to be in such a place where it is possible to built a dam to block it with out much ecological damage. Studies shows that such sites are limited in Kerala because of its high density.

It can be estimated that they for every person for his electrical needs, for light, fan, etc, needs nearly 50-60 kWh (unit) per year. It means that for a family of 5 persons need roughly 300 units per year. Now Kerala has 49.23 lakh households (consumers), which would make the total need only some 15,000 lakh units or 1500 million units. But it is to be noted that this does not include the industrial, infrastructural and other common needs.

Today the per capita consumption (including all electricity needs) of Kerala State is 240 units.

As on 31 March, 1997 Kerala produces a total of 1773.78 MW, out of which 1686.5 MW (i.e. 95%) is hydro power, 85.28 MW (4 x 21.32) (4.8%) is thermal power from Bramapuram diesel plant and rest 2 MW (i.e. 0.2%) is from wind power from Kanjikode.

This is the picture [24] in 31st March 1997:

Generation (Hydel & Thermal)................................	5500.30 mu(million units)	
Auxiliary consumption..	28.00 mu	
Final generation..	5472.30 mu +	
Wind farm..	2.56 mu	
Net generation..	5474.86 mu +	
Purchase..	3298.38 mu	(37.59%)
Total consumption..	8773.24 mu -	
Bilateral exchange..	1.97 mu	
Total available for sale.......................................	8771.27 mu -	
Transmission, distri. loss....................................	1750.50 mu	(19.96%)
Total sold...	**7020.77 mu**	

Now if we look, how this 7020.77 MW was distributed (consumed) sector wise. [25]

1. Domestic sector	3405 mu (48.50%) (all India, around 20%)
2. Industrial sector	2229 mu (31.75%)
3. Commercial sector	650 mu (9.26%)
4. Irrigation sector	329 mu (4.69%)
5. P.W.D	161 mu (2.29%)
6. Bulk supply	137 mu (1.95%)
7. Public lighting	110 mu (1.57%)
Total	7021 mu (100%)

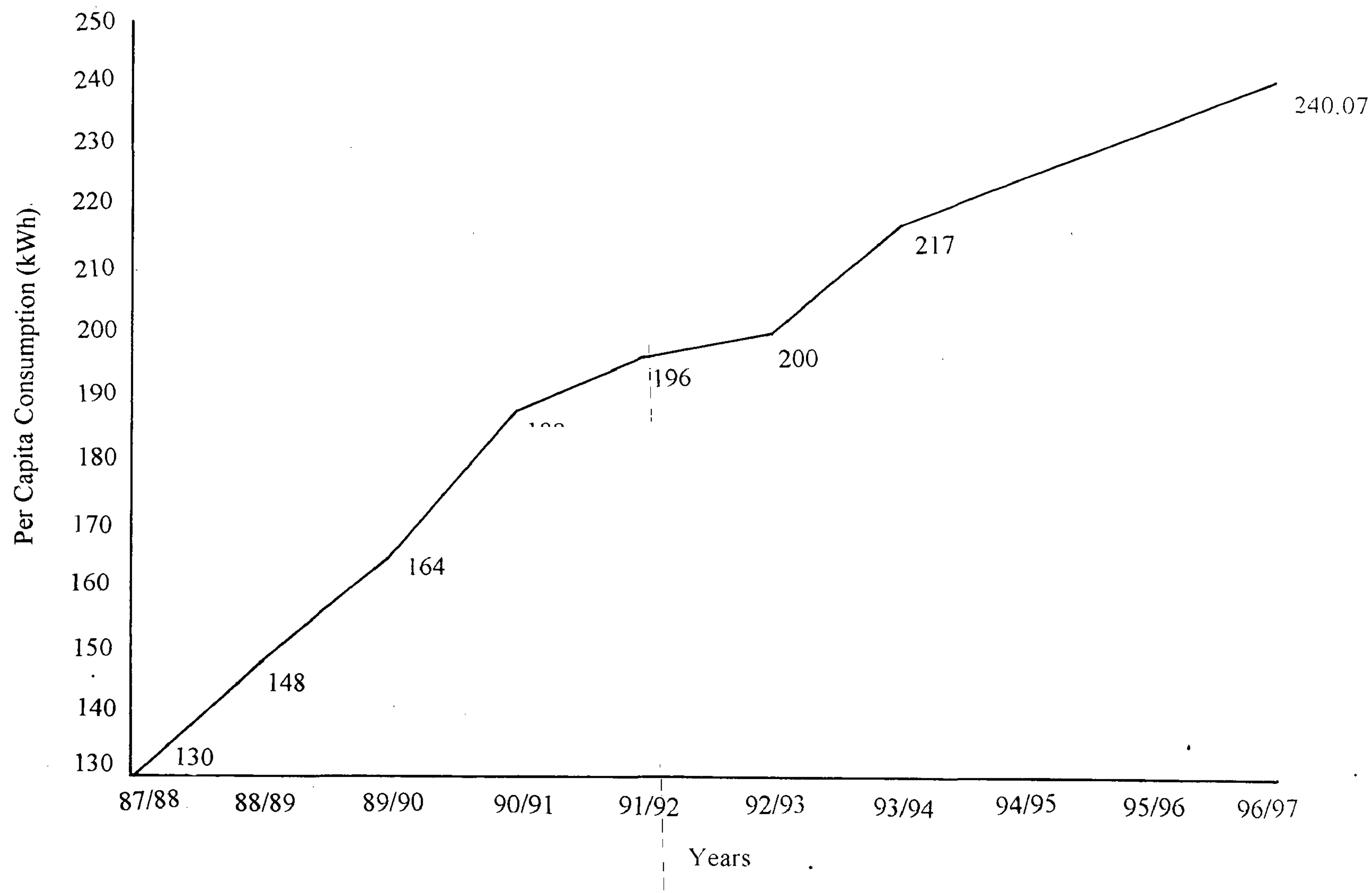


Figure 3.9: Per Capita Consumption of Electricity in Kerala

So it's clear from this chart that the domestic sector is the major consumer of electricity in Kerala. Now the question is how it is used in domestic sector or what is the share of each end-user. According to the study [26] conducted by Tata Energy Research Institute (TERI) on all India level, it was found that the split up would be roughly as follows:

Cooking	- 1.0 %
Space Heating	- 3.8 %
Water Heating	- 7.6 %
Space Cooling	- 25.3 %
Others	- 27.6 % (T.V, Fridge, Iron etc.)
Lighting	- 34.7 %

Total	- 100 %

But in Kerala the 3.8 % accounted for heating will also adds up to space cooling making the total share used for thermal comfort to 29.1 % of total electricity consumed. Again the electricity used for water heating will be less because of absence of winter season. So almost 30% of the electricity in domestic sector are consumed by active cooling systems. Which will account it to roughly 1021.5 mu, 18.6% of total electricity produced in Kerala.

Another important thing the investigator wants to point out is that, the total power need of Kerala is 2500 MW, and as of now Kerala produces around 1500 MW. But today Kerala Government has ambitious plans to produce the much needed 1000 MW by the year 2000, by thermal plants, of which the construction is already progressing.

These new schemes will charge the present ratio of hydropower to thermal power of 95:5 drastically by raising the share of thermal power from 4.8% to some 40% and changing the ratio to 60:40. As I have already mentioned the thermal power is highly polluting. So when the developed world is trying to phase out thermal power, Kerala is stepping into it, because of the lack of other option, except perhaps reducing the electricity needs some how.

Furthermore now only a very small sector of railway line in Kerala are electrified but now works are going on in full swing to the further elaborate electrification of railway lines ion Kerala. Obviously this will have an impact on the electricity sector also. Now railway sector consumes about 2.5% of total power in India, when Kerala lines are electrified the State will also have to contribute its share.

3.6 Inferences

The oil crisis of the 1970's was not due to the physical exhaustion of the reserves. Although fossil fuels are non-renewable, finite resources, the threat of their physical exhaustion in the near future is still to materialize. But today in the light of all the ill effects, mentioned earlier, caused during the conversion of fossil fuels to useful energy forms, the crucial question is not how long the fossil fuels will last, but should we go for it that long even if it lasts for, say 50 or 100 years, now knowing the grave problems caused by it.

Our conventional energy sources like thermal, nuclear and hydro (hydro can also be considered as conventional because of the fertile land submerging and other problems it causes even though it is technically a renewable energy source) all causes many a great environmental problems. But at the same time all of this conventional energy sources has to be used and exploited even more in today's situation to provide a decent living standard to our people because there is no other viable option.

One of the main reasons for this is that the non-conventional or renewable sources like solar, wind, tidal etc., though now used successfully in some specific situations, are not yet in a position technically to make substantial contribution/ replacement to our power needs of today.

Therefore while pumping more money to the development of these renewable sources of energy, more importance and waightage should be given to energy conservation, especially in the domestic sector where most of the energy is actually used.

In Kerala, where almost 30% of the total electricity is used for thermal comfort (space cooling), this should be made even more a strong case for the adaptation of energy conservation measures in building construction. This can be achieved mainly by the incorporation of passive techniques of thermal comfort into buildings.

CHAPTER 4
CASE STUDY AND ANALYSIS

4.1 Introduction.

Of all forms of energy the one we are most dependent on is electricity. It is the most used form of energy, exceptionally in a warm humid climate for thermal comfort requirements. As far as Kerala is concerned, as we already saw, almost 30% of electricity in domestic sector are consumed by active cooling systems. And also the consumption of electricity by the domestic sector itself is very high, 40-50% of total electricity, against the national average of around 20%.

Here the investigator would like to point out that he is no going into the reasons for this high percentage consumption of electricity in the domestic sector; the answer may be the lack of industrial growth etc. But he would like to emphasis the fact that it is a very important fact to be considered, as far as the energy efficiency scenario in Kerala is concerned, that nearly half of the total electricity used in the State is consumed by the domestic sector and also nearly 30% of this consumption is used for thermal comfort.

So any energy conservation method to succeed in the warm-humid climate of Kerala should concentrate on the need for reducing the use of mechanical systems for thermal comfort completely, or at least partially, by providing the same by passive means. The best place to look for guidance for best suitable passive methods of thermal comfort in any place would be its vernacular traditional architecture.

The vernacular architecture of any region must have been evolved after so many years of innovation and the study of climatic problems of that particular geographical area. Our forefathers had constantly tried to make ones living environment more and more comfortable, by trial and error methods, and of course from experience, and also from dedicated studies of regional- macro- climate.

So for the purpose of understanding how the traditional buildings of Kerala used to be constructed before the mechanical systems of thermal comfort ever became possible and how it is different today or not used in modern buildings, some case studies of traditional and modern buildings have been conducted to find out how the passive ways used in the traditional vernacular architecture of Kerala can be interpreted into modern buildings.

4.2 Traditional Buildings of Kerala.

Before going into the case study, a brief description on the traditional residential architecture of Kerala is to be given. The most popular form of traditional residence is the '*Nalukettu*', this word is the Malayalam version of the Sanskrit word '*Charushala*' meaning a building or edifice of four halls. The plan develops from '*Ekashala*' to multiples depending on the physical and economic growth of the family. These extensions are connected or independent or both, resulting in more complex units.

The most prominent character of any traditional Kerala buildings is the huge dominant roof, which acts almost like an umbrella to the whole building, protecting it from the sun. Also this roof has eaves which are so projected so that not only the windows but even the entire external walls gets protected from Sunlight. Some times a corridor is provided around the building to enhance this entire protection of external wall.

The windows and doors are mostly placed in such a linear way that the air passes right through the building at all times without any block. This can be seen done even at the cost of loosing the privacy some times. [Figure 4.1]

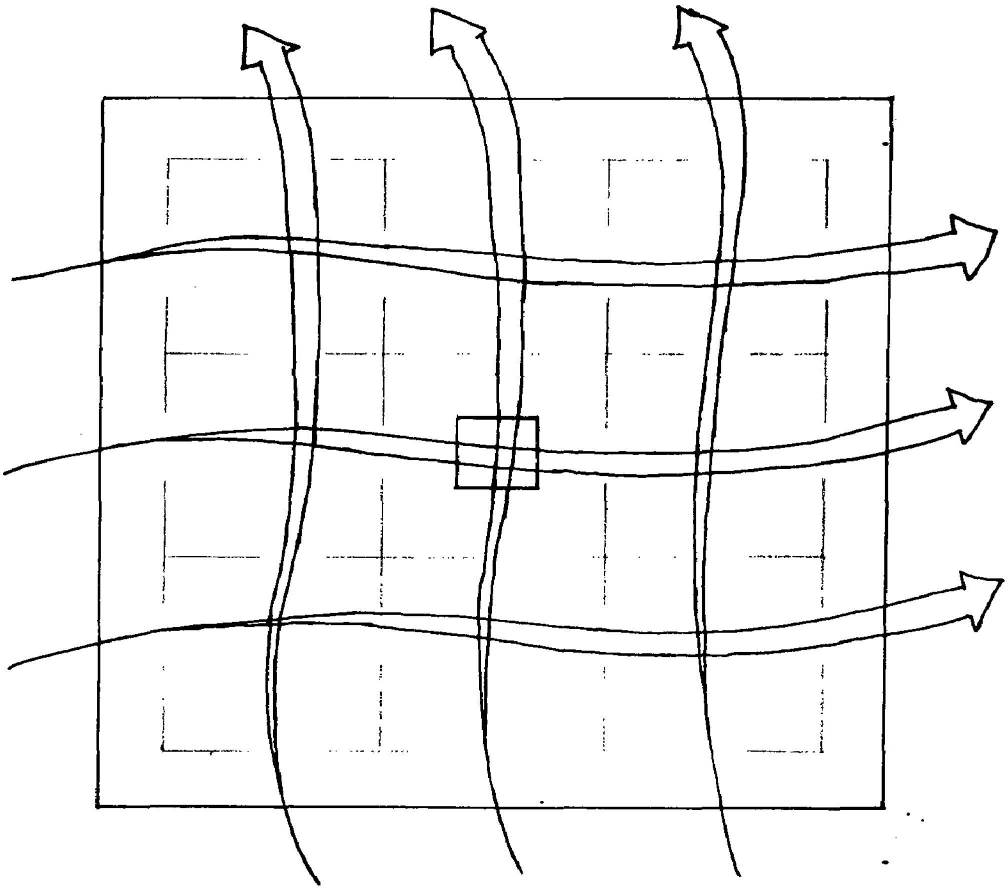


Figure 4.1: Cross Ventilation in Traditional *'Nalukettu'* plan

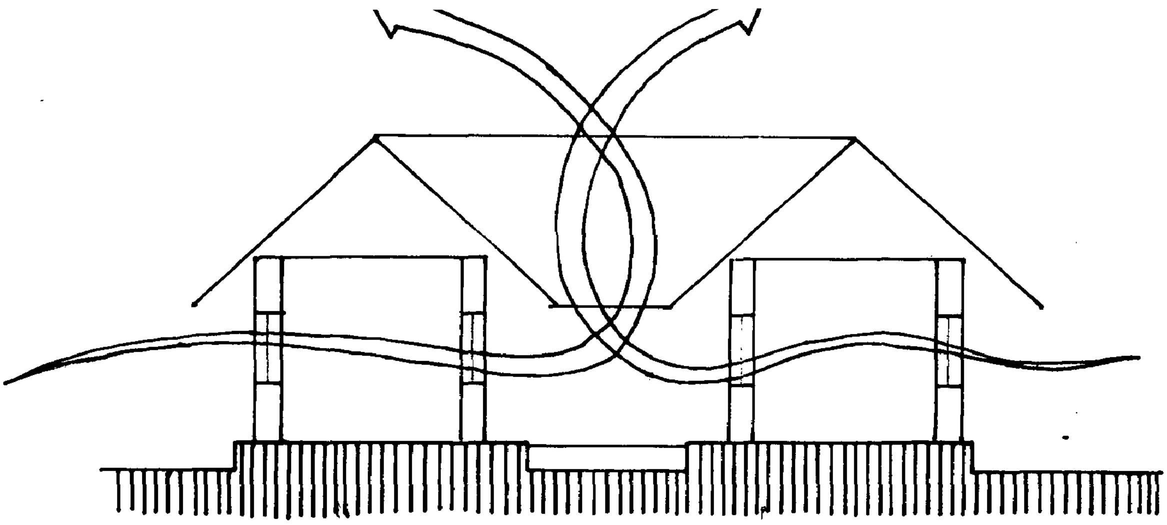


Figure 4.2: Courtyard Helps in enhancing the Air movement

A gable (*Mukhappu*) or ventilator nose on the roof is another common feature, this helps to provide an excellent ventilation to entire building by taking the hot air out.

The courtyard, needless to say, also helps in the air movement by it self. This also helps to make all rooms a single bay type, the best plan form for warm humid regions, around the open courtyard to enhance cross ventilation. [Figure 4.2]

4.3.1 Case Study 1. Medayil House

This house, 150 yrs old, is in Kadaplamattom, near Kottayam. Its a two storied building [Figures 4.3,4.4] with many details of a typical Kerala Houses, many of which can be interpreted and can be used for today's two storied buildings, to which category most residence belong today.

As stated earlier one of the best method to bring thermal comfort is to avoid Sun from coming into the room and heating it in the first place, than trying to cool it later. This building is a perfect example for this, here the sunlight is totally cut off from falling into the building not only to interiors through windows, but even external walls. This is achieved by projecting the eaves and by providing a corridor around the living areas, so that entire external facades are protected.

A corridor 1.2 mts in width is provided all around the main building [Figures 4.5, 4.6] with arched wall on outer facade. [Figure 4.7] And on the 1st floor, a parapet seating, with wooden trelle worked back-rest is provided, which also cuts reflected heat. [Figure 4.8] This wooden back rest itself is projecting some 80 cms from the extended level and further from this the roof is also projecting another 40 cm., thus making an interesting front facade [Figure 4.9] with the total projection of eve to 120 cm from the outer wall on ground floor. Thus shading the top floor complexly, which needs more solar heat protection than ground floor.

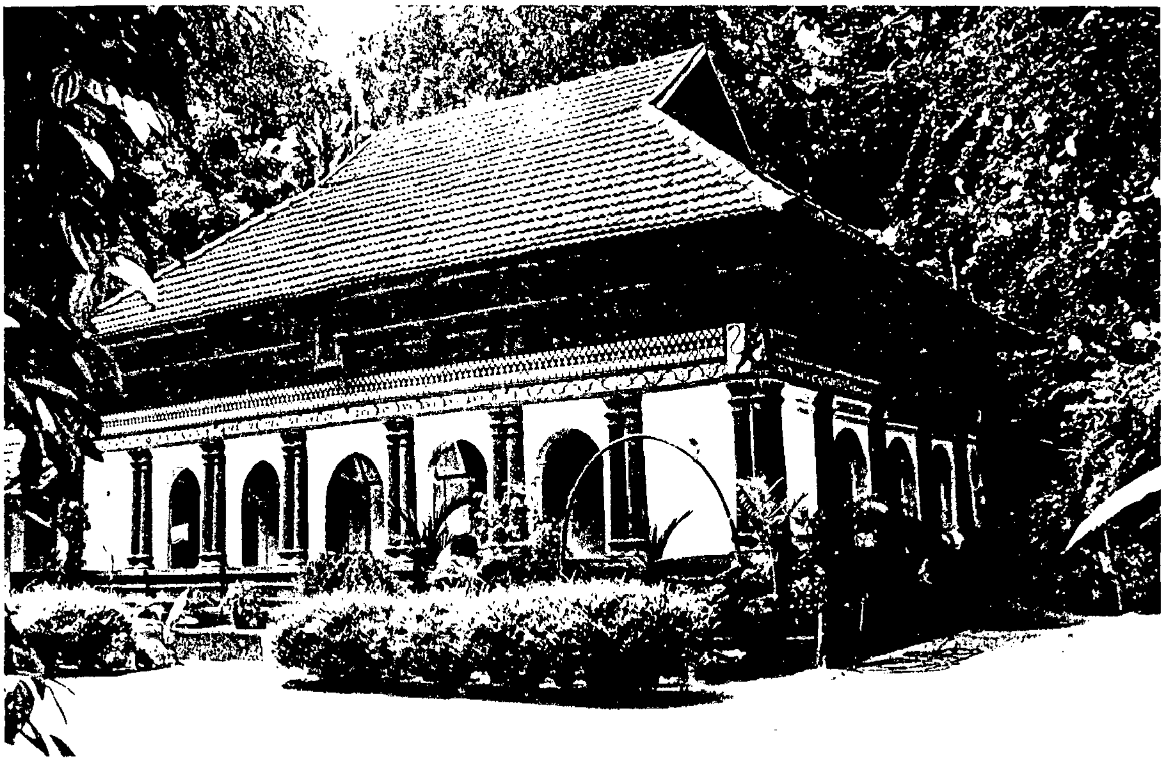


Figure 4.3: The View of *Medayil* House

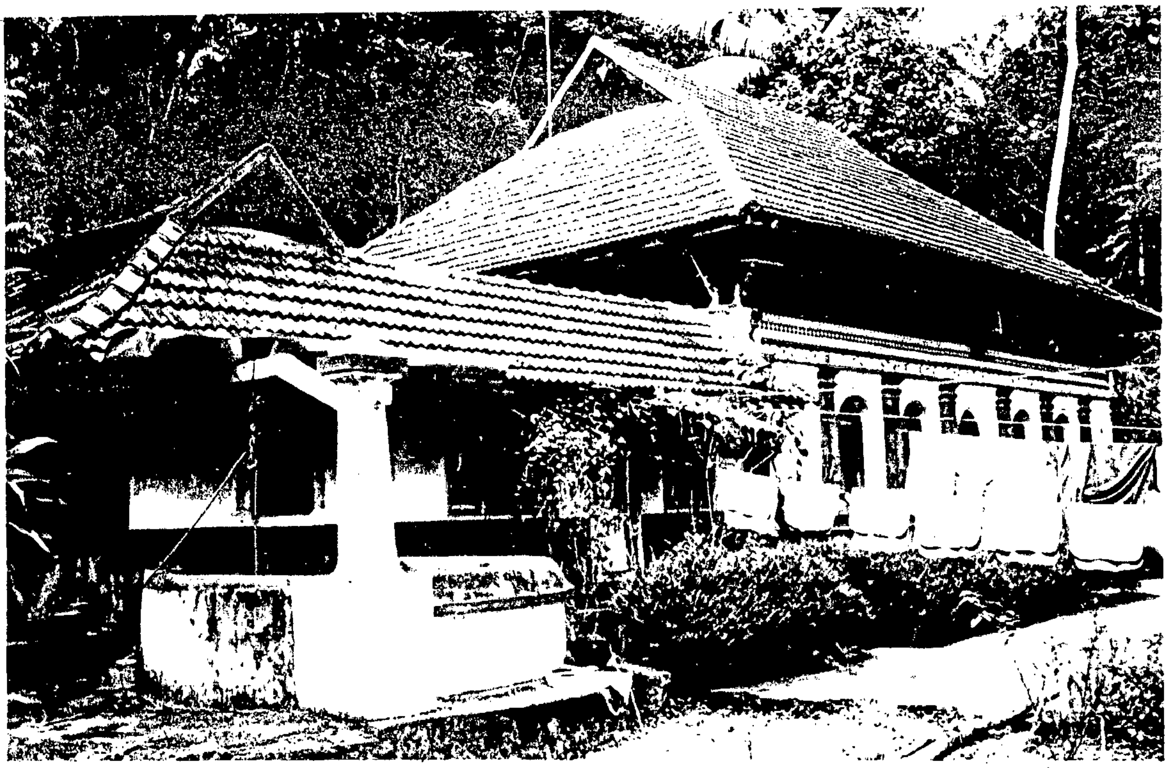


Figure 4.4: Another View of *Medayil* House

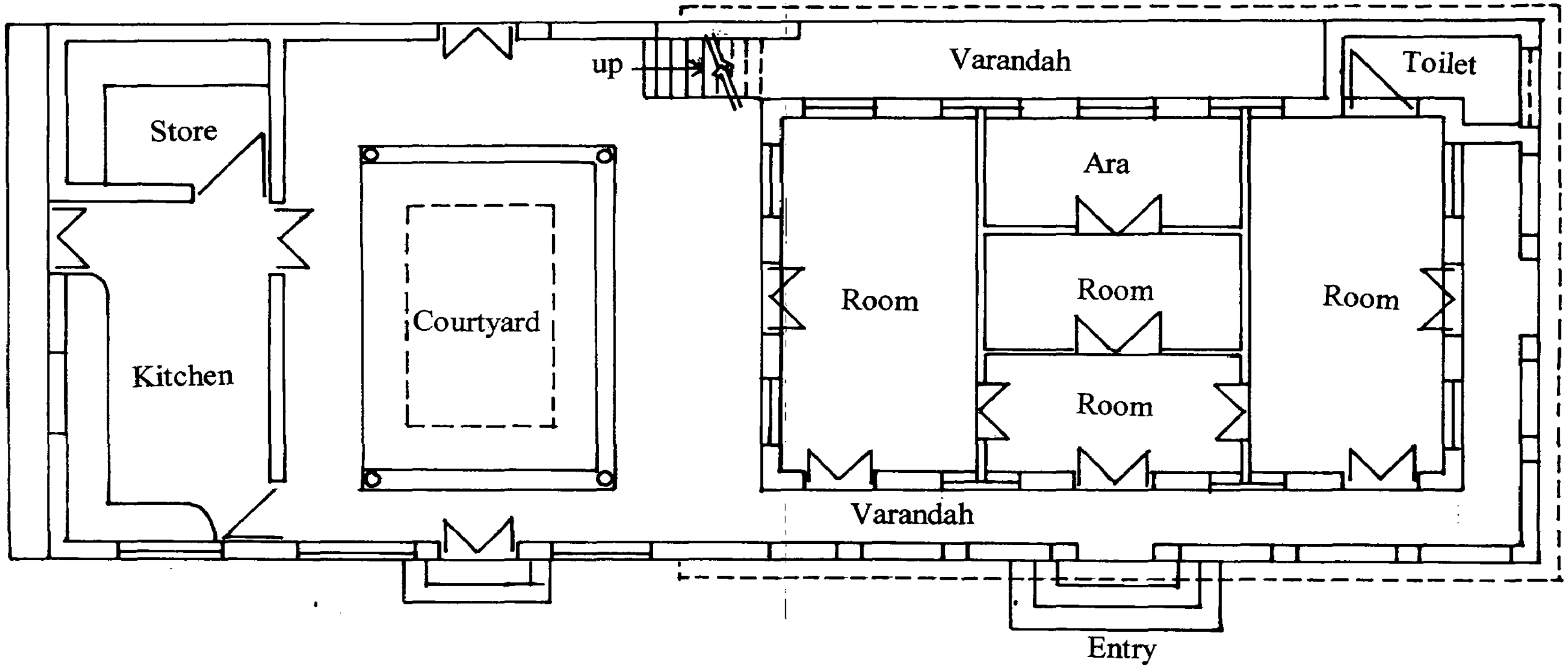


Figure 4.5: Ground Floor plan: *Medayil* House, Scale 1:100

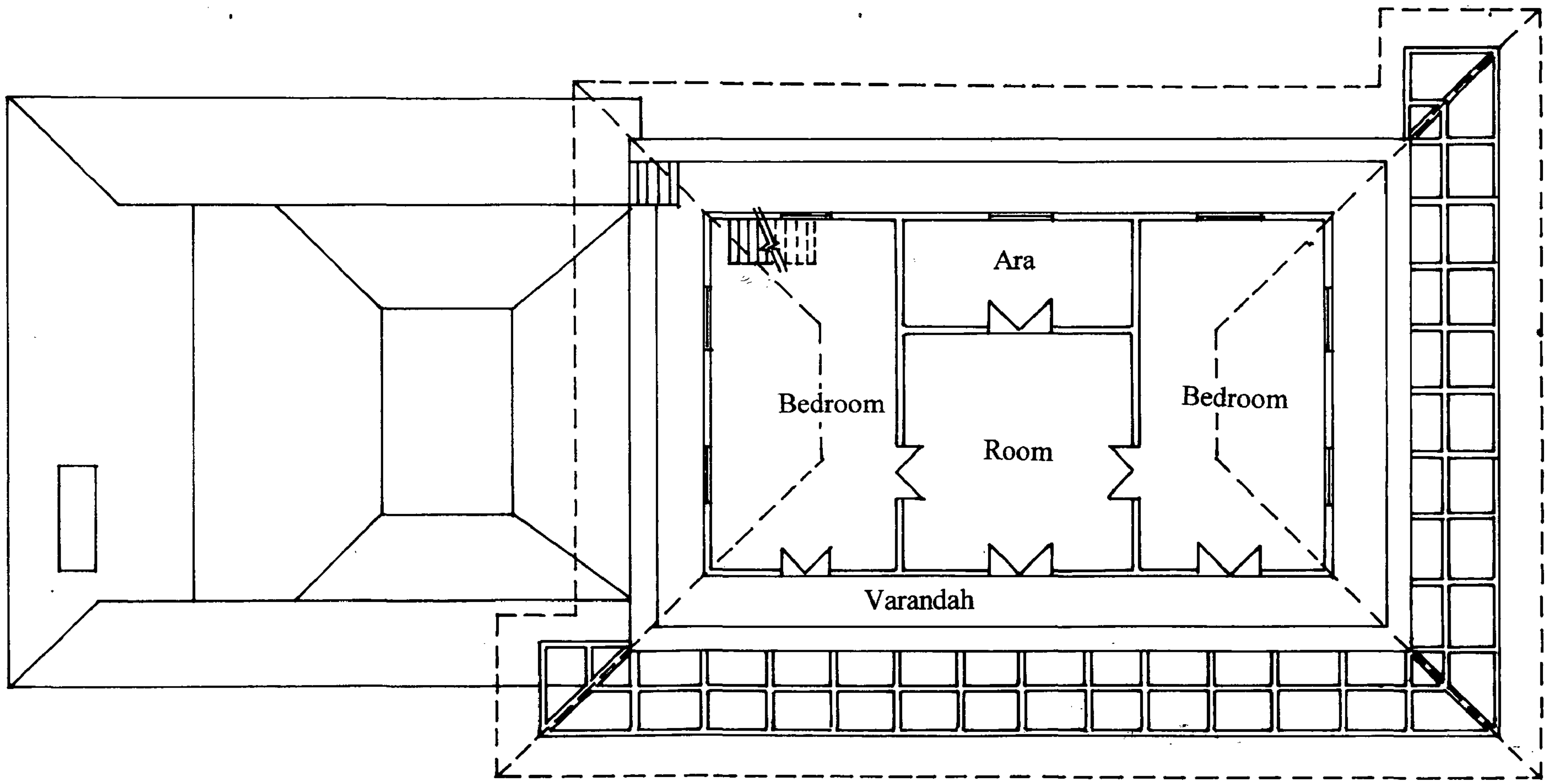


Figure 4.6: First Floor Plan: *Medayil* House, Scale 1:100

Figure 4.7: The Corridor Around the Building: *Medayil* House

Figure 4.8: Corridor on the First Floor: *Medayil* House

Figure 4.9: Front view *Medayil* House

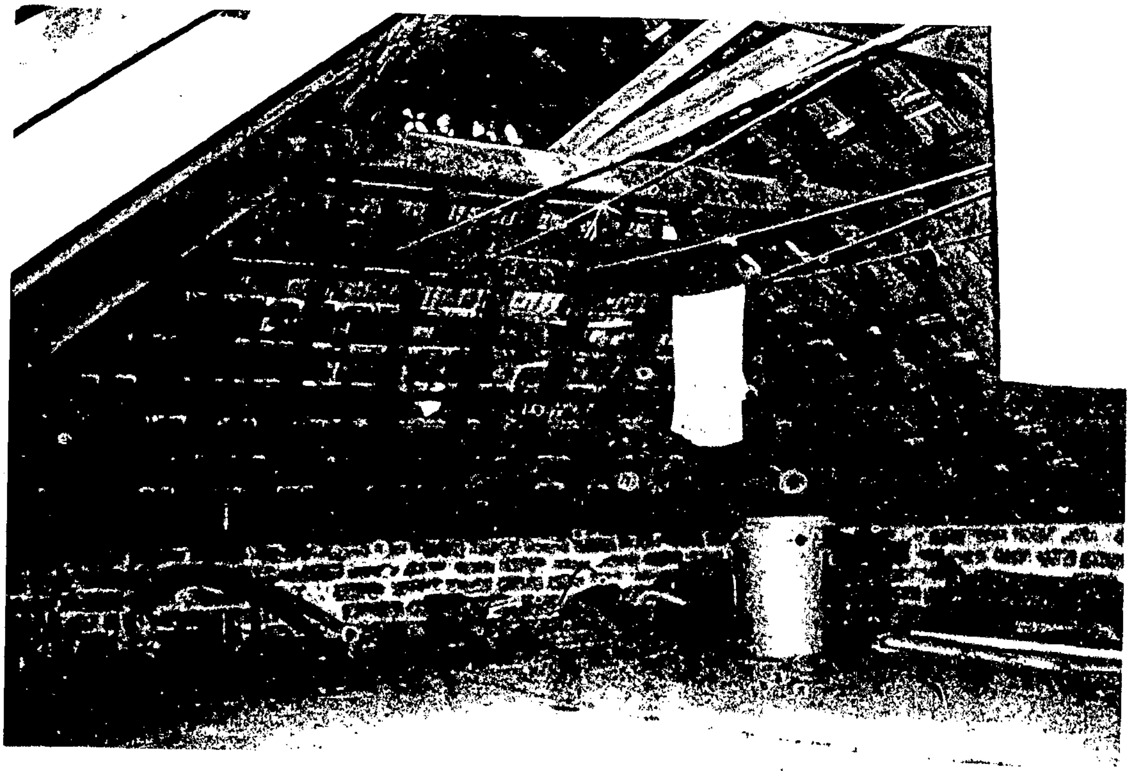


Figure 4.10: The Attic Space: *Medayil* House

Another facade, which cannot be easily shaded like the walls, is the roof, from which, as now precisely calculated in modern buildings, more than half the heat development inside comes from (through convention and conduction). Therefore one of the best and effective method would be one which reduce this heat from passing in.

The traditional method, as in this house, for this is the use of a false ceiling (the actual roof over head), '*Mache*', below the huge outer roof and there by creating an attic space, [Figure 4.10] which acts as a buffer zone in between the heat re-radiation from roof and room below (like a 2 story building, ground floor is cooler).

4.3.2 Case Study 2. Palamthattil House

This 'Ekashala' or the smallest vernacular residential unit is located in Kadaplamattom. It's an 85 yrs. old building, [Figure 4.11] with some additions done 10 yrs back.

Here again the most prominent character is the dominant roof-which almost like an umbrella to the actual built space, protecting it from solar rays (heat), with the typical 'Mukhappu' or nose gable on roof for ventilation.

In Kerala humidity is the all-round villain in the cooling process. It reduces comfort conditions directly, limits the usefulness of passive systems and also promotes growth of mildew. So control of humidity is another key factor. But there are few options: control at source of moisture and above all, prevent local moisture concentrations by good cross ventilation systems.

In this house windows are placed in a linear way opposite to each other so that air passes right through the building at all times with out a block. To achieve this windows are placed in alignence with each other [Figure 4.12] even at the cost of loosing privacy to some rooms and some rooms ending up with four doors (one each on all four sides)

Ventilation is another important factor by which the hot air formed and trapped indoors can be exhausted out. In this house, like most traditional houses, the false ceiling is made of wooden planks closely spaced.

The hot air, which rises up, due to lower density passes through the space between this planks and gets into the attic space and from there it passes out through the gables provided. [Figure 4.13] This air can even pass trough the space between Mangalore tiles (a gap naturally forms in between when tiles are arranged) when the nose gables are absent.

4.3.3 Case Study 3. Martin's Residence

This house, located in Trivandrum is a typical example of a modern conventional middle class residence, a common pattern followed for most conventional building for its plan, elevation & sectional details. [Figure 4.14, 4.15] It was built in 70's, but even today 80% of the middle-class houses follow these same details & style; with flat roofs, big glass windows, sun shade details, etc. The case study of this particular house is done as a prototype of conventional residential buildings.

Flat roof is one of the typical features of most conventional buildings, unlike the big sloping roofs of the past. As a result when the traditional buildings avoided heat from going in, the modern flat roof contributed to it. Because the flat roof absorbs the solar heat and re-radiates it directly to inside, in the absence of any false ceiling.

It has been calculated today that almost half of the heat goes into a single story flat roofed building comes via the roof. Flat roofs also become a contributor to leakage problems in the heavy rains of Kerala. Whereas the slope roofs drained the rainwater easily, the flat roofs with improper workmanship lets the water stay on and causes leaks.

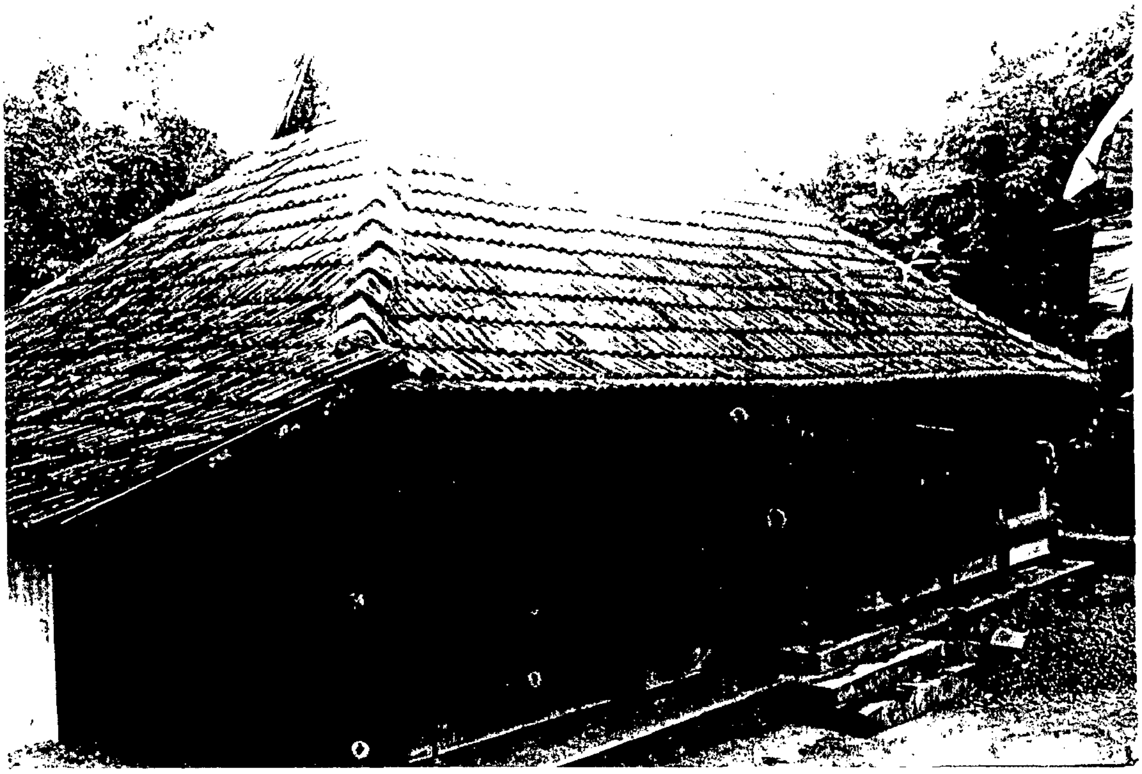
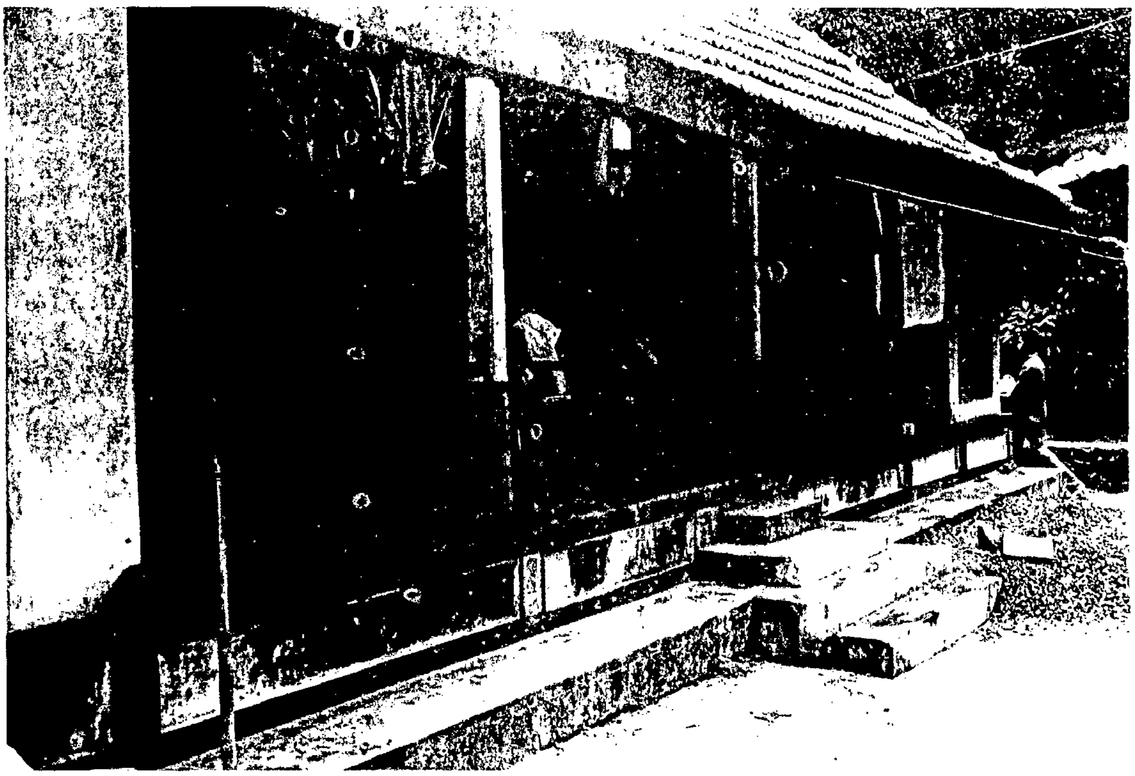


Figure 4.11: Two Views of *Palamthattel* House



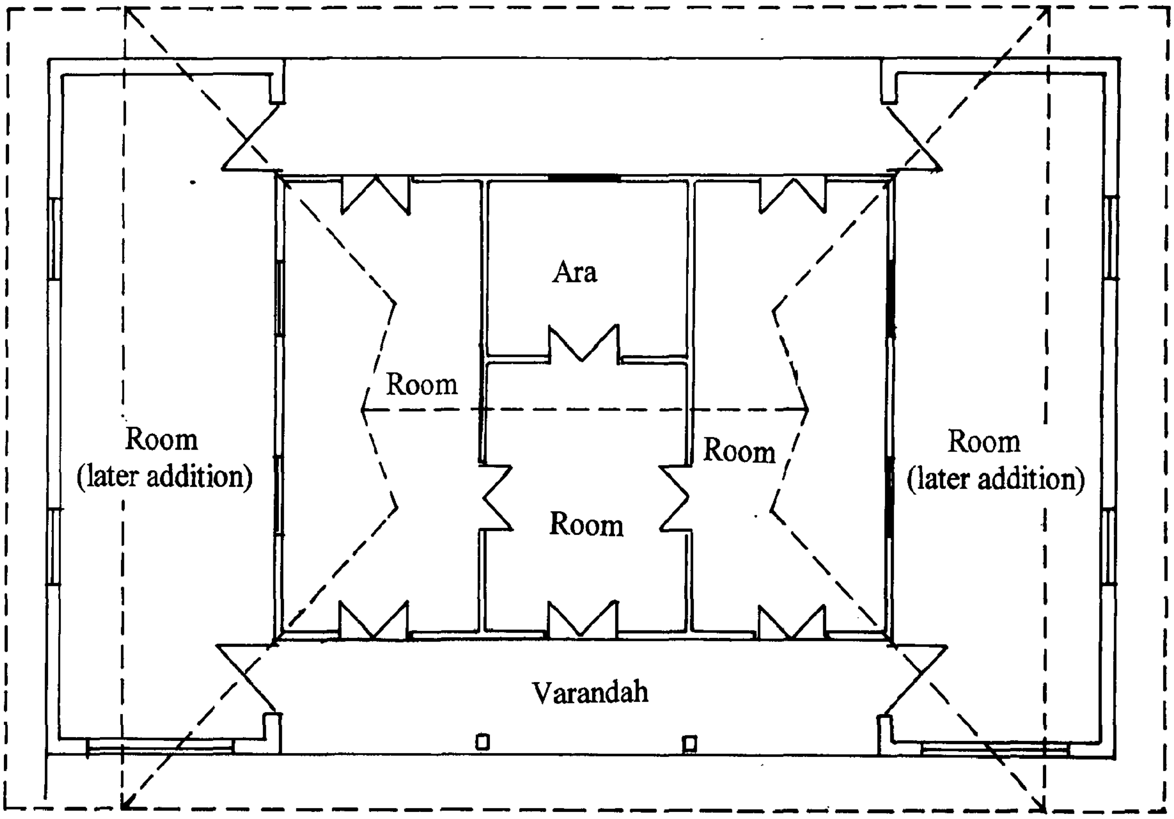


Figure 4.12: Plan: *Palamthattel* House, Scale 1:100

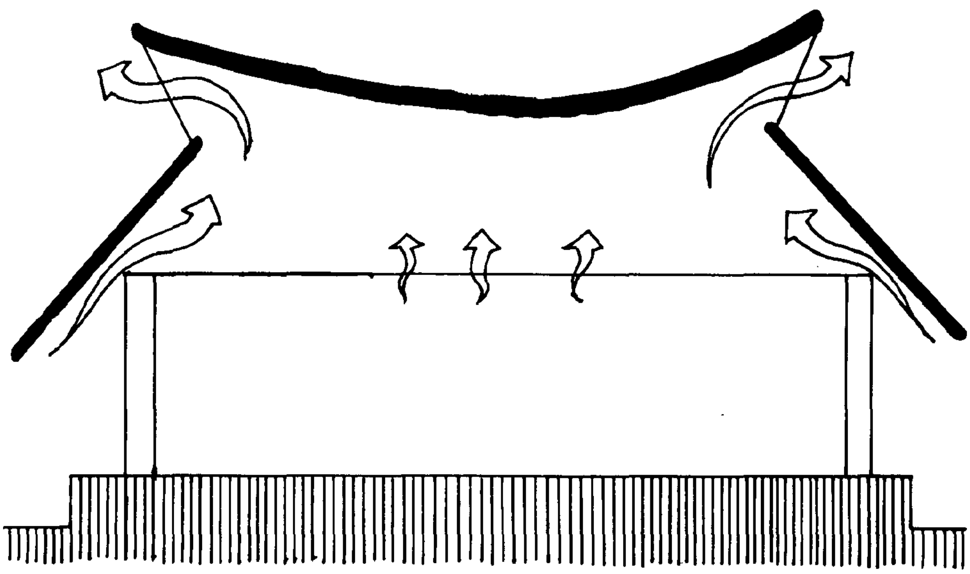


Figure 4.13: Section: *Palamthattel* House

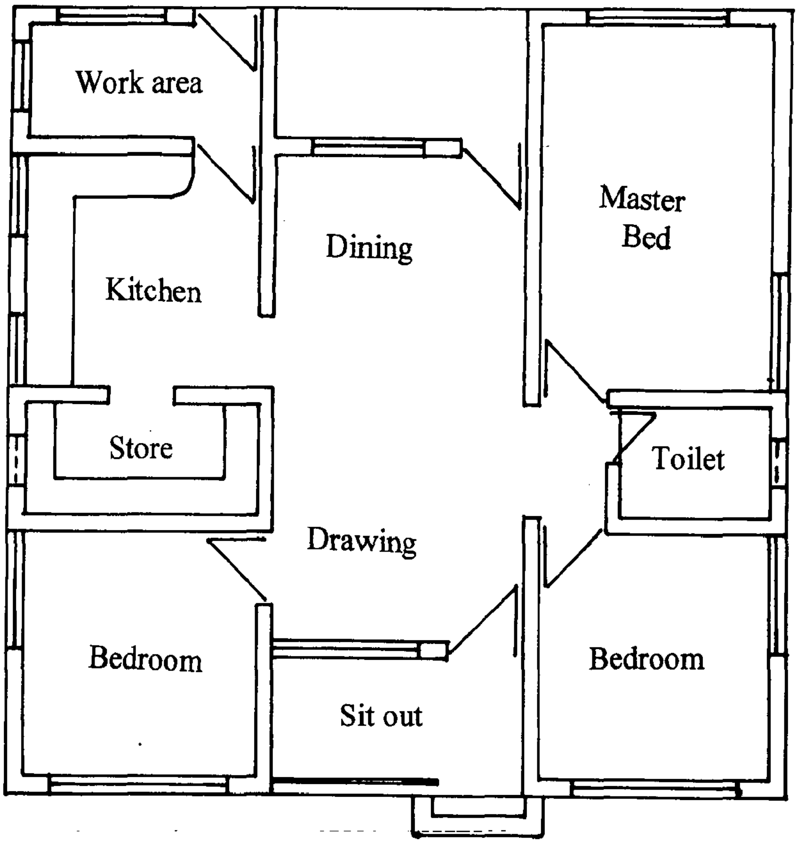


Figure 4.14: Plan: Martin's Residence, Scale 1:100

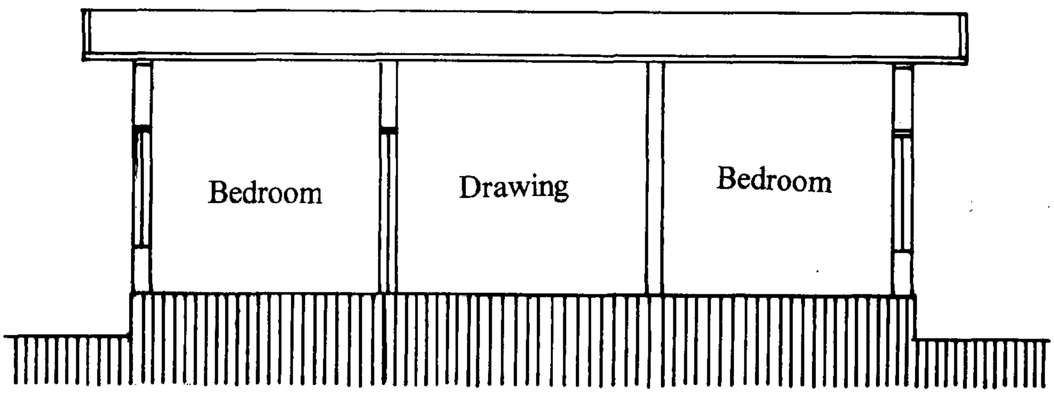


Figure 4.15: Section: Martin's Residence, Scale 1:100

Another common feature in most of today's buildings are the big glass windows. Not only this adds the cost, but also increases the heat inside by greenhouse effect (the investigator observed that most of this windows are rearly open). Solar rays once gets inside the room, through these glass windows in the absence of adequate sun control shades, as long wave radiation and gets trapped there because the reflected rays, being short wave, cannot pass through glass.

The increasing use of glass on building facade since 1970's in place of earlier wooden windows, has become a major concern in many hot regions. Even curtains will not help in reducing this. Actually not only that the curtains will not be able to reduce this but curtains can actually contribute to enhance the heat inside by acting as trombe walls. The solar rays (light energy) falls on these curtains becomes heat energy and slowly spreads into the room by conduction and convection.

As said earlier, in Kerala humidity is the all round problem which can be removed only through good ventilation. But in most of today's residence, the concept of ventilation has reduced to a little slit, 10 cm in height and some one meter in length, on the wall near the roof slab. Although it does help, of course, but if it is given a little more though, on its location and size, it would be useful more. Also thinking about its location to the window's position is also important for more air movement.

Another feature which is lacking in this house, as in most conventional houses, is the lack of cross ventilation through windows. Some of the rooms have only one window facing outside because of improper planning. If more thought is given at planning stage about window placement and the importance of cross ventilation, it will make the rooms more comfortable.

So to conclude, both the basic necessary needs for thermal comfort in warm humid like avoiding the heat from coming inside and the need for cross ventilation, are lacking in most conventional houses like this.

4.3.4 Case Study 4. Antony's Residence

This house, [Figure 4.16, 4.18] in Trivandrum built in 1987, is a typical example of the new architectural trend growing among young architects in Kerala under the influence of eminent architect Laurie Baker.

One prominent feature of this house is that the entire exterior walls are built with rat-trap bond brick work. The advantage of rat-trap bond are three:

1. it saves money as it consumes lesser number of bricks to construct the same cubic meters of wall by any other bond.
2. it acts as an excellent insulator to heat from passing inside because of air gap inside.
3. it saves the earth or mud which would have gone in as brick which would have been needed if any other bond and also the fuel that would have been used to bake it.

Baker's idea of reducing the cost of buildings by saving materials is not only economically efficient but also environmentally efficient. This is because obviously saving natural material or reducing its input for construction always has an ecological value.

Another interesting feature of this house is that here the architect has deliberately used the stair case tower as a ventilator shaft taking hot air out. [Figure 4.17] This has been achieved by projecting up the stair case shaft to act like the nose gables of traditional houses and directly connecting all rooms to it.

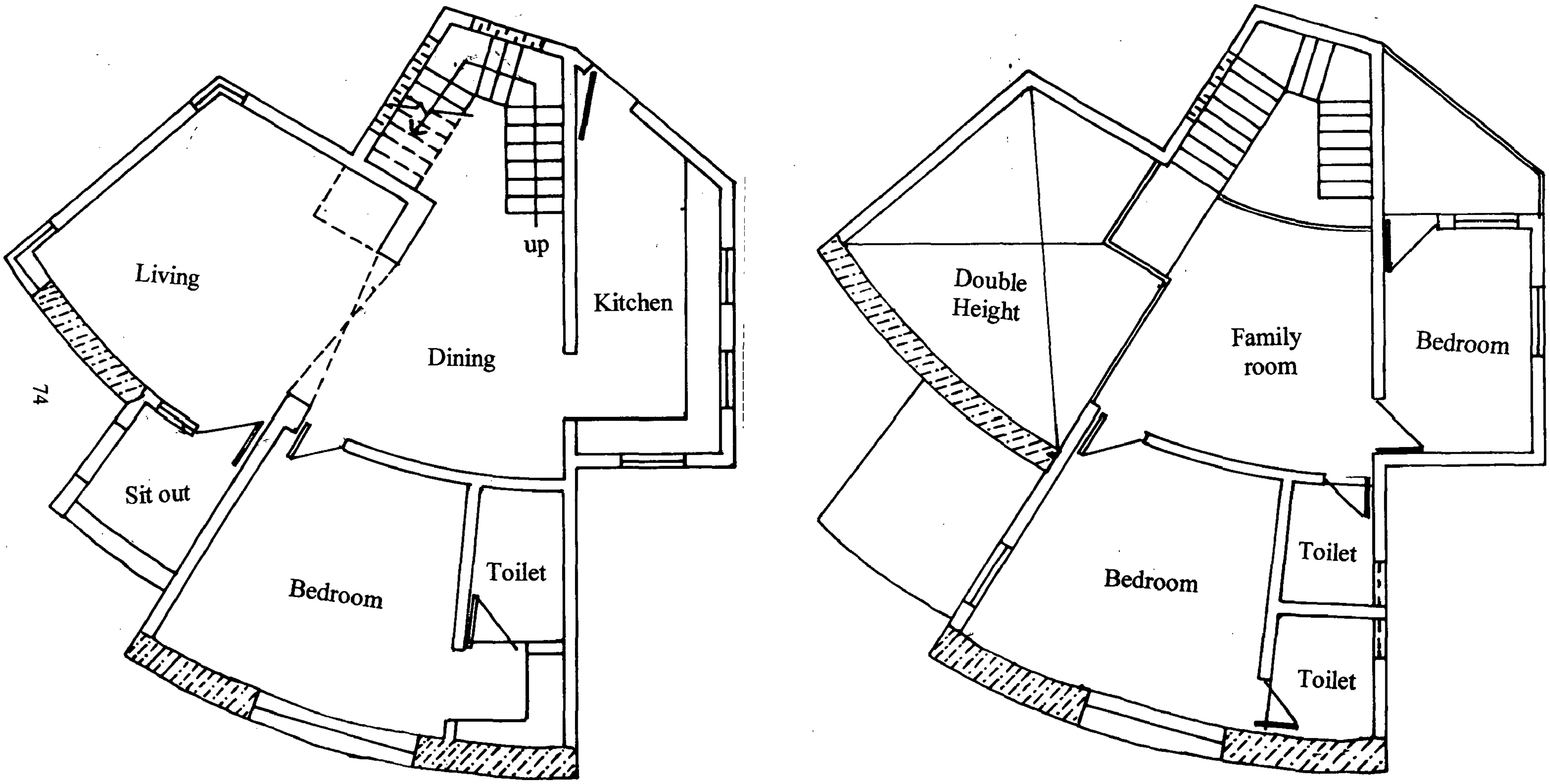


Figure 4.16: Floor Plans: Antony's House, Scale 1:100

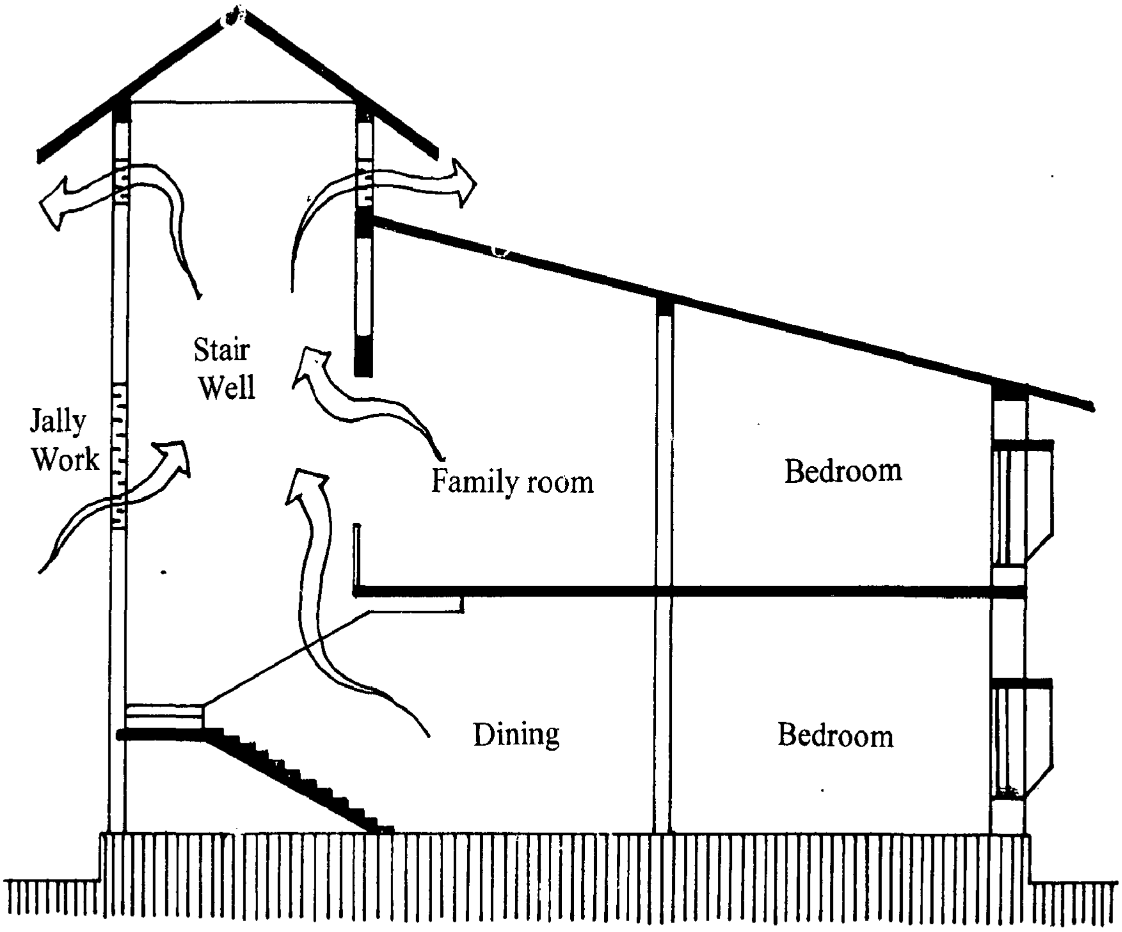


Figure 4.17: Section through Stair-well: Antony's House, Scale 1:100

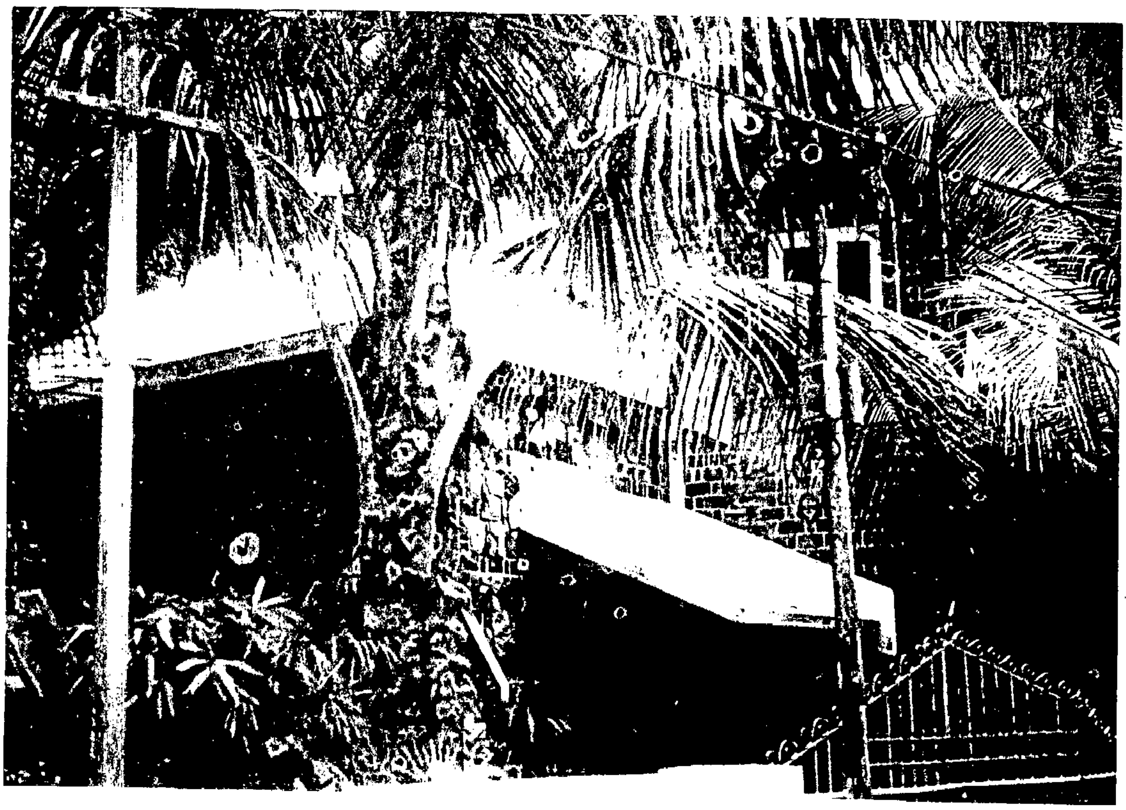


Figure 4.18: Front View: Antony's House

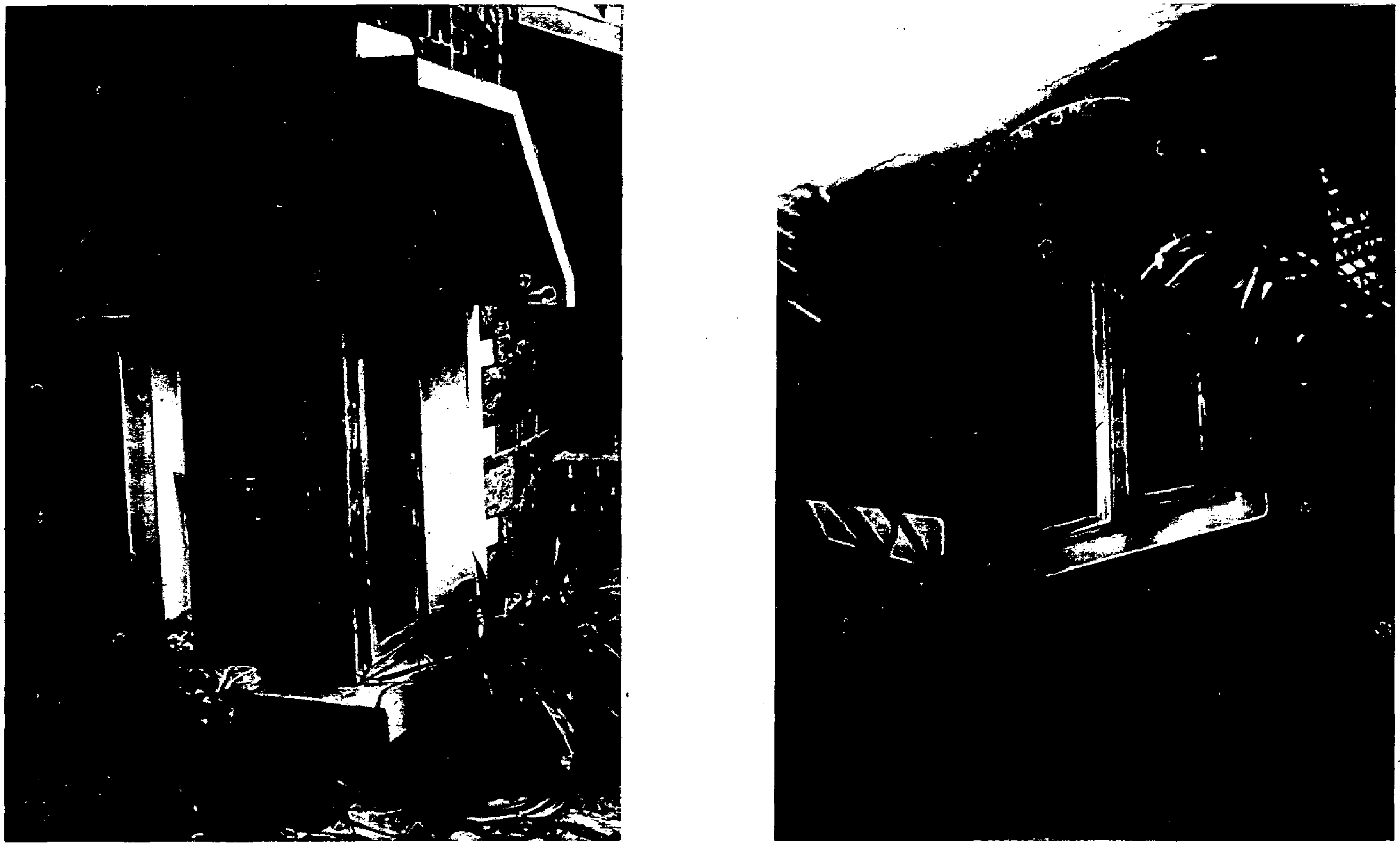


Figure 4.19: Sun Shades became Design Elements: Antony's House

Another plus point of this house, like most of Baker type buildings, is the provision of jally brick work, like wooden trelly works in traditional architecture. Here it is provided on the stair case tower to ensure all time ventilation and air circulation, the much needed provision for this climate. The provision of double height rooms also increases this and acts as a catalyst in the process of natural ventilation and decreases considerably the heat on the ground floor.

But there are some basic flaws also in this building mainly the inadequate shading of external walls and windows. Sunshades have been used as a design element or frill and on this process of transition it has lost its purpose and significance. [Figure 4.19] Also unplastered walls are less desirable for warm humid climate and white washed walls are better for reflecting of heat falling on outer walls.

4.4 Passive Systems for Thermal Comfort.

The passive systems for any building should be designed considering the solar radiation it receives (both intensity and direction), temperature, humidity, rainfall, air movement, vegetation etc. which all varies from place to place and latitude to latitude. So needless to say that the passive systems needs for Kerala's climate will be different from that of other parts of India.

As stated earlier most prominent characteristics of Kerala's climate are the hot, sticky conditions and continual presence of dampness. The temperature remains moderately high, between 21 and 32'c, with little variation between day and night and it seldom exceeds normal skin temperature. Humidity is also high during all seasons varying from 60 to 95%.

And because the air temperature is continually very near to skin temperature, bodily heat loss to air by convection or conduction is negligible. As far as evaporation is concerned, even the evaporation of small quantity of moisture from the body would form a saturated air envelope around the skin, because of high humidity already present, which prevents any further evaporation and there by blocking this last resort of heat dissipation.

But this saturated air envelope can be removed or carried away by air movement and some degree of comfort can be achieved by encouraging out-door breezes to pass not only through building, but across the body surface of occupants. This is, in fact 'the only way of ameliorating thermal conditions'. [27] So the objective for any passive technique, to achieve thermal comfort in Kerala, must be basically by two ways:

1. Reduce heat gains into the building by cutting off solar radiation as much as possible from falling into building through windows and also on the exterior envelope (there by avoiding/reducing heat to built up indoors).
2. To produce more possibilities to let wind/air pass through the building, those too at body height of occupants (there by increasing heat dissipation from body through evaporation).

4.4.1 Site/ Selection of land

The steps for achieving this should start from the conception stage, if possible, that's from the time of choosing the site. One of the best thumb rules is to look for a site where it is possible to give the building an east-west orientation for better protection from sun. And also the position and number of trees, if any, on the site is also another plus point to the site because this can be effectively used for passive comfort later.

But this stage would have been already passed before the architect gets his hand on to the project. But he can still help, with the help of the client, to decide not to cut down any tree which may already exist on the ground. (Now techniques of transplanting trees location with in the site is also are being done for better advantage.) This natural landscape can be very useful not only in terms of solar shading but also in terms of guiding the airflow into the building.

More than half the heat developed inside the building comes through conduction and convection from the roof. And this is a facade, unlike windows and walls, cannot be easily shaded. A suitable solution in shading roof is by planting trees near the building with branches canopy over the roof giving shade. Also vegetable pergolas or creepers over the roof can also be used to shade the roof efficiently.

One of the reasons for cutting down trees (or not being planted) in residential plots is the fear that big trees have bigger roots which might damage the building. Considering this fact, nature has given Kerala a suitable answer for this, the *Kera* tree, or the coconut tree. It has three inherent physical properties which are best for Kerala's climate:

1. It has a long spread of leaves which can virtually act as an umbrella to the building.
2. Its root is not much thick after a few feet and can be placed 4-5 feet near the building, which makes it possible to use it effectively even in small plots, which architects often come across in urban areas.
3. The long steam of coconut tree allows the wind to pass through, below the canopy of leaves, which is a very important need in humid climate.

4.4.2 Orientation of the building.

The building has to be oriented to two things; the sun and the wind. The orientation of the building according to sun depends mainly on the direction from which sunrays fall on the building, which intern changes from latitude to latitude and can be determined easily from a sun-path diagram.

In Kerala it is important to shade all sides, including northern as explained earlier, this one of the facts which is often overlooked, in fact most of the climatological books I went through, being written from western countries or from north India, were dealing mostly on how to avoid southern sun. And most were of the precondition that since India is on the Northern Hemisphere it is only the southern sun that we get and so be concerned. But in reality it's not so for southern India and therefore while orienting the building, sunlight falling on the northern facade is one major factor to be considered as far as Kerala, and also southern parts of Tamilnadu, is concerned.

4.4.3 Cross Ventilation

Another factor to be taken care of while orienting the building is the wind direction. In case of small buildings, say up to 2-3 stories height, it would be better to orient the building for the sun than wind because wind direction can be diverted by building form and by planting plants and trees, whereas nothing can be done, obviously as far as direction of solar rays are concerned.

As stated earlier in Kerala where the diurnal temperature differences is less because of high relative humidity of the region. The air we live is a mixture of dry air and water vapor called moist air. Although the amount of water vapor in air is very small, its effects are great. The rate at which our body can use evaporation for cooling is directly determined by the relative humidity- a measurement of this water vapor content- around us. If there is more relative humidity the evaporative cooling would be naturally less. So in Kerala with 60-95% relative humidity there fore evaporative cooling is not much beneficial under normal air velocity inside the room. But evaporative cooling can be increased if the air movement inside the room is increased. This can be done only by proper cross ventilation at body level.

So all possible steps should be taken to ensure that every possible breadth of air movement will reach our body, to remove this body heat - this is the same reason why we feel more comfortable under a fan. The orientation of room and positioning of windows play a key role in channeling wind through the building. Maximum effort should be given to get cross ventilation so as to let air pass through the room, at body level.

The direction of wind is very difficult to categorize because the given predominant wind directions in data books, although they are very useful, will change considerably according to the geographical conditions of the surroundings of site, like other buildings surrounding the site, trees in and around the site etc. So it is better to infer data directly from (observational) the site concerned and use it for orientation.

As seen beneficial in traditional buildings the placement of windows for cross ventilation is very useful. Instead of placing one big window in a room with only one wall facing outside it would be more beneficial to put two smaller windows separately for better results. The position and size of wind inlet and outlet in a room determines the air velocity inside. The shape of the building can direct and accelerate the air flow inside.

4.4.4 Solar control shades.

One of the best methods to bring thermal comfort to the building is to avoid sun from coming to the room, or avoid the building to heat up in the first place, than trying to cool it later. And this can be achieved mainly by cutting down the sunrays coming through windows, and also falling on the external walls, by sunshades.

Among the characteristics of conventional architecture in Kerala, as in most of the modern world, is the wide spread use of glass in building facades. This increasing use of glazed surface, in place of earlier, say before the 70's, wooden shutter windows has caused considerable changes and the problem of over heating has become 'a major concern even in temperate and cold countries', [28] not to tell of Kerala's tropical climate.

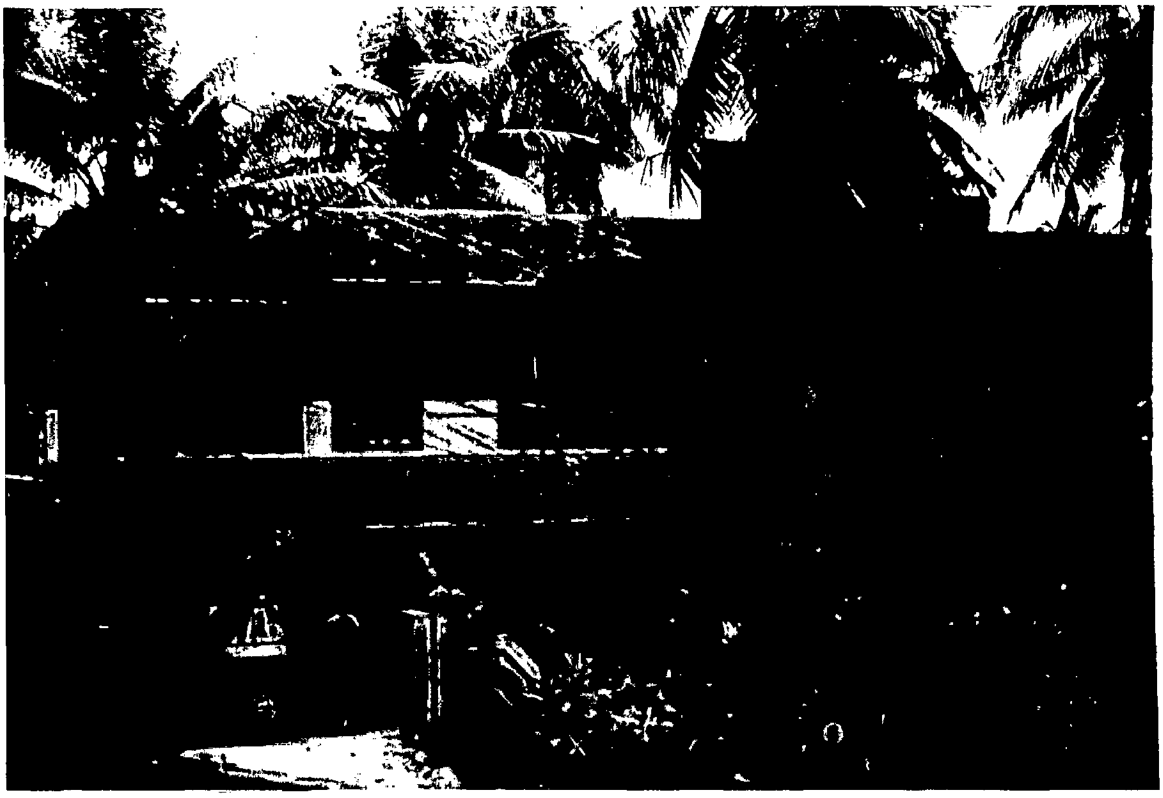
Its generally defined that the aim of sunshade is to let sun into the building in winter and to intercept it summer. But in Kerala's warm humid climate the question of heating the room in winter does not arise. So here the sunshades are to be designed with the sole objective of cutting sunrays from entering the room through out the year. And also it would be even better to provide sunshade through out so that even the exterior walls are protected from the sun, because if the exterior walls get heated up it will intern heat up the interior again through conduction and convection. This will also protect the wall from pouring rains of this humid zone.

But the current trend of making sunshades into an design element or frill [Figures 4.20, 4.21] with out proper thought will lead to inadequate shading of external walls and windows. In this process of transition if the sunshade has lost its purpose and significance it is of no use.

Also, as stated earlier, more than half of the heat developed inside comes via. the roof through conduction and convection. So the best and most effective method would be one which reduces this heat from passing in.

Figure 4.20: Inadequate shading of Windows in conventional houses

Figure 4.21: Inadequate shading of Windows in conventional houses



The traditional method used for this is the use of a false ceiling, *'mache'*, and thereby creating an attic space, which acts as a buffer zone between this heat re-radiation from roof and the room below. This is a very effective method to bring down the internal temperature. (In a two storied building the rooms on the ground floor feel less hotter than 1^{st} floor is because of this effect, here the entire 1^{st} floor acts as an attic)

Now modern verity of this is the double roof casting, where two layers of RCC slabs are cast one over other with a gap in between to get this effect. But because of the obvious cost factor involved, it has not become popular. But the roof slab construction by filler slab method, popularized by Laurie Baker, helps in bringing down this re-radiation, although only to a very limited extent, by the air gap provided between the two mangalore tiles embedded.

And also the investigator would like to add here that the current 'trend' of putting tile roof over RCC slab will be of little use if it is fixed (sticked) over a cement layer. But at the same time if there is an air gap between this tile and the roof it do help to reduce the main roof from getting heated up directly, which intern will obviously reduce the re-radiation from the roof.

4.4.5 Proper ventilation.

Ventilation is another important factor by which the hot air formed and trapped indoors can be exhausted out. In traditional wooden houses, the false roof mentioned earlier was made of wooden planks closely put together above the rafters. And here the hot air, which rises up, due to lower density pass through the space between this planks and gets into the attic space and from there it pass out through the gables, the *'mukhappu'*. Or the air can even pass through the very tile roof as it by the virtue of the shape of the mangalore tiles, when tiles are arranged it will naturally form a gap between them which lets air passes through the 'roof'.

But today the concept of ventilation has reduced to a little slit on wall near the roof slab. Although it do help, of course, but if it is given a little more thought, on its location and size by the architect, and not leave it the mason, it would be more useful.

In Kerala humidity is the all-round villain in the cooling process. It reduces comfort conditions directly, limits the usefulness of passive cooling system and as a final blow, it promotes the growth of unsavory organisms such as mildew. Mildew can spring to life quickly, needing only relative humidity of 70% or more maintained for 12 hours (for example the blue-green growth we see on a pair of shoes, tucked into a dark closet corner). So control of humidity is another key factor for thermal comfort, and for this there are but few options. The key points to control humidity are, control of source of moisture and, above all, prevent local moisture concentrations by good ventilation systems.

So ventilation is another very important factor to be considered while designing for Kerala's humid climate. There for care must be taken also to vent all moisture-producing appliances and equipments, which add up to the existing high humidity factor, such as washing machine, oven, cooking range etc. Another major producer of water vapor is the bathing area, the role of bathrooms in increasing the humidity of air is very high. So extra care must be taken in ventilating the bathrooms.

If no proper ventilators holes are given in a room, the ceiling fans in that room will only circulate the hot air on the top (immediately below the ceiling) of that room. This will again cause discomfort. Also to avoid the growth of mildew it is better to provide louvered doors for built-in almarahs and storage areas to encourage air circulation inside.

4.5 Other methods and New approaches

There are of course many other traditional methods which we are aware of, which have faded off from use due to various other reasons. The role of verandah on all sides, which shades all the external walls directly, and internal courtyards also play a vital role in bringing the thermal comfort, but the cost factor and security reasons pulls down its popularity. Also increasing the room height also helps to give better thermal comfort inside the room but again the cost of the brick work increases as we increases the height.

The method of using rat-trap bond, filler slabs, jally openings etc. Are also very useful as already discussed. There are also new methods like roof ponds and double roof systems which again did not became popular because of the cost factors, with today's workmanship culture roof-ponds may lead to leaks and other problems.

And also are some systems which combines passive and active (that's with the input of energy) systems together, of which the one most advantageous to Kerala's climate is the 'whole house fan', which gives a good forced ventilation to the whole house.

4.6 Inferences.

The vernacular architecture of any region must have been evolved after so many years of innovation and the study of climatic problems of that particular geographical area. Our forefathers had constantly tried to make ones living environment more and more comfortable, by trial and error methods, and of course from experience, and also from dedicated studies of regional- macro- climate.

It's a well known fact that Kerala had many a traditional texts of its own which contained many rules, or certain guide lines, to guide any one who wants to build a structure in this geographical area. This will, among other things, also acted as a climatological data-base for efficient design for many years.

Now in the wake of so called 'modernity' and new construction techniques, we have been consciously rebelling against the vernacular climate- conscious designs, which have been perfected through years- centuries- of work and innovation. And which we 'did' felt giving us the near comfort conditions, and considering them as superstition and irrelevant, even though the new modern structures we live in are found to be not appropriate for our climate.

Actually what we understand as passive design is nothing but a further improvement of climatic control system, as applied to traditional architecture for a long time already. So much can be learned from the past, if one bothers to look, to find solutions for the complex problems of the present and lay down blue print for a sustainable future.

CHAPTER 5
LOW ENERGY MATERIALS

5.1 Introduction.

Until a recent past attempts in reducing the energy use in buildings have concentrated largely on the energy used by the occupants for thermal comfort, lighting etc. So the design strategies evolved have consequently focused largely on the energy used after it is built. Such strategies have virtually ignored the energy required. to produce the materials and to transport them to site. [29]

For a new building, the 'embodied' energy, or energy content in the building's structure, its fabric [Table 5.1] and its services can be upwards of five times the amount of energy used by the occupants in the first year. [30] Techniques for the calculation of the embodied energy of materials are not new but, however, these have not yet found their way in to the energy efficient design approach. There are many reasons for this:

1. There is no generally agreed or accepted methodology for calculating energy content of materials.
2. There are many different verities of materials which make up a building, exceptionally in the under developed countries and rural areas.
3. And this energy content is only a small proportion of the total energy used by the building over its whole life.

This chapter discusses the concept of embodied energy.

5.2 Significance of Embodied Energy.

Next to food and clothing, the basic need for human being is a shelter to live in. Mankind has been evolving different kinds of shelter with the civilizations and time. In earlier times man has used natural materials like stone slabs and branches of trees to make a roof, a shelter for him and he didn't need to buy the 'materials of construction' as we term them today.

But as the time went on he progressed or 'modernized' that today the construction of an abode has become a costly affair both in terms of labour and materials: And above all, in earlier times when he got the materials of construction free from nature and all he has to do was to put them together as an house, today the cost of materials consume unto 85% of the total cost of construction. (See Appendix II) Today a lot of energy is going into the making of this construction materials.

The building industry is in fact the largest consumer of highly energy intensive materials. [Table 5.2] The total energy required for the production of 4 major building materials i.e. cement, steel, brick & lime, was 742.5 PJ in 1989-90 in India. Its projected that by 2020 AD, it will go up to 2363.0 PJ. [31] And obviously the corresponding carbon dioxide emissions will also follow such a drastic increase. In fact

Material	Energy Requirement	
	MJ/kg	MJ/Cu.m
Aggregate	0.03-0.3	50-450
Aluminium	250-275	700,000-900,000
Bitumen	0.2-0.6	200-550
Brick: common	1.0-1.5	1250-1875
Brick: wire cut	3.0-5.0	3750-6250
Cement	7.25-8.25	10,800-12,400
Copper	45-75	400,000-540,000
Glass	22.5-28.5	60,000-75,000
Glass fibre	15	180
Plaster	3.2	2400
Plastic	70-150	2200-4200
Steel	30-50	210,000-390,000
Timber (transport)	1.5-6.0	1500-2500

Figure 5.2: Manufacturing Energy Requirement

Component	Materials	Energy per unit	
Concrete	Mix 1:20 cube strength, say } 10–20 N/mm²	750–1350	MJ/m³
	1:15 cube strength, say } 10–20 N/mm²	1000–1700	MJ/m³
	1:3:6 cube strength, say } 10–20 N/mm²	1500–2250	MJ/m³
	1:2:4 cube strength, say 21 N/mm²	2500–3500	MJ/m³
	1:1·5:3 cube strength, say 28 N/mm²	3250–4250	MJ/m³
	Screed 1:3 by volume	2750–3500	MJ/m³
Beam and slabs	*In situ* reinforced concrete	8800	MJ/m³
House foundations	Piled reinforced concrete foundations	3500–4000	MJ/m² floor area
	Trench fill mass concrete foundations	1500–2000	MJ/m² floor area
Walling	Single leaf brick: commons	200–285	MJ/m² wall
	facings	500–800	MJ/m² wall
	Single leaf block: 75 mm	220–290	MJ/m² wall
	100 mm	280–380	MJ/m² wall
	150 mm	400–550	MJ/m² wall
	Plasterboard: 10 mm thick	65	MJ/m² wall
External walling	Brick/block cavity and plasterboard	850–1250	MJ/m² wall
	Timber frame: timber sheeting and studs, insulation, plasterboard and brick facing	600–950	MJ/m² wall
Party walling	150 mm block and plasterboard	500–700	MJ/m² wall
	Timber frame: studs and plasterboard	400–450	MJ/m² wall
Windows	Timber frame: single glazed	275–350	MJ/m² window
	double glazed	500–660	
	Aluminium frame: single glazed	6800–8400	MJ/m² window
	double glazed	7100–8700	
Roof truss	Nail plate truss, spacing B timber section A	7000 A/B + 30	MJ/m² roof area
Roof	Trussed roof with tiles, insulation and plasterboard ceiling	400–440	MJ/m² roof
	Short span flat roof, with weatherproofing, insulation and plasterboard	120–140	MJ/m² roof
Stairway	Reinforced concrete stair 1 m width	12 900	MJ/2·7 m rise
	Timber stair 1 m width	440–730	MJ/2·7 m rise
Floor	Reinforced concrete slab floor	900	MJ/m²
	Timber joists and plywood	50–80	MJ/m²

Table 5.1: Energy Requirement of Building Components

these for building materials account for nearly 80% of total carbon dioxide emission from the construction sector, which is 17.6 % of the total carbon dioxide emissions in the country.[32]

The ever growing population and the consequent need for dwelling units will increase this again drastically. This sector is also consuming a large share of global resources, accounting to about 1/6 to 1/2 of world's minerals, water, wood and energy.

It consumes very large quantities of non-renewable energy sources for their manufacture, transportation of raw materials to the factory and then to site and finally for its use in construction. This sector is also a substantial source of solid waste, a polluter of air & water, and an important contributor to land dereliction. It is responsible for 22% of the annual carbon dioxide emissions, making it the single largest contributor of greenhouse gases.

5.3 Building Materials and Natural Resources.

Every built object consumes some natural resources and energy for its manufacture and it also creates an alteration to the natural landscape. Wooden logs mean a tree cut, stone boulders mean hill flattened & brick mean earth excavated somewhere. Knowing the finiteness of the natural resources and recurring implications of its consumption, all construction requires to be sustainable. But this should be done without disturbing the flow of building materials needed for construction.

So the question is how to achieve sustainability in construction, while continuing to provide the much needed building materials? It can be achieved by the following ways: -

- Minimize the use of non-renewable natural resources as much as possible in building construction.
- Reduce consumption of high-energy intensive materials, traditional or modern.

- Use of alternative/ innovative building materials which need less energy for its manufacture.
- Use of locally available building materials as much as possible.
- Making all manufacturing process of construction materials more energy efficient.

Of these the 1st four will come into preview of architect more than the last one. But to implement these ideas the architect must know capital energy cost (CEC) of each material that he is going to deal with.

5.4 The Capital Energy Cost.

The Capital Energy Cost or CEC of any material is made up of following components:

- The energy input in production of building materials
- The energy needed for transportation of building materials to site.
- The energy needed for the actual construction work.

Use of locally available materials can solve the second problem. Regarding 1 & 3 a more in-depth understanding is necessary because comparison of the CEC charts can be often misleading.

For example, if we look at the chart given [Figure 5.1] we can see that the flat glass has a material is about 4 times more energy intensive than bricks, per tone. But 1 Sq.m of one brick wall is about 8 times more energy intensive than 1 Sq.m of 4mm float glass. So before applying and reading this CEC, it is important to convert it into units appropriate to construction. Therefore before making any comparison it should be converted to same combination units of construction, like Cu.m of wall, roof etc.

The out come of one such study [33] in case of wall construction, shows that the construction with hollow concrete block of size 40 x 20 x 20cm in cement mortar 1 : 6

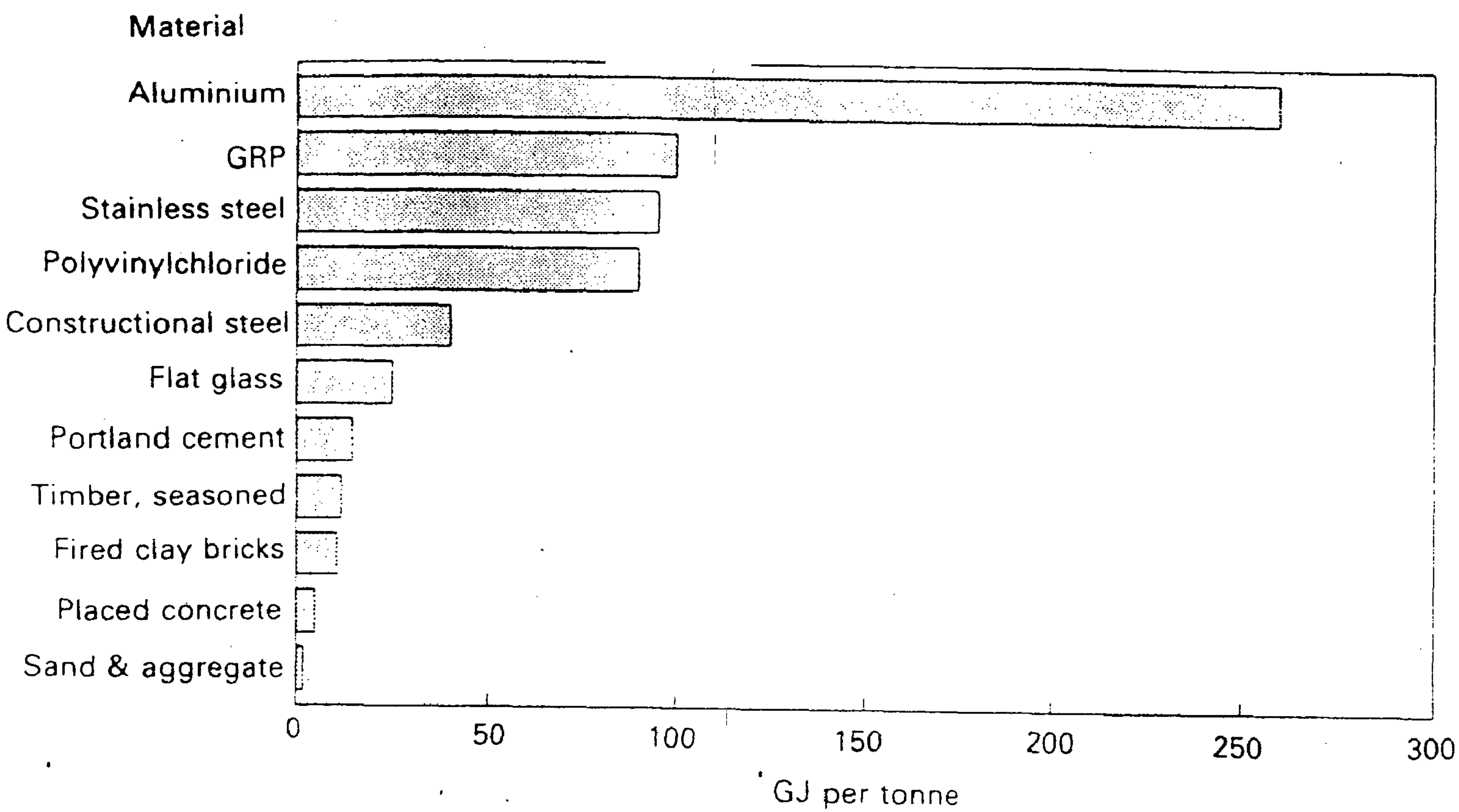


Figure 5.1: Capital Energy Cost of Common Materials

requires only a very low in energy input of 193.25 MJ/Sq.m, which is almost 1/3 rd of traditional brick work in composite mortar (1 :1 : 6) which required 637.95 MJ/Sq.m. This is because large blocks have less mortar joints and so has only less mortar consumption for its construction. In general this study has shown that larger the building block, lower will be the energy cost. The final results of this study are given in Table 5.3, given below.

Sl. No	Basic Building Block (Dimensions in centimeters)	**Energy Inputs in MJ per Sq.m**		
		In Cement mortar (1:6)	In Composite mortar (1:1:6)	In Composite mortar (1:2:9)
1	Traditional brick (22.9x11.4x7.6)	614.65	**637.95**	621.23
2	Modular brick (20x10x10)	538.78	562.01	547.69
3	Clay flyash brick (20x10x10)	320.78	344.01	329.69
4	Sand lime brick (20x10x10)	367.78	391.01	376.69
5	Hollow concrete brick (40x20x10)	347.80	364.72	353.61
6	Hollow concrete block (40x20x20)	**193.25**	203.52	195.40
7	Solid concrete block (30x20x15)	299.50	312.11	302.83
8	Fal. G. Block (30x20x15)	242.00	254.61	245.33
9	Aerated block (39x19x19)	209.58	221.11	215.44

Table 5.3: Comparative energy inputs per unit Sq.m. of Alternate Walling Elements.

5.5 Energy Auditing as a Tool for Sustainable Construction

Energy auditing or energy cost estimation of housing construction enables us to quantify the energy consumed in the construction work. This quantification is useful in reducing the energy consumed in housing construction through the efficient use of building materials. Therefore energy auditing can be considered as an important tool for achieving a sustainable growth in housing construction.

This importance of studying the problem can be better understood from the fact that like any other developing country, India too is presently passing through a phase of acute housing shortage. As per National Building Code (NBO) estimates, in 1991, there was a shortage of 31 million dwelling units in the country out of which 10.4 are in urban sector and 20.6 million in rural sector. It is also significant that against the annual population growth rate of 2% in the country, the number of residential buildings has increased at an annual rate of only 1.5 percent.

To achieve a sustainable growth in building construction, it will be necessary to study the use of contemporary and innovative building materials and thus a saving in energy and non-renewable resources. For this an energy auditing has to be done to the most used building materials of Kerala State.

5.6 Building Materials of Kerala, Facts & Figures From 1991 Census.

According to 1991 census, if we look into the chart of the distribution of houses in Kerala by the predominant materiel of wall [34] we can see that 36.3% of the total houses are built with stone (i.e. Laterite in Kerala), 24.4% are with burned bricks, 16.5% houses are with unburned bricks, 8.2% are mud houses, 8% lives in houses build with grass, leaves, reeds and bamboo.

That means only 24.5% of the total houses in Kerala are built with burned bricks and the remaining 75.5% lives in houses with other indigenous materials. So for achieving sustainability in building industry of Kerala, the concentration should be more on developing the indigenous materiel industry, which is used by more than three forth of the total housing industry.

Now if we look into the list of census houses by predominant materiel of roof [35] in the order of importance, 57.1% has tile roof, 25.2% has grass, leaves, reeds and bamboo (i.e. mainly coconut thatch in Kerala), 12.5% uses concrete roof, here again we can see indigenous materials and methods dominate higher on use than conventional concrete roof.

The construction in Kerala, like that of rural India had always been a local activity based on the use of indigenous materials and self help. And also in the past this activity formed an essential part of the 'way of life' of people. But in the wake of time, growing population, fading joint family system, industrial set of agriculture and all, changed this and housing became a business activity with houses constructed mainly by contractors and the beneficiaries role is limited to financier. His personal involvement on the implementation, except in some modern self- help schemes, reduced and as a result the quality of construction deteriorated.

In the light of this if we analyze the earlier given figures of most used materials of construction in Kerala, we can see that the prominent materials are 1.Latarite, 2.Mud, 3.unburned bricks 4.cocunut thatch and 5.bricks.

5.7 Locally Available Materials Of Kerala.

Kerala is famous for its wooden architecture. In olden days it was possible because wood was easily available and economically suitable solution in yester years, but today, as any where else in the country, it is not viable anymore. Today the first choice of building materiel comes to anyone's mind is brick. But now there is a growing concern and awareness over the use of bricks, as it consumes a lot of energy for its production. It is not only that it consumes huge amounts of wood or coal but also the amount of natural resources like fertile soil it consumes.

According to a study conducted by HUDCO, our country needs about '60 billion bricks every year, which means this would exhaust about 1600 X 10 m of agricultural lands or clay fields annually. It will thus make barren about 3000 hectors of fertile land'. [36] The extend of damage it will be cause can be imagined, taking into account the demand for bricks which required is rising continuously due to tremendous need for housing, growing population etc. It will also lead to the erosion of fertile soil, degradation of soil and disturbance of ecology.

The energy needed to burn the mud blocks to brick is another hazard. So the need for the time is to develop alternative building materials or to improve and upgrade the other indigenous materials and construction technology of the region. Which not only saves earth and causes minimum environmental damage but also one which needs no energy input or less energy input for its production and construction.

5.7.1 Laterite, the Stone of Kerala.

As stated earlier larger the building blocks, it has less mortar joints and so has only less mortar consumption for its construction and lower will be the energy cost. In this context construction with latarite block, the traditional building block of Kerala, would become very lower in energy content because its natural and less energy (CEC) is needed for its "manufacture".

In Kerala, according to 1991 census, 36.3% of buildings have latarite walls compared to 24.4% with brick (burned) and 16.5% with unburned bricks, 8.2% mud & 8.1% in grass reeds, bamboo etc. So latarite was one of the prime materials used. Many traditional vernacular buildings of Kerala, some up to 200 or more years old and many with two/three stories high are constructed with latarite as the building block are still in good condition and use. But in the new era when 'cement & brick' construction started to be known as 'modern', latarite was termed 'older' and is phasing out in urban areas, but it is still in use in rural areas. At areas where it is readily available, architects should encourage its use.

It is a readily available stone in the north and central parts of Kerala, where it is mostly used. It is a type of stone, hard earth, digged and cut out from 1-15 meters deep below the ground level. It is brown/ golden red in colour and is very hard. It can be directly used on construction and does not need any treatment for getting in final form. And since it is cut out from earth it can be cut to any possible size, but usually the usually followed one is 9"X12"X6". And this fact that it can be cut into any required size, its hardness and getting in ready-made form has made it a popular building material, even in high income group housing.

It was one of the prime materiel used to build houses in Kerala's northern and central areas along with wood for centuries. Its toughness and easy workability like brick-work was another reason for making this happen. Many traditional *'nalu-kettu'* (house with courtyard) were build with latarite as the prime building material are still in good condition and use. But in the new era when 'cement and brick construction' started be known as 'modern' and all the other traditional vernacular materials and methods were termed 'older', the use of latarite as the prime building material of construction is declining now, but its heartening that this practice is still followed in north Kerala by many.

In the geological classification, Latarite comes under metamorphic rocks, which are formed by the change in character of the pre-existing rocks. The igneous rocks (which are formed by cooling of magma, the molten substance inside earth's surface), as well as sedimentary rocks (which are formed by the deposition of products of weathering on the pre-existing rocks) are changed in character when they are subjected to great heat and pressure. The process of change is known as the metamorphism and the outcome is metamorphic rocks.

It has a porous and spongy structure, which make it easily quarried in blocks. It contains high percentage of oxides of iron, which gives it its brown/ golden red colour. It has a comparatively low compressive strength which varies from 1.80 to 3.10 N/mm. (the compressive strength of brick can vary from 3.5 - 14.0 N/mm and that of granite is 75.0-127 N/mm.)

It is mainly used to construct load bearing walled houses. Such buildings even up to three stories can still be seen in Kerala. It is now used also for non-load bearing partition walls in multi-storied construction. It has been used, in a four star hotel in Calicut in northern Kerala, as an architectural facade treatment element and used it to cover the external facade of a ten storey, column-beam construction and exposed it with out plastering outside.

It is also used as road metal, course aggregate for concrete, for foundation etc. It has been also used in the past to construct bridges which are still in use and this again shows the strength of this materiel.

Although it has a main disadvantage that it is easily attachable by termites, but this can be rectified by chemical treatment. More research should also be done on increasing the compressive strength of this material. As it is taken from earth below a certain level it is not fertile soil. And further if the latarite used for a particular building is cut from the same spot it is to be built, it solves ecological problems too.

But the most important advantage of using latarite is that, as stated earlier it does not need any energy other than man-power to make it. This means that laterite saves energy, comparing it to brick, not only in the fuel used in burning brick but also the fuel used to transport it to the site, if it is cut out from or around the site itself, if available.

5.7.2 Back to Mud- A Step Forward.

Mud is another natural building materiel which has no embodied energy- except the human energy needed to make it to useful form. It is used as a major wall building material in Kerala's rural sector, almost 70% of the rural houses, build to the low-income group are made of mud. It is most heartening that probably Kerala is one among the very few regions in India where mud is used most extensively, even among higher income groups.

For example many of the *'nalu-kettu'* in Malabar area was built with mud and still in good condition. In the Travancore areas of south Kerala too one can find such mud houses of more than 200 years old. Perhaps one of the most interesting aspects of Travancore habitat system is that use of mud was limited not only for house construction but also for construction of compound walls called *'kasala'* and there by avoiding the use of brick altogether.

Today when most of the people in rural areas cannot hope to even afford the cheapest housing materials available in the market mud is a great blessing to them because the greatest advantage of mud is that it is cheap and easily available to common man. But the problem associated with mud construction is its strength.

In India 80- 90% of rural and 30- 40% of urban population leave in mud houses. So considering the substantial component of population living in mud houses, it would be wrong to reject mud on the ground that it is not strong and its an out-dated materiel. It should, on the other hand, make us realize that mud is still a relevant material providing homes to millions of peoples, and therefore more appropriate adaptive research should go into it and also its extension into the fields should be given more importance.

Mud or earth as a building material used for construction since time immemorial and has been a subject of revival of interest in resent years, because of its energy efficiency and ecological value as a natural bio-degradable material. And it is still a principal building material in many developing countries. In Egypt, for example, architect Hassen Fathy's work is worth mentioning in using mud even in high-income group housing. There are at least 20 different methods in the use of mud as walling material world over.

In Kerala the most used method is, what's known as the 'cobwall' method. It is a simple method using mud lumps for wall construction. In this technique, the local soil which is neither too clayey nor too sandy is mixed with required amount of water to form lumps of good consistency and finally these lumps, mud balls, are placed layer over layer and pressed, pasted by itself, manually. The height of layers put on one day is limited to make allowance for sufficient time for drying, and built-up till the finally the entire height is reached.

The wall so constructed is then plastered with a coat of mud, mixed with some organic material such as cow-dung. Generally height of this wall does not exceed 2.5 meters and thickness is the usual 9 inches.

Mud has certain advantages which the industry can explore. Foremost among this is the low energy input required for its production. Another advantage is that it does not create a dependence on imported products and can be made locally. And as far as individual is concerned, the advantages of being able to build his own house is great and often comes out with indigenous solutions and designs.

It has another advantage that its a labour intensive process and there for capable of generating opportunities for employment in the rural sector. And climatologically also it is sound because it provides excellent heat insulation. Inside a mud building is cooler in summer and hotter in winter than a building with concrete and steel.

Though mud architecture will be able to play a very significant role in maintaining environmental stability and energy resource availability, it has got inherent limitations also. It has, as a materiel, low in strength and requires relatively high maintenance for longer life. And also in Kerala where rainfall is very high it has to be designed with proper protection. So what is the need of the time is, more research and development of mud wall technology which can solve the problems of this building materiel used by millions.

5.7.3 Unburned Bricks/ Sun Dried Bricks.

Next to latarite and burned bricks, the material on which most people built their house in Kerala is unburned bricks. It accounts for 16.5% of total households, (both urban and rural together). It makes stronger walls than mud walls. The major difference with burned brick is that it saves the energy used to burn the brick and so it can be called 'energy efficient brick'. It replaces the baking fuel with the heat of sun.

This method is actually an improvement of popular mud wall construction, developed through years. Under this method walls are prepared from bricks which are just dried in sun. For the preparation of sun dried bricks any soil which contains 80% clay and 20% sand (or 40% clay and 60% sand) may be used. Water is added to soil in requisite quantity and then so prepared mud is molded into shape of bricks/ blocks of suitable size with the help of wooden mould and is left in the sun for drying. The green dried mud bricks are then used for the construction of walls.

Though they are normally larger in size than kiln-fired bricks, they do not confirm to any standards. The bricks are laid in courses in mud mortar. The wall is raised in stages, about one meter high every day. The mud wall so prepared is well formed and strong.

The sun-dried bricks are known as 'adobe' in Mexico and USA. Other than south India, it is also popular in Egypt, Peru, New Mexico, South Africa and West Tunisia. The State of New Mexico has developed a regulatory code for mud buildings which covers mainly adobe (sun dried bricks) as its so popular there.

Now it is becoming more popular in rural India recently after the dedicated works by ASTRA in Bangalore, Nirmithi Kendras from Kerala and other NGO's. ASTRA has developed many techniques and machines which have contributed in long way for the development of sun dried brick.

5.7.4 Coconut Thatch.

Kerala means the land of '*Kera*' or coconut tree. Coconut tree covers more than half of the total tree population in the state. The abundance in availability of coconut tree had made it a very popular building materiel of the state. Thatch also being a natural material has no embodied energy except for the human energy needed to make it.

Coconut thatch is used for wall construction, roof construction and even compound wall construction. Although the life of this material is considerably low, the low cost of replacement- which is practically nil for rural people as they do the making and thatching of coconut leaves themselves from there own coconut trees- made it even more easy.

And also in coastal areas where the destruction of houses by high tides and cyclones are common, it is more appropriate to use temporary materials for construction, where the chances of loosing the materials are high.

The main problems faced by thatch is its low life and probability of fire hazard. Now many agencies are working on solutions to overcome these problems. The general method used for improving the life of coconut thatch is by immersing it into a solution of copper sulphate and then brushing or spraying with cashew-nut oil over it. It is found that it increases the life of the thatch from the usual one year to five years. But increases the cost by 25%. The Government or panchyath can subsidize to give copper sulphate and cashew-nut oil to rural areas for treating thatch and increasing the life of it.

Another major problem is fire hazard. Research is going on this field also. CBRI had come out with a solution some years back, to cut the fire hazards by thatch roof with the use of locally available materials. This technology uses locally available materials like clay, straw, kerosene and cow-dung. The technique consists of applying the non-erodable mud plaster to both top and bottom of the thatch. If cracks have been developed in this plaster, they are sealed off with the same mud plaster. Over this two coats of cattle dung slurry and two coats of bitumen cutback (bitumen and kerosene in equal parts) are applied. This is then fully covered with a coat of dung slurry.

This fire proofing method costs some 25-30 rupees per square meter. And this roof is neither combustible nor a supporter of combustion. This roof is not affected even by storms and lavishing rains. It has also a very long life of six to eight years. However it has not yet become popular. A more easily usable solution has to come out for this.

But with proper government assistance and NGO support this energy efficient material can be used in a more efficient way in rural areas where it is most popular now.

5.7.5 Brick Construction.

As far as brick is concerned, today there is a growing concern over the use of brick, as it consumes a lot of fertile soil for its making (which the nature took millions of years to make) and also it consumes a lot of wood or coal (energy resources) for its baking.

According to the studies conducted by HUDCO, our country needs 60 billion bricks every year, which means this would exhaust about 1600 x 10^6 Sq.m of agriculture land or clay field annually. It will make barren, about 3000 hectors of fertile land. [37]

But the primary energy charts commonly available can also be misleading, for example the common charts on embodied energy, like Table 5.4 given below, shows that brick has low energy input compared to bigger similar basic blocks. But only

Sl.No.	Building Block	Size. (Dim. In cm.)	Energy (MJ/ Unit)
1	Traditional brick	22.9x11.4x7.6	4.50
2	Modular brick	20x10x10	4.50
3	Clay flyash brick	20x10x10	2.32
4	Sand lime brick	20x10x10	2.79
5	Hollow concrete brick	40x20x10	10.8
6	Hollow concrete block	40x20x20	11.0
7	Solid concrete block	30x20x15	10.4
8	Fal. G. Block	30x20x15	7.90
9	Aerated block	39x19x19	11.5

Table 5.4 : Primary Energy Values of Basic Building Blocks.

in a comparative study of walling with different basic blocks can only give the correct answer because the number of blocks consumed to construct one Sq.m would be different with different materials.

As the earlier mentioned study on capital energy cost comparison of walling materials [38] clearly shows, traditional bricks, which are most the widely used walling material in India, prove to be the worst choice with respect to the energy input involved.

Brick is in Kerala, as anywhere else in the country, the most accepted and easily available modern building material. Since it does not require any dressing and the art of laying bricks is so simple that it can be carried out with little skill and the time tested quality makes it the most popular building material and adds to this is its strength, durability, low cost, fire proofness and easy availability.

It is one of the oldest building materials and has been in use since the dawn of civilization. In India the Indus valley civilization used bricks for their construction in 1500 BC. And after 4500 years it is still as popular. Today India has the production capacity to manufacture 10,000 crore bricks through about 45,000 local kilns in unorganized sector.

But because of the poor composition of the soil, the strength of bricks in Kerala is very poor. It varies from 2.5- 4.0N/mm. in Kerala, where as per BIS: 1077-1957, the minimum crushing strength or compressive strength of bricks should be 3.5 N/mm. (The bricks with crushing strength of 7-14 N/mm are graded as A and those above 14 N/mm as AA). In some parts of southern Kerala, like Trivandrum for example, most of the bricks are coming from neighboring state of Tamilnadu.

Considering the poor quality factor, high embodied energy factor and also of the environmental hazards caused by it, it would be better to look for an alternate material for wall construction. Or at least reducing the environmental hazards and improving the quality of brick by using industrial waste like fly-ash, choir-waste etc. to give brick industry a new boom. CBRI is working on developing good quality bricks from inferior black cotton soil, but again it has to be made commercially viable.

5.8 Lime, the Sustainable Cement.

Lime is a material which is again abundant in Kerala as it covers more than 560 kilometers of coastal area. And lime was one of the principal cementing materiel of yester years, along with mud, until it was replaced by modern cement just a century ago. All the main historic buildings in Kerala, like most parts of India, were built with lime mortar as the only cementing material. To state a few examples are the famous Padmanabhapuram palace, the Secretariat, the historic churches, mosques and temples of Kerala.

But today it has been extinguished from construction field because of modern cement and also the lack of awareness of its strength, lack of emphasis of this common material in technical educational system, which was forced on to us by foreigners.

Cement as it is produced much lesser than urban demands, rural people may get a very little share of it. It is therefore much wiser to give more emphasis on establishing lime factories to produce refined lime on commercial basis to meet the needs of future. It is another field which building industry can explore.

CBRI is also working on improving hydrated lime which can be a substitute to modern cement in a big way. But in this field more than technology development it is the creation of awareness of strength oh lime mortar is to be given more importance.

5.9 Inferences.

Since it has been revealed from 1991 census (Table on household amenities) break-up, that more than 75% of the houses in Kerala are built not from bricks and are by other indigenous materials, any attempt to solve the problem energy shortage and to provide low energy houses in rural sector with out considering the existing indigenous vernacular material industry would be a failure.

Therefore more efforts has to be made in improving the manufacturing process more energy efficient. And also provision has to be made some how to mention the energy content of the product to the user. If there is a comprehensive data available to architects and builders on the energy content of the materials, much the designers can do based on that. This has to be done in the building material industry with upholding the indigenous tradition, on the light of Census records, and it had to be given more importance to develop the living conditions of rural area.

In rural areas the prime body for administration is 'grama-panchayath', now it's hopefully going to be given more power, so its a good time to give some energy efficient boost to the vernacular technology and materials in a big way. One way is to establish a body to improve rural indigenous building material industry on line with the upcoming Energy Bill. It should collaborate with voluntary agencies, private industry, co-operatives, Universities and other institutions and utilize their services and experiences to develop local methods.

They should also conduct vocational training courses, with stipend if possible to attract more people for such trainings, to develop the indigenous ways of energy efficient construction and teach local masons about the latest developments on this field elsewhere and the importance of energy efficiency. So the core aim of this local bodies should be to upgrade traditional sustainable building construction technology suitable for their particular region (panchayat) suiting its vernacular styles and climate.

Another major concern is that, although a number of energy efficient technologies have been already been improved- like stabilized mud blocks for example- by building research institutions across the country and by professional organizations working in this field which are also cost efficient, but a few of them have only gained wide spread knowledge. This problem of upgrading old skills and imparting new skills to local artisans for energy efficient construction can be solved to a great extent by these local bodies.

Since the construction of new buildings is entirely a process of assembly of already manufactured or processed material and is characterized by labour intensive process, introduction for architects and masons to the new energy efficient materials has a far-reaching social and economic significance. It will not only help in extending new techniques and improving the earning capacity and economic status of rural people but also contribute in a small way to solve the energy shortage of the State.

CHAPTER 6
CONCLUSION AND RECOMMENDATIONS

6.1 Introduction.

Today it has become obvious that the era of low cost abundant energy is over, but at the same time the demand for energy is increasing at an alarming rate than ever before. In spite of all the research in non-renewable energy field, to produce energy systems based the on renewable sources like sun, biomass, wind etc., the supply is still limited. This increased the pressure in fulfilling the energy demands and threatens the economic growth, which intern encourages the use of environmentally damaging forms of energy.

'A great many of the environmental problems confronting mankind at present time are connected, one way or another, to the extraction, conversion, transformation or use of energy. This is the principal reason why a through understanding of energy and environment interactions is a prerequisite for planning and implementing sustainable development. The role of energy in sustainable development has been acknowledged by various stake holders as one which should be understood from both economic and environmental perspectives'. [39]

Furthermore, today the boundaries of these side effects of human activities cannot be compartmentalized within nations or sectors, but can only be looked only on a global scale. So now the attention world over is focused on the economic and social development on one hand and preservation of environment on the other hand. Energy being the most fundamental requirement in every sphere of life, providing cleaner energy for multiple uses and needs, but at the same time preserving the environment, reducing the pollution and reducing deforestation has become the need of our time.

6.2 Summery of Findings.

Through out the history of mankind the availability and exploitation of new energy sources has always accompanied by major economic and social changes. It can rightly be said that the energy has always been a primary agent in rising the quality of life of people, through out the history. Rising the quality of life of the people is what is termed as development and as stated in the introductory chapter sustainable development is understood as rising the quality of life of present generation without sacrificing the right of future generations to a similar quality of life.

In another year time we are entering into a new millenium and today the world is changing more rapidly than ever. Sometimes we do not even realize the effects of our actions simply because these actions are almost invisibly rapid and overwhelming. As we now know it took us many decades to realize that the chemicals used for refrigeration and many other applications were actually threatening the very existence of life on earth because of their ozone-depleting characteristics. It has taken us almost a century to discover the ill effects of carbon dioxide and other gases on the earth's climate caused mainly by energy production. Now these realizations have made us understand that the path of development needs to be evaluated in terms of long-term impacts and possible ill effects.

But at the same time abundant energy is essential to maintain the high standard of living in industrialized countries and to achieve development of third world countries. The energy sector in India, as in most other countries, can and does contribute significantly to adverse impacts on the environment- be it the combustion of the energy forms like coal, oil and gas or the use of biomass energy forms resulting in forest and soil degradation and associated impacts. But the process of economic reforms in the country is irreversible and the need for accelerated growth indisputable. In Kerala State also this is very much true as explained in the third chapter. Now the question is how this can be achieved and the answer lies only in two sectors:

1. Increasing the dependence on renewable sources of energy.
2. Enforcement of energy conservation and efficiency in all arenas of energy use.

As far as the first one is considered it is more a technological and decision making problem to be solved mainly by scientists and decision-makers. But about the second option it is something anybody and everybody can contribute. An architect's/ builder's contribution towards this saving is especially great. And as the investigator has stated in the first chapter it is this that, he has fixed as the aim of this study.

Then the question of where all this can be achieved was discussed on the subsequent chapters, especially the potential and share of building construction sector on energy efficiency. It was clearly found that the construction sector is one major sector which consumes lot of energy.

Like any other developing country, India too is presently passing through a phase of acute housing shortage. As per National Building Code (NBO) estimates, in 1991, there was a shortage of 31 million dwelling units in the country out of which 10.4 are in urban sector and 20.6 million in rural sector. It is also significant that against the annual population growth rate of 2% in the country, the number of residential buildings has increased at an annual rate of only 1.5 %. The situation in Kerala is also similar and all this will result in an increased construction activity in the coming years.

Coming to the energy scenario in Kerala it was found from the study that the consumption of energy, especially electricity is very high in Kerala for thermal comfort reasons. Today the urgent need to design buildings in Kerala State that consume less energy for its construction and sustenance arise from a variety of external pressures like:

1. The present high shortage of energy to run the day to day needs and the increasing demands of the State.
2. The proposal to increase the thermal power generation of the State from the present 5% of the total generation to 40% in 2-3 years to meet the increasing need and its effects to climate change.
3. The high share of electricity consumption of the domestic sector in the State (nearly 50%) compared to the national level (around 20%).
4. The proposed increase in the share of electric railway lines in the State and its effects on electricity production.
5. The developing scenario of introducing new legislation on building's energy consumption, as already started in some other States of India, which can be anticipated in Kerala also in the near future.
6. The increasing demands to reduce energy consumption from various planning bodies from the national and international levels.
7. The increasing number of clients who aspire for a 'low energy' building for moral and/ or economic reasons.
8. And finally on the global scale, the Central Government is also under great pressure from international agencies to reduce energy consumption, especially in buildings.

These reasons coupled with the personal commitment of a new generation of architects who believe it imperative to build green buildings, exceptionally in Kerala under the influence of eminent architect Laurie Baker. They appreciate the importance to all of us in stabilizing emissions of green house and ozone depleting gases, and minimizing our pollution of this planet. They believe it is their duty as architects to develop buildings which will align themselves more strongly with the environment and depend less on conventional sources of energy for its construction ant sustenance.

In the light of this it became clear that immediate steps must be taken to bring energy efficiency in all fields and especially in building construction and the contribution of architect/ builder in this is very high. On the subsequent investigation it was found that he can do this basically by three ways:

1. Integration of passive techniques for thermal comfort which are suitable for the climate of Kerala into building design to reduce the need for energy intensive active cooling.
2. Reducing the input of high energy materials into building construction and replacing it with low energy substitutes to reduce excess energy use for the production of those materials.
3. Maximising the use of locally available materials of Kerala rather than importing materials from afar to save energy spent on transportation of the materials.

To find out what are the thermal comfort needs of Kerala, the climate of Kerala was analysed and it became clear that the objective any passive techniques in Kerala must be basically by two ways:

1. Reduce heat gains into the building by cutting off solar radiation as much as possible from falling into building through windows and also on the exterior envelope (there by avoiding/reducing heat to built up indoors).
2. To produce more possibilities to let wind/air pass through the building, those too at body height of occupants (there by increasing heat dissipation from body through evaporation).

To understand more about the suitable passive techniques, a study of traditional, conventional and 'Baker type' buildings were conducted and analysed, through selected case studies, to understand the pros and cons of all types. As a result it became clear that what we understand as passive design is actually nothing but a further improvement of climatic control system, as applied to traditional architecture for a long time already. And also that so much can be learned from the traditional buildings about passive techniques, if one bothers to look, to find solutions for the present problems in thermal comfort and lay down the blue print for a sustainable future.

And about the other option of using low energy materials a theoretical analysis was done on the most used construction materials of Kerala were identified and analysed for their environmental and energy efficiency properties to find out the potential low energy and locally available materials of the State.

These inferences were discussed and some recommendations were brought out for the use of architects and builders to be used as guide lines, or thump rules, while designing and constructing buildings in Kerala.

6.3 Recommendations.

Architects/ Builders can contribute greatly in solving the problem of energy shortage by taking proactive action based on the following recommendations:

Incorporation of passive techniques to design:

1. It is highly recommended that all construction be done based on or respecting the traditional vernacular architectural techniques, methods and materials used. The 'international style' which lingers perniciously in Kerala must be adopted with extreme caution as many of its details can be a direct cause of thermal discomfort inside the rooms, especially the flat roof, big glass windows and inadequate sunshade.
2. The siteing and landscaping of the building should be done in such a way as to achieve maximum use of available sunlight to light all nook and corners of interiors.

But at the same time shading from excess glare and minimizing solar gain also must be thought about properly.

3. It is recommended that attention should be paid to introduce appropriate passive systems for thermal comfort at all possible areas, understanding that today the use of passive techniques in design is not an addition but a basic necessity.
4. Reduce by incorporating design elements, the heating up of rooms in the first place than trying to cool it later by giving proper shading of windows, and even the complete external walls if possible.
5. Attention should be given to sun shade detailing so that it becomes useful for what it is meant to be, and not reducing it to some design element, frill or decoration without being useful.
6. Extreme attention should be given to the placement, location and size of windows to get maximum cross ventilation and maximum exposure to prevailing winds but at the same time the heavy rains of Kerala should be considered.
7. The size and location of the ventilators must thought about in such a way that it helps to take the hot air out and improves the cross ventilation vertically.
8. Always encourage white washing of external walls, even if it is only brick pointed, to help to reflect heat and so to reduce heat from going into the rooms through walls.
9. In a two-storied house through proper design, the staircase tower can be efficiently used as a ventilator shaft to take the hot air out.
10. Care must be taken to replace glass windows altogether by wooden windows if possible or otherwise at least limit the glazed area on windows and thereby contributing considerably to reduce heat gain inside.
11. If cost factor permits consider extending the sunshades projections to shade the complete external walls.

12. Planting or not cutting trees, especially coconut trees near the building to shade the roof, remembering that almost half the heat formed inside comes via the roof in a single-story building.
13. Try to tap the potentials of this Tropical State by incorporating solar energy for water heating and also for other electrical use. India receives sunshine of about 1648-2108 kWh/ Sq.m per year in nearly 250-300 days.
14. Since the rat-trap bond wall and filler slab roof adds insulation against heat, its use is highly recommended.

Use of low energy materials:

1. It is highly recommended that as far as possible architects must encourage the use of low energy materials like laterite, stone, big terra-cotta blocks for walling and roofing, etc., as far as possible.
2. Architects/ builders must be made understood that saving materials means saving energy. Always ask whether this material is absolutely necessary for the building before using it. It applies also to plastering of walls, painting etc.
3. Bring richness and architectural character to the building only by labour intensive process and not by the use of expensive (and so high energy) materials.
4. Reduce the number of bricks needed for construction by using innovative techniques of brick bonds like rat-trap bond, etc.
5. If strength parameters permit, try to replace cement with other low energy binding materials like lime, surki, mud etc.
6. Consider the possibility of using sun-dried bricks before opting for burned bricks if strength parameters permit, drawing inspiration from Hassen Fathy's work in Egypt.

7. Always prefer the use of bigger basic blocks of construction in place of ordinary brick, remembering bigger the basic block higher will be the energy saved.
8. Discourage the use of wire cut bricks because they are more energy intensive than ordinary bricks.
9. Since the fittings in bathrooms and toilets are highly energy intensive and expensive care should be given to limit the number of attached-toilets and replace by common toilets where ever possible.
10. It is highly recommended to discourage the prevailing popular habit of bringing granite all the way from Rajasthan for flooring/ skirting. Limit polished stone's use to kitchen slabs (until an appropriate low energy replacement is available for this)
11. Always encourage the use of locally available materials of construction as much as possible.
12. Always encourage the use of material and products that are eco-friendly and sustainable.
13. Encourage the recycling of construction materials if anything is available on site, especially in case of renovation or modernising an old building.
14. Encourage the buying/ using of old and used timber from second hand sale markets instead of going for fresh timber for wood-works.
15. Encourage the use of clay tiles, red/ black oxide floors in place of mozice, glazed tiles and marble floors. It not only saves energy but is cost effective also.
16. Discourage the use of aluminium as much as possible for railings, door/ window frames etc. even replacing it with wood is better option.
17. Always make sure that no materials are wasted in the construction site, remembering energy saved is energy produced.

18. Try to reduce the wood requirements for door/ window frames by effectively replacing it with wooden plugs fitted on to the walls.
19. Encourage the construction methods popularised by Laurie Baker like reducing the cost of construction by saving/ reducing materials, innovative design to avoid concrete beams, pillars and substituting it with arches and piers, substituting plastering with pointing where ever possible, etc.

<u>General recommendations:</u>

1. It is highly recommended that architects must be made understood (students of architecture must be taught) the magnitude of the problem of energy scenario of present and future projections so that they wake into it.
2. Energy efficient building construction must be made a compulsory subject in the architecture curriculum.
3. The building bylaws must be modified to incorporate the energy efficiency aspects of design/ building construction.
4. For Government buildings now rat-trap bond walls and filler slab roofs cannot be used because both these items are not included in the NBC, it is highly recommended to immediately take steps to ratify this.
5. Steps must be immediately taken to include these plus points and also design of filler slabs in to the architecture and civil engineering curriculum.
6. It should be made mandatory that all building material available in market must also supply with it the embodied energy content data on it.

6.4 Enforcement Through Building Regulations.

It has been pointed out many a times that some legislative measures must compel the architects/ builders to design and make their buildings more energy efficient, because only through such enforcement this can be implemented to its fullest potential.

These measures can be enforced by amending the building bylaws. Many other countries have already implemented rules of this kind, after the energy crisis. Of late the awareness that a building should have a strong basis of sound energy efficiency seems to be gaining ground and gradually spreading among our planners also.

In Britain the building Regulation minimum standards for insulation for new houses were increased in 1975 and further increases are being considered. Energy saving building regulations are being introduced for other buildings than housing also. And from 1977, money is being made available to local authorities to subsidize the insulation of houses and since 1978 as grants to private households for the same purpose. [40]

In cold countries it is comparatively easy by specifying the thermal conductivity of wall/ roof or by specifying the thickness and type of insulation. But in India things are more different but still things are changing here also. It's only recently Punjab Government has come up with some proposals of this kind, like making solar energy use mandatory in public buildings etc. [41]

Today the Indian Government is planning to enact a new legislation to institutionalize energy conservation measures and to set up a regulating mechanism. In order to implement this, the Energy Conservation Bill 1998 is to be brought to the next session of Parliament [42] This Bill will provide for a rational and efficient use of energy and the creation of a new organization called Bureau of Energy Efficiency (BEE). The Bureau will formulate policies and programs, and coordinate the implementation of energy conservation activities. Among the provisions of this Bill is the creation of a specific strategy for the creation of awareness among domestic consumers of energy.

The Bill also would suggest that the State Governments, in consultation with the BEE may designate one or more agencies to coordinate and regulate matters relating to implementation of energy conservation. Therefore the Kerala Government can use this as a stepping stone to build up a strong case for the incorporation of energy efficient measures into the building bylaws.

6.5 Conclusion.

It is now certain that today's 'energy crisis' is not just the shortage of energy than the present demand, as commonly perceived, although insufficient availability of energy resources is a part of it. But the more serious part of the dilemma associated with this is that the conversion of the energy resources to useful forms are always accompanied by undesirable as well as unhealthy side effects throughout the world.

As they say, change is the most permanent phenomenon, today's human world of about 6 billion must make room, in a foreseeable, not too distant future for another human world of same order. Therefore any path of development we take must not hurt in any way their sustenance and development, and this path of development is what is called the sustainable development. The energy conservation has the highest priority on this path. This is especially true in the present situation of building construction sector in Kerala.

Today's conventional concrete box type buildings of Kerala, with its flat roof and glass paneled exteriors are contributing in a drastic way to the excess need for energy to sustain inside that. And also many a high-energy materials we use for beautification of the buildings, consumes a lot of energy for its production and transportation.

The investigator is absolutely certain, if the recommendations made here are incorporated into the design and construction of buildings, it will do a great help in reducing the energy needs of the domestic sector. And this will definitely contribute in a large way for reducing the energy shortcomings of Kerala State in a very drastic way.

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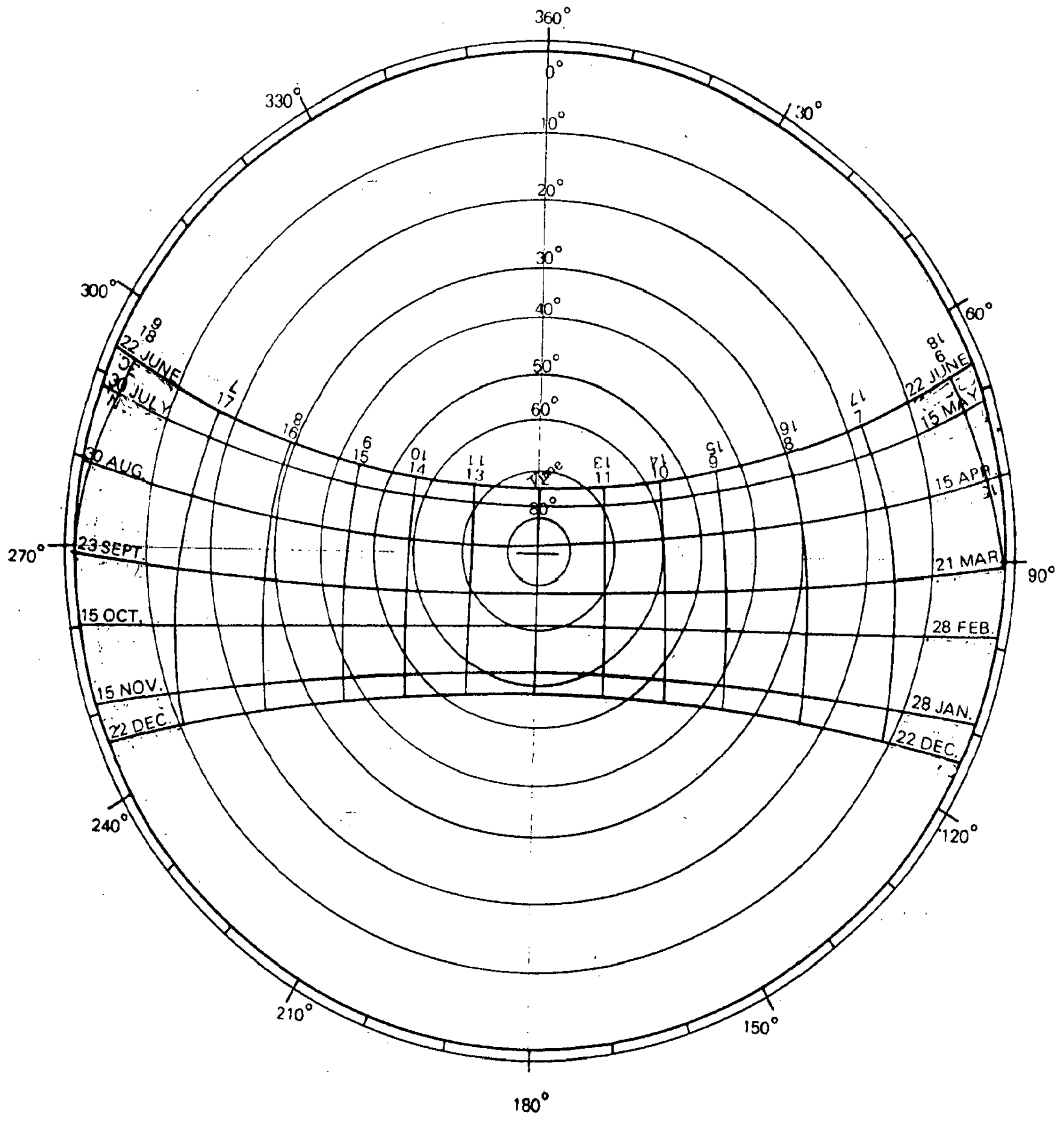
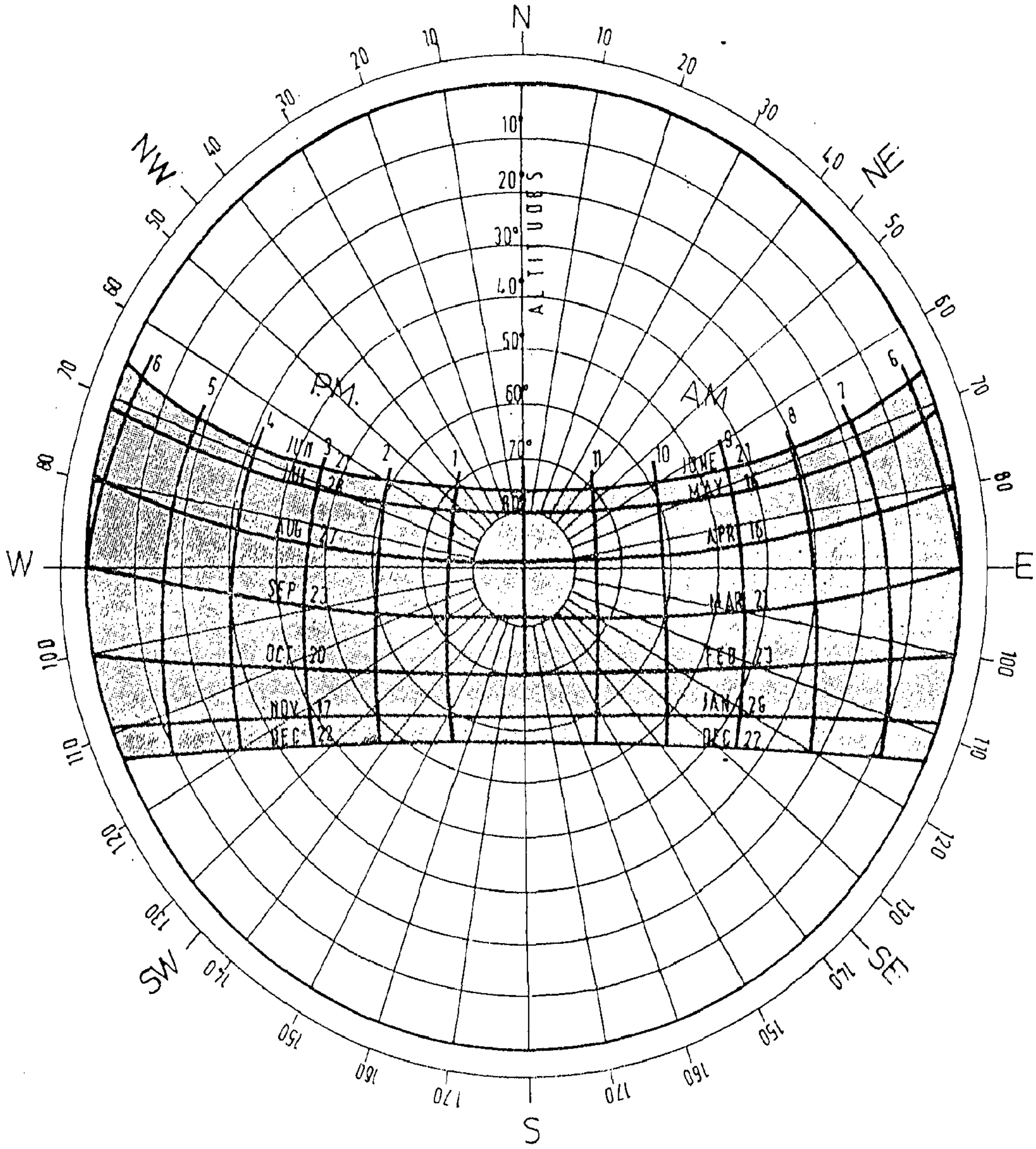
Appendix:

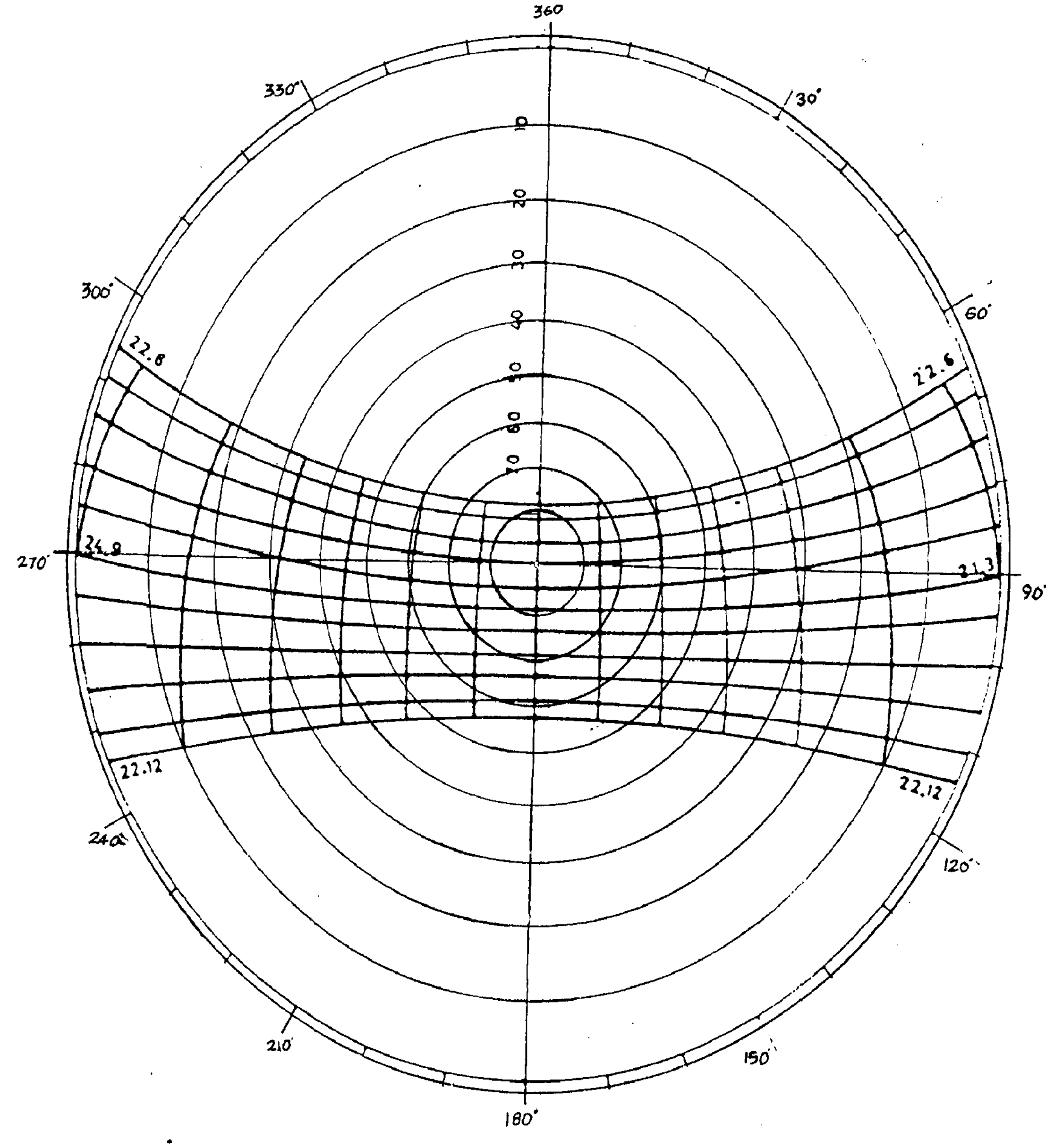
Sun-path diagrams pertaining to study area



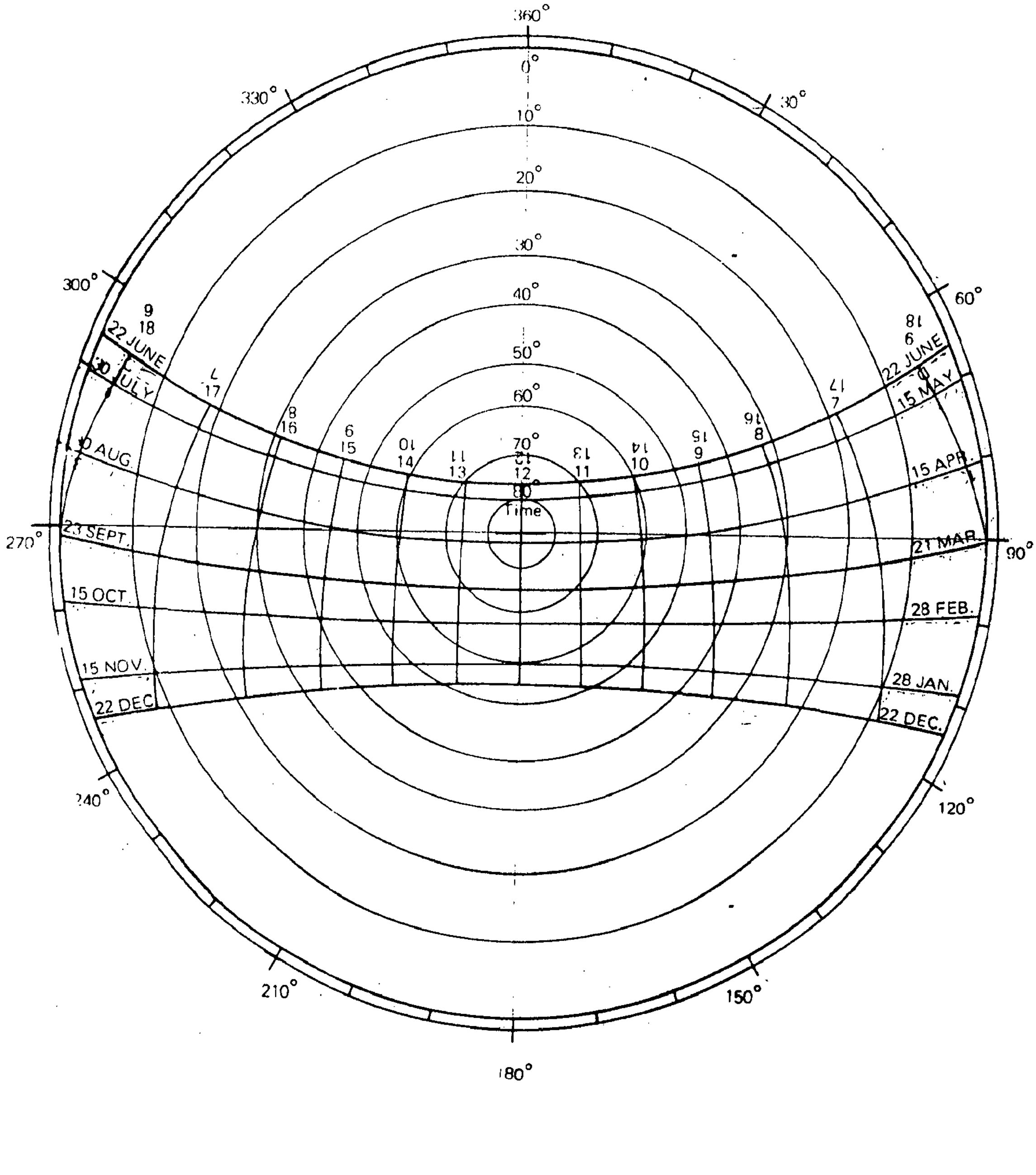
Latitude 8° North (source: Koenigsberger)



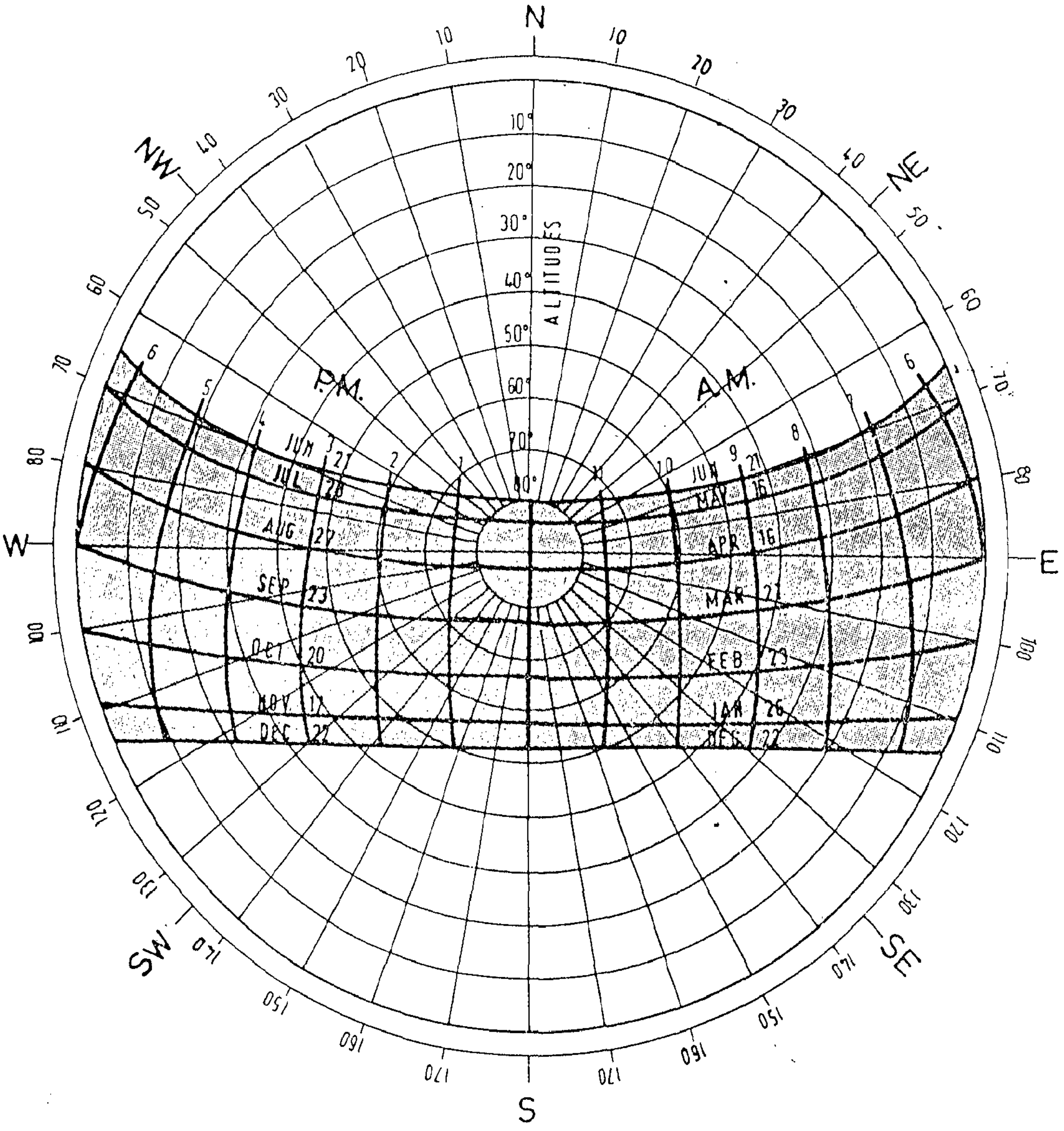
Latitude 9° North (source: Kukreja)



Latitude 10° North (source: COE, Trivandrum)



Latitude 12° North (source: Koenigsberger)



Latitude 13° North (source: Kukreja)