THE SOLAR HABITAT, KADUNA.

A thesis submitted to the Post-graduate school, Ahmadu Bello University, in partial fulfilment of the requirement for the decree of Master of Science in Architecture.

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DECLARATION

I hereby declare that this thesis has been composed by myself and that it is a record of my research work. It has not been accepted in any previous application for a higher degree. All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of references.

KEN K. OFILI

DEDICATION

This thesis is dedicated to Junior, and the Youth of Today. On who the success of Tomorrow's solar energy rests.

ACKNOWLEDGEMENT

This thesis will not be complete without a mention of those who have been of immense help to me - financially, morally intellectually and spiritually.

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Mama and Papa: You showed a lot of patience and guided me through-safely. How can I express my gratitude?

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My Brothers: Brother Val, and Eguye. Thanks for everything.

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Only an ass denies his family.

May God Bless you all.

TO GOD

I thank the Almighty Architect, Creator of Heaven and Earth. ... I give you my mind that you may guide me through this life .... My brain, that I may express your greatness. Make me a symbol of your greatness, perish me not until my sermon is preached, for I am not worthy to cross the gates of your heavenly domain - yet.

My acknowledgement is due to lots, for these mentioned and those I cannot remember, I am most grateful.

THE SOLAR HABITAT, KADUNA
THESIS ABSTRACT

THE RISING COSTS OF ENERGY CONSUMPTION, THE RECOGNITION OF THE ENVIRONMENTAL IMPACTS ASSOCIATED WITH CURRENT METHODS OF ENERGY GENERATION - COAL AND PETROLEUM PRODUCTS - COUPLED WITH THE INABILITY OF THE NATIONAL ELECTRIC POWER AUTHORITY TO EFFECTIVELY MEET THE DEMANDS OF THE NATIONAL ENERGY NEEDS HAS LED TO A SEARCH FOR DIFFERENT APPROACHES TO NATIONAL AND WORLD ENERGY PRODUCTION.

THE USE OF SOLAR ENERGY IS ONE SUCH APPROACH AND THIS THESIS SEEKS TO EXPLORE THIS POSSIBILITY. THIS THESIS IS ALSO AN ATTEMPT AT CREATING A COMMUNITY ALMOST RURAL IN NATURE BUT SITED IN THE CITY WITH ALL THE RESIDENCES, COMMERCIAL CENTRES, FOOTPATHS, OPEN SPACES AND FOUNTAINS ETC. THAT ONE FINDS IN A HIGHLY URBANISED COMMUNITY ALL LOCATED.ON ONE SITE.

THE SOLAR HABITAT, THE AUTONOMOUS HABITAT.

THIS THESIS SEEKS SECONDARILY TO EXPLORE THE POSSIBILITY OF USING HUMAN AND ANIMAL WASTES FOR THE GENERATION OF METHANE GAS FOR THE HOME.

THE PROPOSAL IS TO ACCOMMODATE 315 FAMILIES BETWEEN THE MIDDLE AND THE INCOME GROUPS WITH THE HOUSES VARYING IN SIZE FROM A ONE-BEDROOM DWELLING TO A 5 BED?ROOM HOUSE.

THE ESTIMATED POPULATION OF THE COMMUNITY IS 2,000.

FINALLY, THOUGH THE THESIS IS SITED IN A CITY, IT IS INTENDED AS A LESSON TO THE AUTHORITIES THAT OUR RURAL AREAS HAVE A HOPE IN THE PROLIFERATION OF SOLAR TECHNOLOGY. AND IF WE, ARCHITECTS, ARE TO TAKE SOLAR ENERGY SERIOUSLY, THEN WE WILL HAVE TO FIND SOLUTIONS IN WHICH THE EQUIPMENT BECOMES AN INTEGRAL PART OF THE BUILDING.

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Figures 2 to 6 are from "Sun Earth. How to Use Solar and Climatic Eneagies".

By R.L. Crowther.

CHAPTER 2

All figures from "Sun Earth. How to Use Solar and Climatic Eneagies".

By R.L.Crowther

Except figure 10 from "Architectural Graphic Standards"

By Ransey and Sleeper

CHAPTER 3

Table 1 from "Cost Effectiveness of Photovoltaic Plants in Nigeria by the year 2000".

By S.C. Bajpai and A.T. Sulaiman

CHAPTER 4.

Figures 17 to 20 from "Solar Heated Buildings of North America. 120

Outstanding Examples;

By W.A. Shurcliff.

Figures 21 to 23 from "Sun Earth How to Use Solar and Climatic Eneagies".

By R.L.Crowther

CHAPTER 5

Figure 24 from "Kaduna Master Plan". By Max Lock and Partners.

Table 2 from Meteorological Department, Federal Ministry of Transport and Aviation, Kaduna.

CHAPTER 6

Figures 25 to 31 from "Conceptual Development of a Solar Town".

By Sarr, M.A.

GLOSSARY

ABSORPTANCE - A ratio of the radiation absorbed by a surface to the radiation incident on that surface.

ABSORPTION - TYPE COOLING SYSTEM - A system in which cooling is produced by the evaporation of water into a near-vacuum, the vacuum being maintained by absorption of the resulting water vapour by a liquid solution that contains much lithium bromide or other material with strong afinity for water. Solar energy can be used to recondition, or rejuvenate, the solution by heating it so hot that the water is driven off.

AMBIZIENT TEMPERATURE - The temperature of the outside air or air surrounding a space or building.

BEAD WALL - A transparent or translucent window employing two glazing sheets a few centimetres apart, this space being filled, on cold nights, with tiny, insulating beads of polystyrene foam.

During the day the beads are stored elsewhere and solar radiation is free to pass through the window.

BIO-CONVERSION - Conversion of solar energy to fuel by the natural process of photosynthesis.

BIOFUELS - Renewable fuels and energy sources derived from organic material.

COLLECTOR TILT - The angle at which a solar collector is inclined with respect to a horizontal plane.

CONCENTRATORS - A device used to intensify the solar radiation striking a surface.

COOLING POND - A body of water which dissipates heat by evaporation, convection, and radiation.

EUTECTIC SALT - A combination of two (or more) mutually soluble materials, requiring a large amount of heat to melt or an equally large amount of heat to solidify, which melts at constant temperature and with constant composition. The phase change temperature is the lowest achievable with these materials.

GEOTHERMAL - Heat energy contained in large underground reservoirs of steam, and hot water, produced by molten material from the earth's interior.

HEAT EXCHANGER - A device used to transfer heat from one temperature level to another.

PASSIVE SOLAR COOLING SYSTEM - If a solar cooling system does not employ machines for circulating liquid through pipes, or air through ducts, the system is said to be passive. Note that the system may, nevertheless, make use of shutters, dampers, vanes, or curtains that are operated at the start and finish of the day and may employ fans to help circulate air in an informal manner. A system that contains no mechanical moving parts whatsoever might be called an ultrapassive system; very few solar cooling systems conform to this definition.

PLENUM - A compartment for the passage and distribution of air.

SELECTIVE SURFACE - Pertaining to solar collectors, the surface produced by the application of a coating to an absorber plate, with spectral selective properties, which maximizes the absorption of incoming solar radiation (0.3 to 3.0 micron range) and emits much less radiation (3.0 to 30.0 micron range) than an crdinary black surface at this same temperature.

SKYSHAFT - A multi-chambered plexiglass device which penetrates a roof used to provide natural illumination with a minimum of heat loss or gain.

SOLAR CELL- Also, photovoltaic cell. A device employing crystals (silicon for example) which when exposed to solar radiation, generates an electric current.

SOLAR COOKER - A device for cooking which uses the sun as an energy source.

SOLAR POWER FARM - An installation for generating electricity on a large scale using solar energy, consisting of an array of solar collectors.

SUN TRACKING - The ability to follow the apparent motion of the sum across the sky.

THERMO-SYPHON - The hydraulic system in which a fluid circulation is caused by temperature (thus density) differences in the fluid.

VAPOUR BARRIER - A component of construction which is impervious to the flow of moisture, used to prevent moisture travel to a point where it may condense.

WIND MACHINE - Any one of a number of devices used to convert the kinetic energy of wind to another form of energy for useful purposes.

1.1 THE HOUSE

1.2 SOLAR ARCHITECTURE

1.3 ARCHITECTURAL SIGNIFICANCE

1.4 THE SUN ....

(a) The source

(b) Derivatives

(c) Collecting the Energy.

1.5 FLAT PLATE SOLAR COLLECTOR

1.6 EVACUATED TUBE COLLECTOR

1.7 PARABOLIC COLLECTORS

1.8 PHOTOVOLTAIC COLLECTOR SYSTEM

"Energy problem carries within itself its own solution, a solution to be reached only by the intense inner concentration of a devotion to truth."

CHAPTER ONE

I N T R O D U C T I O N

1.1 THE HOUSE

WHEN THE WORD 'HOUSE' IS MENTIONED, it means so many different things to different people. One person sees it on a dirt track in the village; another sees it on an open road in a sub-urban setting; one thinks of a farm; another of a cave dwelling while yet another thinks of a flat or a flat-let in noisy urban centre. What do they all have in common? It is the ability to protect the occupant from harsh weather. Like the shell of a tortoise, a house is basically a shell; but unlike the shell of a tortoise or a snail, the 'house' is supposed to contribute to the daily needs of the occupants. House is culture and culture is archetypal; it grows from deep within you, embodies long-lived feelings towards shelter, family, community and self.

1.2 SOLAR ARCHITECTURE.

The Almighty Creator has given us the ever-glorious sun, the sustainer of life on this universe, but of what use is the sun to us if we do not use the great tool-brain - given us to change this "shell" to a "house".

I seek a superior sense of use and a finer sense of comfort, expressed in solar simplicity. This implies solar architecture. What is that solar architecture, any way? As Frank Lloyd Wright said: "When we endeavour to make for ourselves an atmosphere in which to live and work according to our own faith and feeling for nature, we are performing a genuine service not only to our time, but especially to the future". Solar architecture is that expression of feelings and it is the scientific art of making solar energy express ideas. It is a triumph of human imagination over the harsh weather.

1.3 ARCHITECTURAL SIGNIGICANCE

The significance of this THESIS are:

To enhance awareness of the magnitude of national energy and resource enigma in the design profession.

To research into the design tools and other architectural technologies of active, passive and hybrid solar systems.

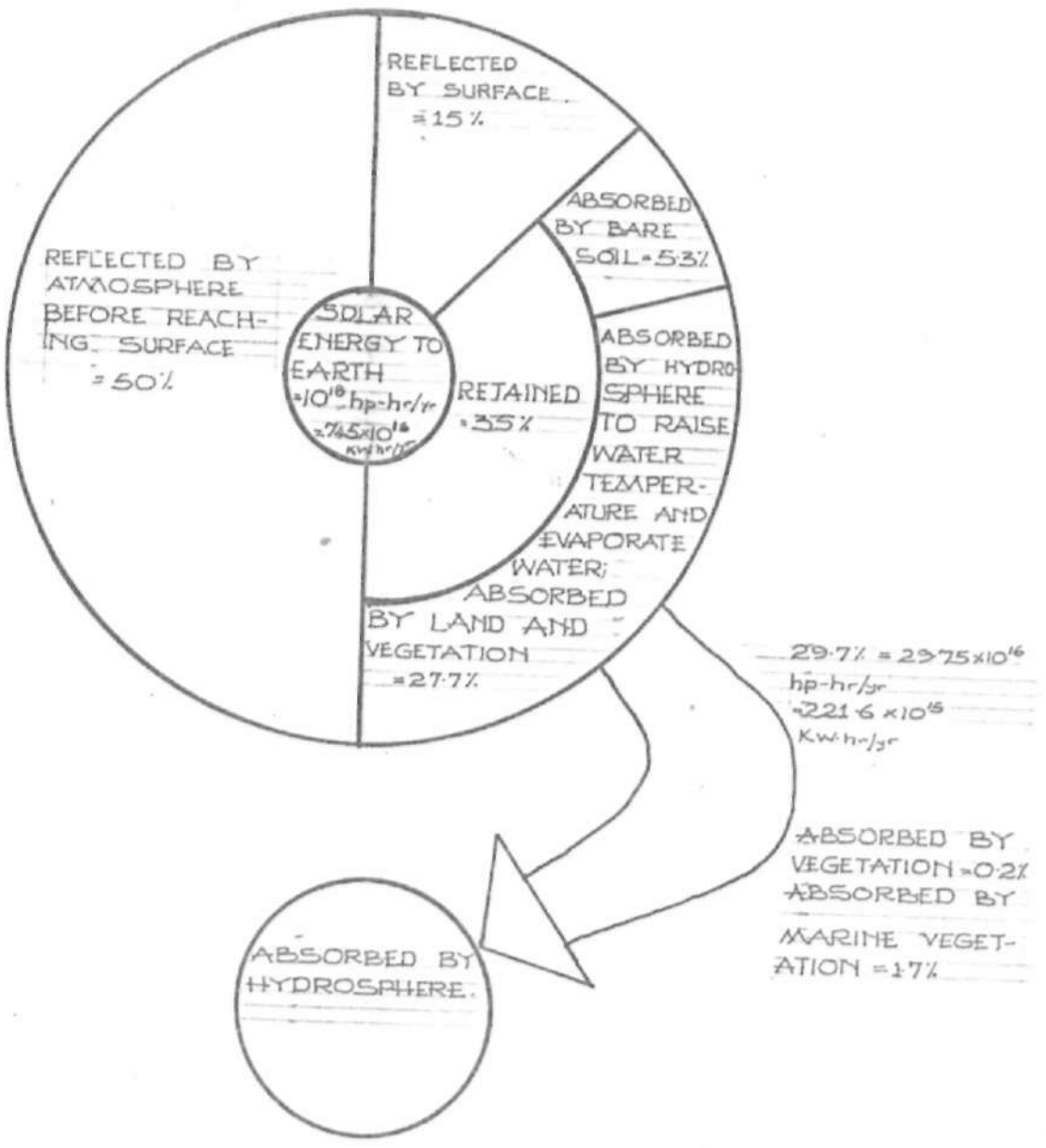
To study building design in relation to climate , energy and resource conservation and alternative energy sources.

To illustrate applications of energy and environmental education through case studies.

To stimulate awareness of the benefits of gas production through Bioconversion.

FIG. I

SOLAR ENERGY TO EARTH — DISTRIBUTION BY PERCENTAGE.



1.4 THE SUN....

(a) THE SOURCE

The sun is the star around which the earth resolves and it is our planet's major source of heat and light.

It is in fact, the ultimate source of nearly all energy utilized by this civilization in the form of water power, fuels and wind. Only atomic energy, radioactivity and the lunar tides are examples of non-solar energy. Our ultimate aim, however is to 'capture' the infinite energy sources offered to us directly by the sun.... and infinite it is!

This potent star is firmly ensconced some 150 million kilometers from the earth, it's position changing by the season, day and hour in relation to our planet. Earth receives about one-half of one-billionth of the total energy output of the sun. This tiny fraction of this gaseous orb's output represents some 745 million billion kilowatt hours annually on earth and the natural life of our planet uses only a minute portion of that energy. Mankind on this earth uses considerably more, and that usage is increasing exponentially

The sun retains 35% of its energy in a self-regenarating process. Of that energy directed toward the earth, 50% is reflected by the atmosphere before reaching the surface, 15% is reflected by that surface, 5.3% is absorbed by bare soil and the remaining 29.7% is absorbed by the hydrosphere to raise water temperature and evaporate water, and is absorbed by land and marine vegetation(fig.1).

THE SUN... (b) DERIVATIVES

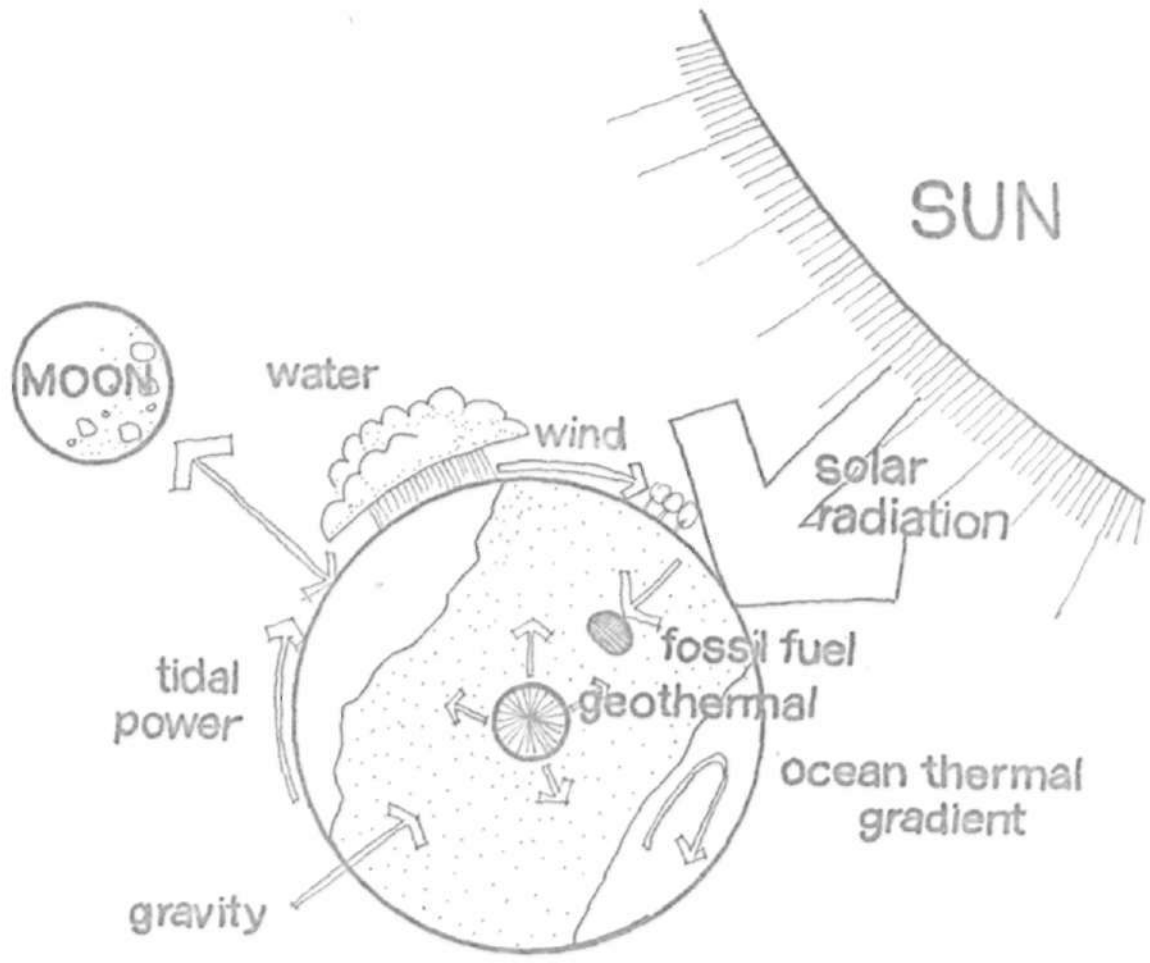
Most of the energy on earth, as has been noted, comes or has come indirectly from the sun. The direct solar energy which strikes this planet (incident solar radiation has evolved the term 'insolation') provides and sustains the biosphere in which we live. The radiation from the sun heats our atmosphere and causes air movement or wind. (fig.2) It also heats the oceans and water reservoirs of the earth, and in combination with wind creates weather and sustains the continued water cycle of the planet. The sun provides the energy for plant metabolic activities. Energy is stored by them in the form of carbohydrates, wood, or as fossil fuels. Fossil fuels are created with energy stored by the forces of heat and pressure acting upon decaying plant material over millions of years.

(c) COLLECTING THE ENERGY

A solar collector is a device used to absorb heat which comes from the sun in the form of radiation, and transfers it to a circulating fluid (air or liquid).

FIG. 2

THE SUN
— SOLAR-RELATED ENERGY SOURCES.



FROM "SUN EARTH HOW TO USE SOLAR AND CLIMATIC ENERGIES" BY R.L. CROWTHER.

1.5 FLAT PLATE SOLAR COLLECTOR

The flat plate solar collector consists of a black metal plate covered with glass or plastic and backed with insulation. The metal plate is known as an absorber and may have tubing built in to contain the circulating fluid. An airspace separates the cover from the absorber (fig.3).

The glass or plastic is transparent to incoming solar radiation, yet glass in particular is opaque to radiation of longer wavelengths. Solar radiation passes through the cover and is absorbed by the black surface, increasing the temperature of the metal. Longer wavelength infrared radiation is emitted from the absorber, but most of it cannot pass back through the glass. This produces what is known as the GREEN HOUSE EFFECT.

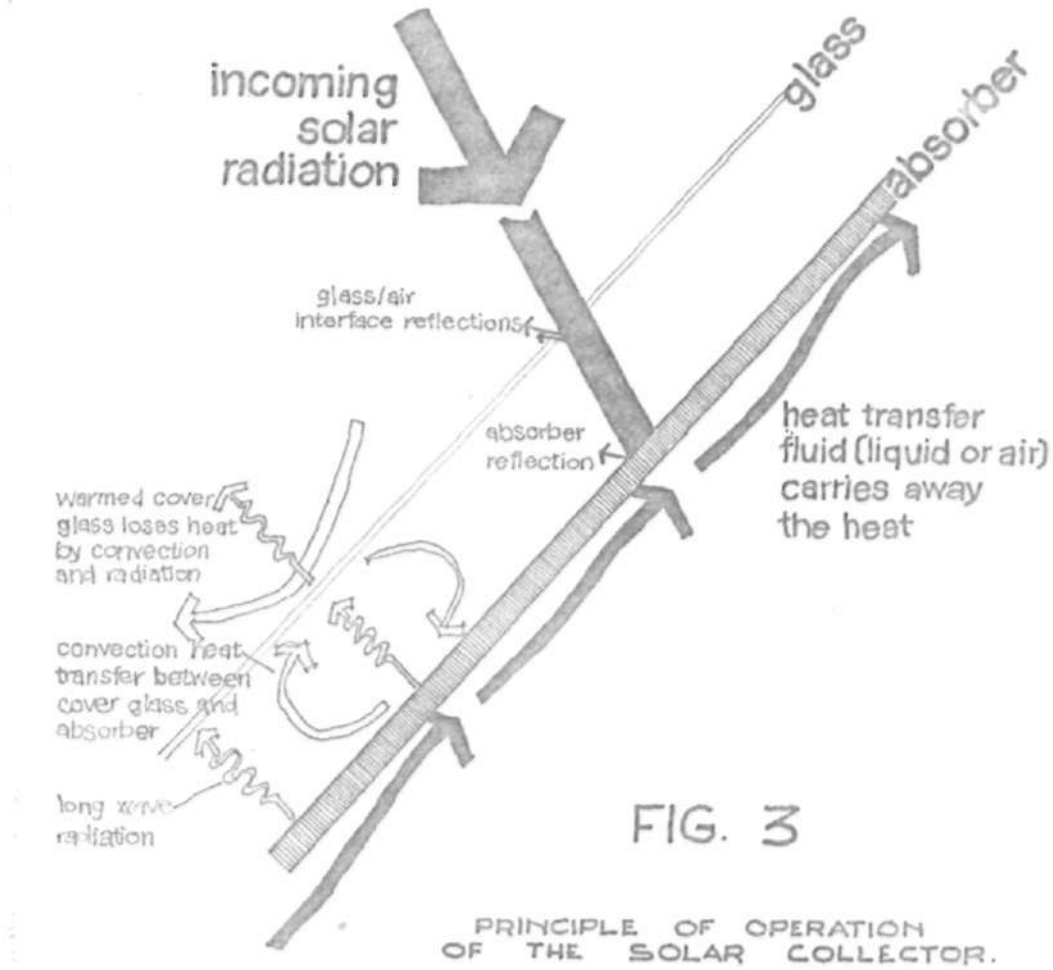


FIG. 3

PRINCIPLE OF OPERATION OF THE SOLAR COLLECTOR.

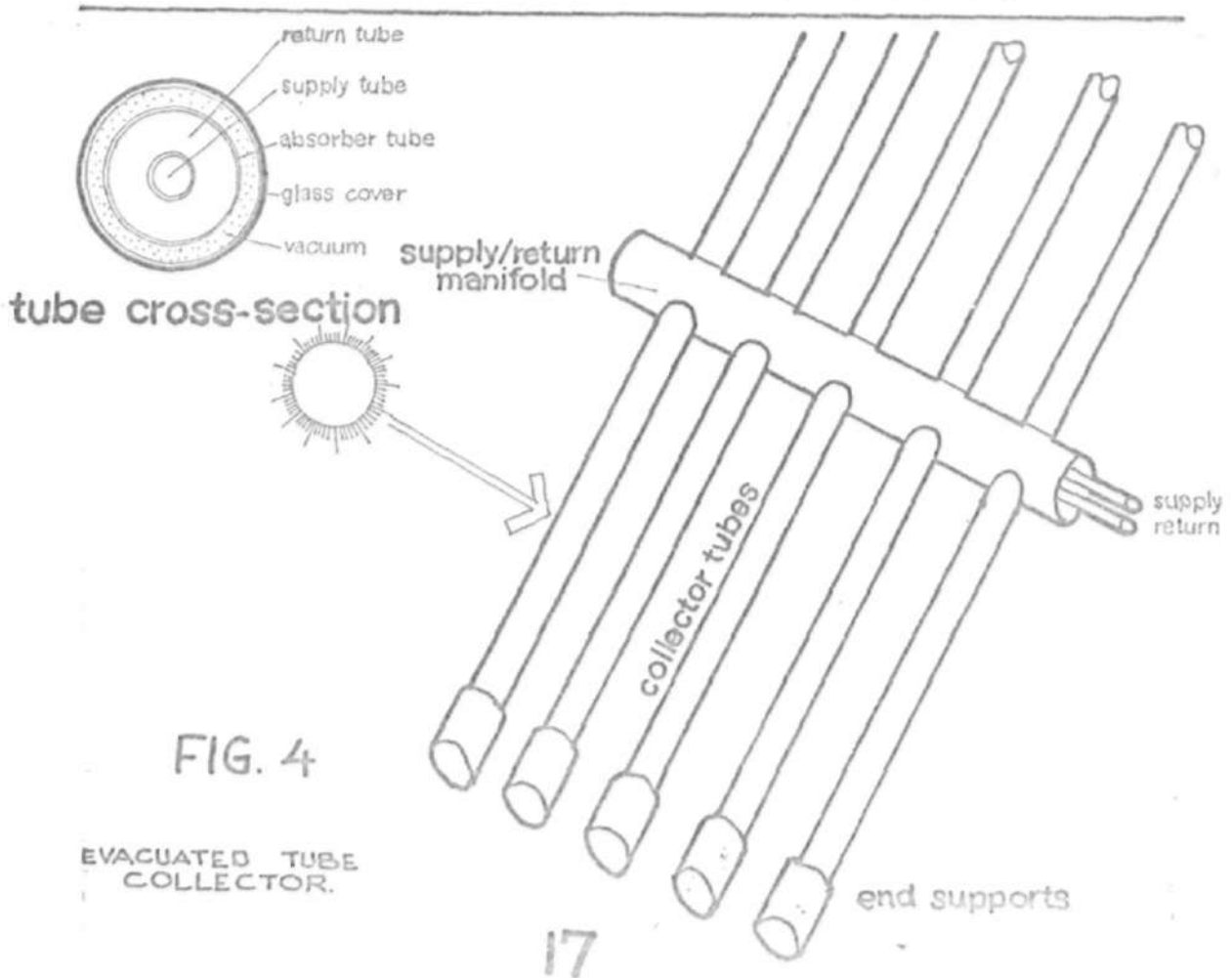


FIG. 4

EVACUATED TUBE COLLECTOR.

1.6 EVACUATED TUBE COLLECTOR

This is a series of tubes with special absorptive coatings to collect solar energy (fig.4). The tubes have the advantage that almost the same amount of surface area is exposed and perpendicular to the sun at any time during the day.

The evacuated tube collector is composed of a series of three concentric cylindrical tubes, with a vacuum (nearly zero air pressure) between the outer and middle tubes and a black selective coating on the outer surface of the middle tube. Water or air (usually water because of its higher specific heat capacity) is circulated from supply pipes through the inner tube. As it travels through this space it picks up heat. Upon reaching one end of a collector module, it enters the volume between the inner and middle tubes where it reverses flow direction and continues to build up heat content. It is then drawn off by the return tube and circulated into the heating system.

An evacuated tube system has the advantages of higher collection efficiency at standard operating temperature and the utilization of high temperatures in its collection process without excessive heat loss.

The vacuum between the outer tubes of glass helps attenuate conductive and convective heat loss, but can do nothing for radiation heat loss. This latter loss can be decreased by applying a "selective surface" interior coating to the outer tube.

1.7 PARABOLIC COLLECTORS (fig.5)

The paraboloidal collector concentrates large amounts of solar energy on a small area. This concentration allows high temperatures to be attained. For effective collection, the parabolic concentrator must track the sun so the sun's rays are perpendicular to the frontal plane of the paraboloid. In the altazimuth system, the unit moves vertically to match the sun's attitude, and tracks horizontally to follow the solar azimuths during the day. Since the sun is in different positions everyday, the tracking mechanism must be very sensitive and exact.

Another system to concentrate the solar radiation has a parabolic through oriented along an east-west axis. The angle of the trough with respect to the horizontal is adjusted weekly to accomodate changes in solar altitude. The reflective trough concentrates energy on an absorber tube through which a heat absorbing fluid is circulated.

FIGs 6

PHOTOVOLTAIC COLLECTOR.

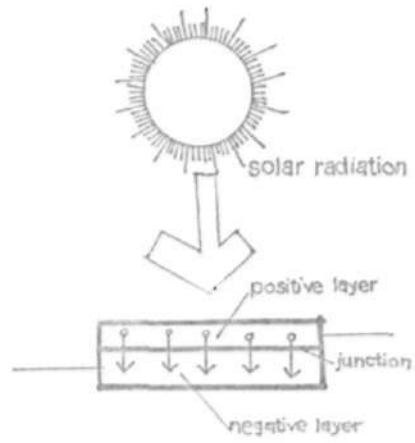


FIG 6(a) photocell

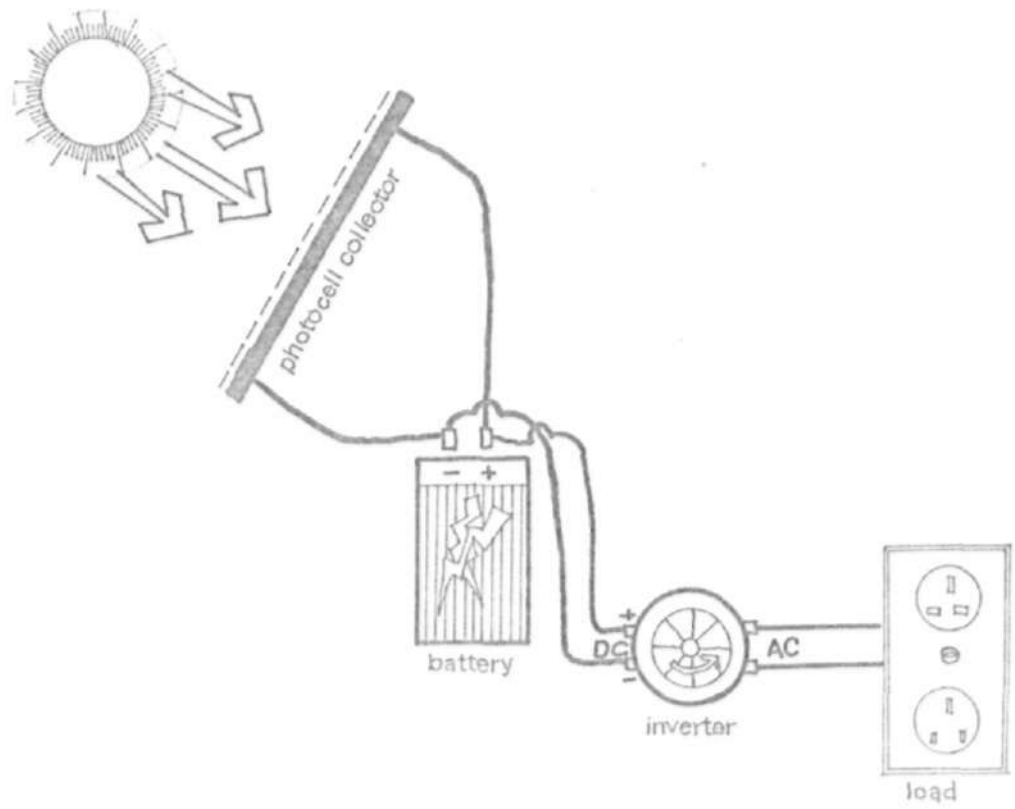


FIG 6(b) PHOTOVOLTAIC SYSTEM.

The paraboloidal surface of the collector is mirrored and reflective. Radiant Energy is reflected onto an absorber area which is usually glass covered to minimize heat loss by convection and radiation. The absorber has a liquid circulating inside it to carry away the heat energy. It is essential to keep reflective surfaces very clean to avoid reflective loss.

1.8 PHOTOVOLTAIC COLLECTOR SYSTEM: (Fig.6)

The photovoltaic collector system converts radiant energy directly into electricity (fig. 6a). Silicon for photovoltaic cells is "grown" in large single crystals, then wafer thin stripe are carefully sliced from the crystal to form the basic unit of the cell. The silicon wafer is then coated with another material, such as baron, to produce a positive electric layer which interacts with the negatively charged silicon layer. The interface between the two layers forms the p-n (positive-negative) junction.

When photons, the basic energy particles of light, strike the silicon cell, they are converted to electrons in the p-n junction. The possitive layer accepts the negatively charged electrons, and the negative layer rejects them, producing direct current (D.C.) electricity.



Plate 1

The power of the sun! Close-up of a solar reflector cooker. The pot is placed at the focus of the reflector. A major disadvantage being that the position has to be changed regularly to follow the sun's path. On a sunny day, this device can boil water in the thirty minutes, if reflector is properly placed.



Plate 3

The solar water distillation device. Has a place in the central water treatment unit.

The D.C. electricity generated by the photovoltaic cells can be stored in batteries. Wet cell batteries store electricity as chemical potential energy by charging particles and plates in a solution; they can be recharged many times. The electricity used in homes is A.C. alternating current. The generated D.C. may produce AC. power through batteries using inverters (fig. 6b)

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2.1 Historical Review

2.2 Uses

(a) Termitaries

(b) Man

2.3 BUILDING DESIGN FOR ENERGY OPTIMISATION.

(a) Site and Climate

(b) Entrances

(c) Walls and Roofs

(d) Windows and Other Openings

(e) Ventilation.

Solar architecture seeks a superior sense of use and a finer sense of comfort expressed in solar simplicity.

CHAPTER TWO

SOLAR TECHNOLOGY AND ITS APPLICATIONS

2.1 HISTORICAL REVIEW

The main aim of building design is the creation of an artificial microclimate which satisfies contemporary definitions of thermal comfort: air speed and temperature, radiation, humidity. Other factors of building design are: defensive, non-climatic, environmental, historical, etc.

It can indeed be maintained that the idea of solar architecture' is redundant - throughout the world there are no animal habitats which neglect those thermal parameters directly related to local insolation levels.

Solar energy can be reduced schematically to four elements:

i. Insulation (a) Radiation reflection: albedo, surface conditions, colour, surface properties.

(b) Distribution of heat flow: for example double partitinoning, air circulation, external heat rejection.

ii. Exothermic reactions to solar radiation: elevation of the temperature of a body exposed to solar radiation.

iii. Endothermic reactions to solar radiation:

(a) Evaporation

(b) noctural re-radiation of solar heat:

iv. Storage: required principally to compensate for the effects of nocturnal heat loss.

2,2 USES

(a) TERMITARIES

The most complex application of solar energy appear in termite nests, and all the most desirable techniques have been brought into use. Termitaries do not use other energy sources to control humidity, ventilation or temperature.

Termites (Hamitermes Meridionalis) build a vertical nest of laminar form (exceeding 5 metres in height in which the major axis of the horizontal section is invariably in a north-south orientation, thus offering a maximum surface area to the low harmattan sun and a reduced surface to the strong hot season sun.

The cellular structure of the termitary possesses insulation properties. These properties allow the inhabited areas of the nest to remain at 30 °c whether the outside temperature is at 70°c in sunlight or 10°c at night.

(b) MAN

One of the first recorded uses of solar energy was made by the Greek mathematician and engineer Archimedes. When the Roman fleet was attacking syracuse harbor in 212 B.C., he allegedly set the ships on fire by focusing the sun onto their sails using approximately 4,000 gold and bronze shields.

It is reported that the sails were black, which helped to make this amazing feat possible.

A twelfth-century writer has reported that a similar solar display was mounted at constantinople in 600 A.D. when a mirror focusing system designed by Proclus was used to ignite ships in the fleet of Vitellius. Other pyrogenic military operations have been reported through history.

One of the first machines which could harness the sun's energy and convert it to mechanical work was invented by a Frenchman, Solomon de Caux in 1615. In his machine, air was expanded by the sun's heat. This expansion caused an increase in internal pressure which was then used to pump water.

Another Frenchman, Antoine Lavoisier (1743-1794) used a 128cm diameter lens to concentrate the sun's rays and develop temperatures of up to 1775°c which were sufficient to melt metals. His lens was filled with white wine because it had better optical properties than the glass that was available to him. This was the predecessor of today's solar furnaces.

An American inventor, John Ericsson designed and built solar powered hot-air engines which adapted to conventional steam power for cloudly day operation.

FIG 7
ERICSSON SOLAR POWER PLANT.

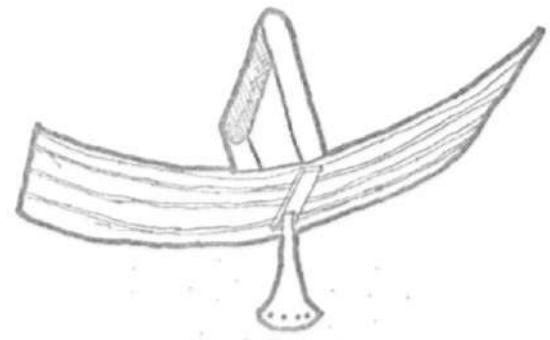


FIG 8
SHUMAN CONCENTRATOR COLLECTOR.

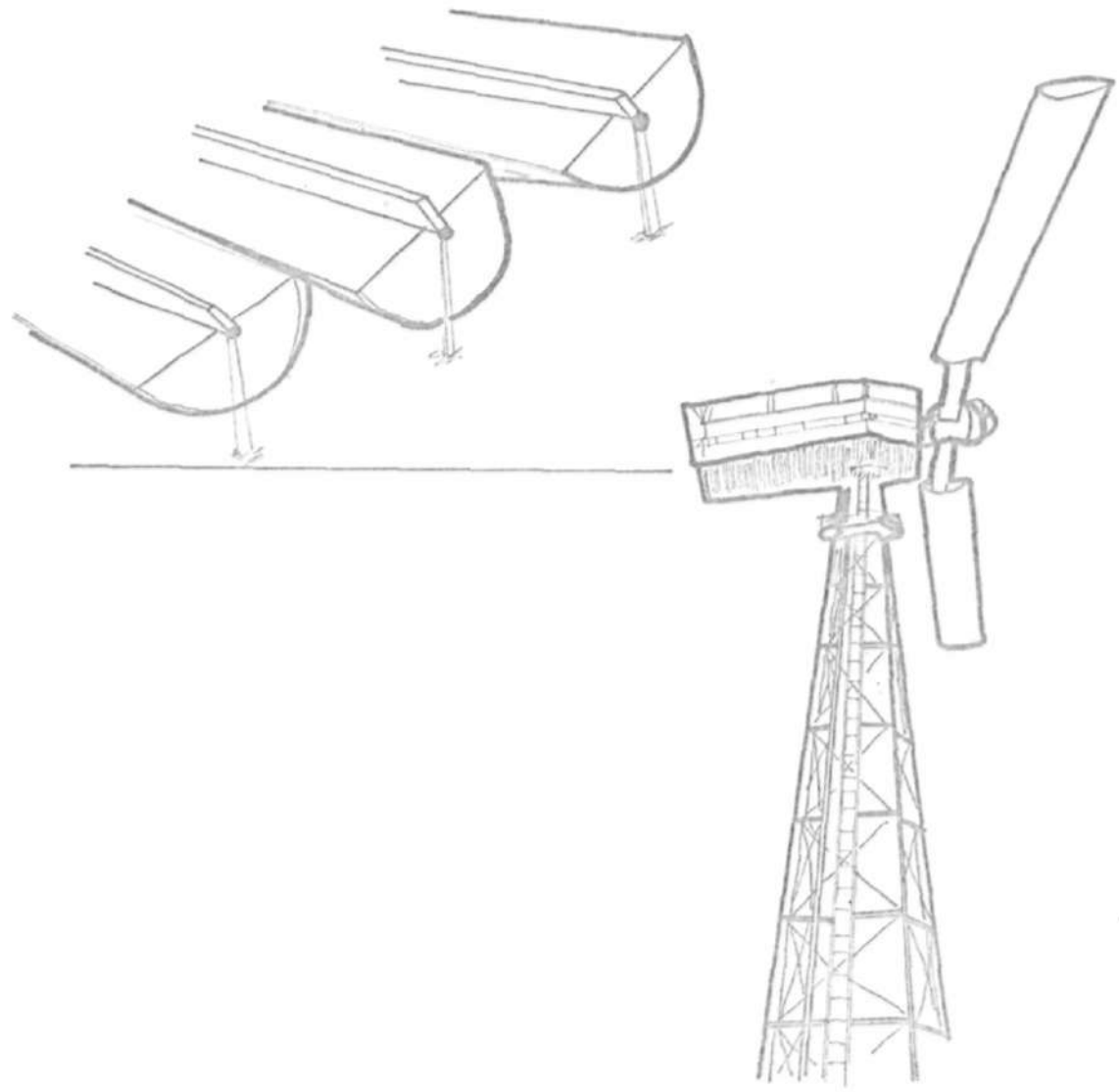


FIG 9 WIND GENERATOR, GRANDPA'S KNOB

In 1908 Frank Shuman built a demonstration plant of more than 900 square metres in collector area. The system which was installed in Meadi, Egypt powered a 100 hp steam engine (fig.8).

In the early 1940's a large scale driven electrical generator was installed at Grandpa's Knob, Vermont. The machine was conceived by Palmer C. Putman, an engineer, who coordinated the design and construction of the 1,250 Kilo watt machine (fig.9). It had a useful life of only 18 months, eventually losing a rotor blade which was never repaired because cost calculations indicated that it could not compete economically with generators powered by fossil fuels.

2.3 BUILDING DESIGN FOR ENERGY OPTIMISATION

In order for the manmade environment to use the natural energy available to it most efficiently, it must be planned with consideration given to materials selection, site and building orientation, micro climatic conditions, Landscaping, etc. The environmentally responsive building should have minimal negative impact on its site, maximize efficient use of all energy, maximize human comfort and effort, and promote human talents by providing a pleasing atmosphere in which to live or work. The solar architecture seeks a superior sense of use and a finer sense of comfort, expressed in solar simplicity.

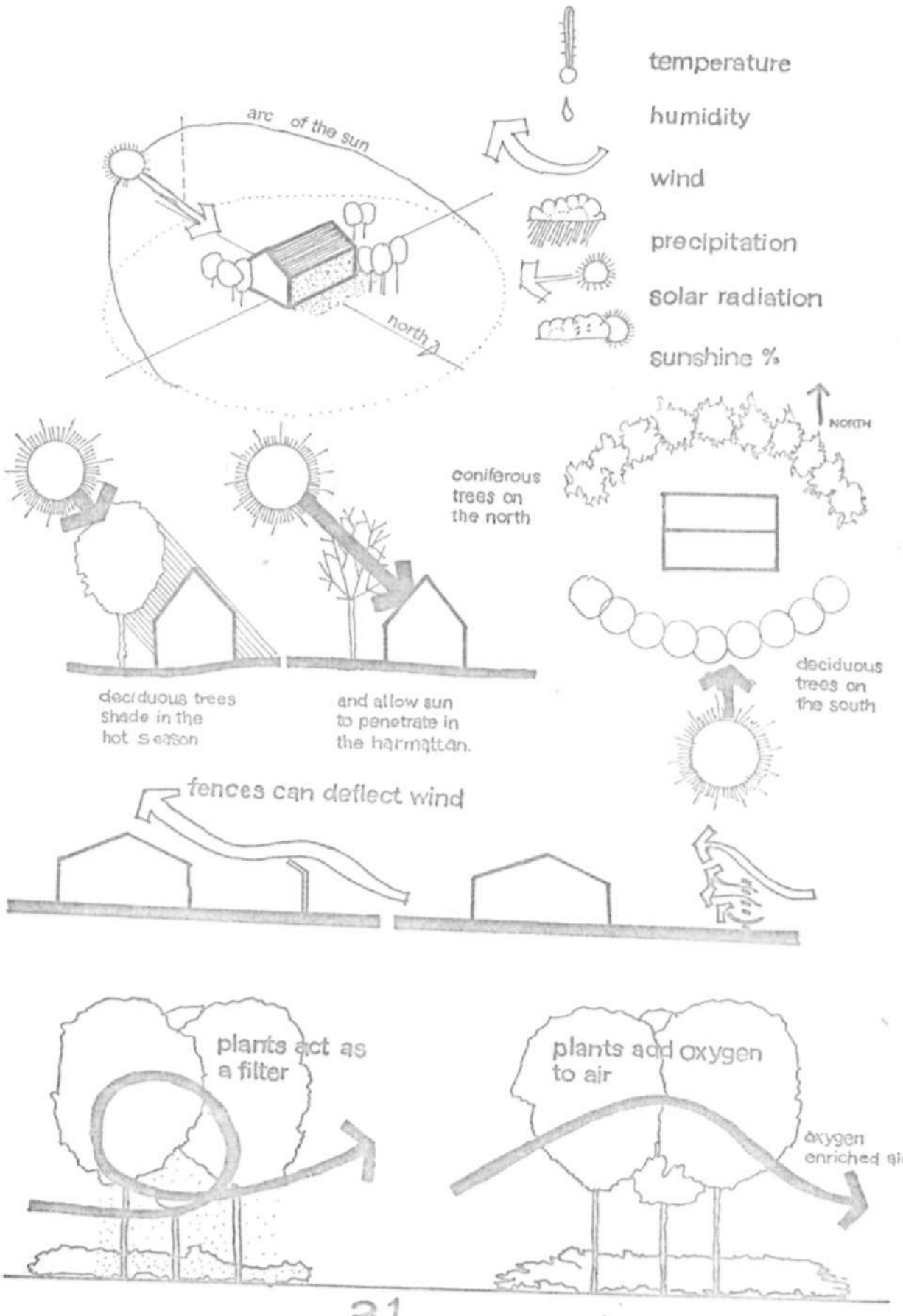
Areas in which energy conserving practises can be employed have been divided into five categories and are:

(a) site and climate
(b) Entrances
(c) Walls and Roofs
(d) Windows and Other Openings
(e) Ventilation

2.3.1 SITE AND CLIMATE. (fig.10)

To properly consider the placement and orientation of any building on a site, its macro- and micro-climatic conditions must be evaluated.

FIG 10
SITE TREATMENT.



The micro-climate is peculiar to each individual site and results from the influences of surrounding buildings and Landscaping, topography, soil structure, and ground cover, as well as regional geographic influences.

For improved comfort and energy conservation, the following Landscaping tips and site modifications are suggested.

1. Plant decidious trees and vines on the south side of the building to decrease summer heat gains, yet allow the harmattan sun to enter. Conifers planted on the noth side will act as an effective wind break, decreasing harmattan heat loss.

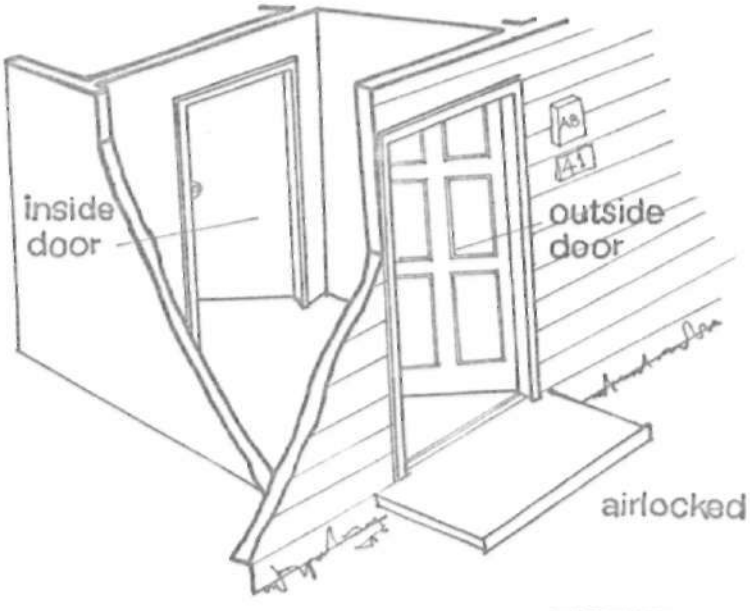
2. Fences of the proper design will provide privacy, security, sound control, and wind control.

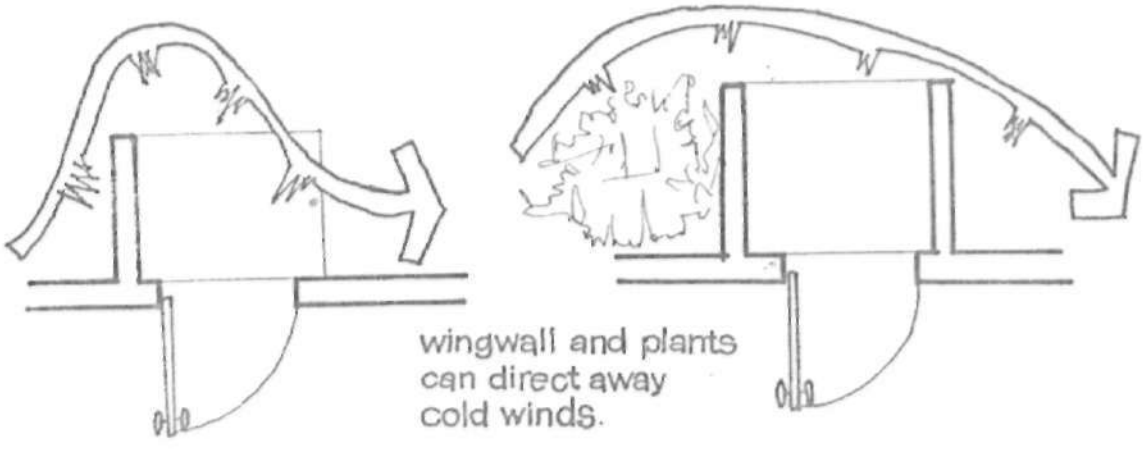
3. Patios, offering outdoor areas to comfortably spend leisure time, may also be used to temper indoor temperatures. Patios with white gravel on the south can be used in cold climates to reflect heat to interior spaces or occupants. Deep trenches around patios filled with gravel and moistened with water will reduce temperatures through evaporation.

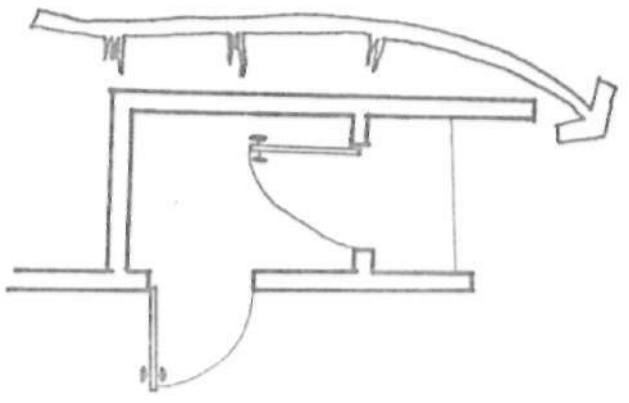
2.3.2 ENTRANCES: (fig. 11)

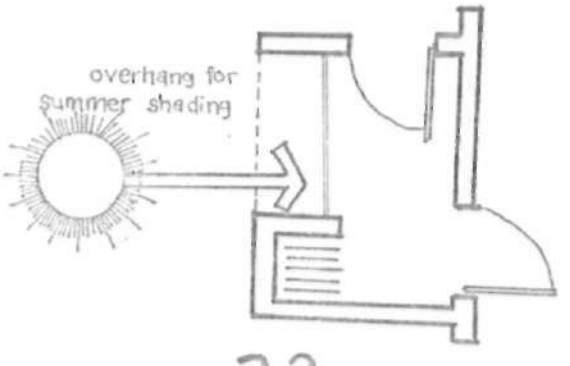
Controlling heat loss and gain through entrances is a major concern. All edges around entrances leak air and correspondingly lose of gain heat. To minimize these heat transfers door must seal as tightly as possible at the sides and at the bottom threshold.

FIG 11
ENTRANCE TREATMENT.









The edges must set square with a weatherstrip to prevent air movement. Weatherstripping can usually provide adequate protection in this area. Winds will carry away heat at a greater rate than still air outside a door. To keep air as still as possible, wingwalls and landscaping can provide windbreaks. One of the greatest and immutable problems with an entrance is that each time it is opened a great quantity of cold or warm air enters the adjoining room. It is possible for the entire volume of air in a room to be exchanged when the adjoining door is opened. This problem can be intensified if the entrance is oriented to intercept the prevailing harmattan winds. (North-east Trade winds).

To prevent large heat gains due to infiltration when a door is opened, airlocks can be provided. An airlock has two doors and an airspace between them; one opens to the exterior and another to the interior.

When the exterior door is opened, only the air in the airlock can escape; therefore only a small quantity of heat can come in. The exterior door is then closed before the interior door is opened, allowing only a small increase in the interior heat. This prevents the entire room from being infiltrated with hot or cold air.
In absence of the airlock, porch can effectively act in an average weather condition like Nigeria's, in which case there will be adequate planting to decrease infiltration.

Some hints for improving the energy efficiency of entrances are presented below.

1. Weatherstrip around all doors to decrease infiltration. Continuity is important, especially at corners.

2. Storm doors can serve as additional insulation panels. Be certain these fit tightly enough to create a dead air space.

3. Avoid using entrance doors against which the cold harmattan wind directly blows.

4. A porch can be added to a house to serve as an airlock entry.

5. Wingwalls can be added to shelter entrances from prevailing winds.

6. During cold or hot weather avoid having doors open for extended lengths of time.

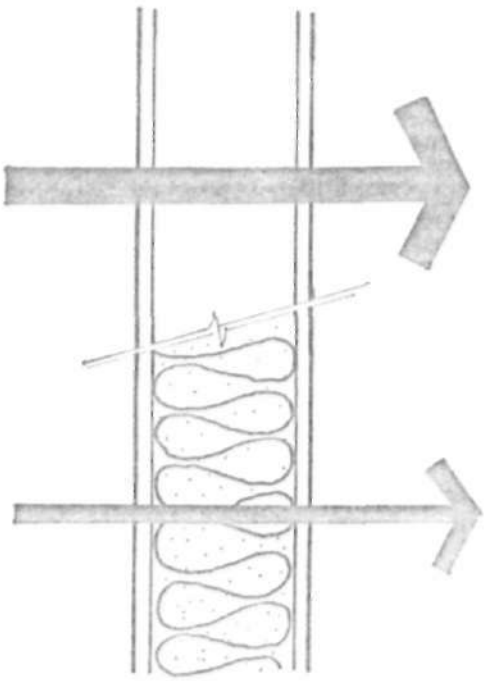
7. Use insulated exterior doors.

2.3.3 WALLS AND ROOFS (Fig.12)

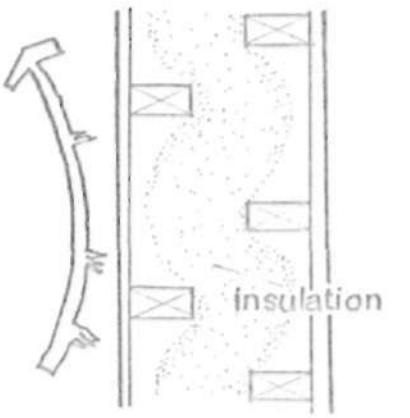
Walls and roofs form barriers which separate the inside of a building from the outside environment. Ideally, the shells walls and roofs - are designed and constructed to minimize harmattan heat loss and summer heat gain, while maximizing harmattan heat gain and summer heat loss from interior spaces. Two important properties which regulate heat flow are the thermal resistance (insulation) and thermal mass (thermal inertia) of walls and roofs.

FIG 12

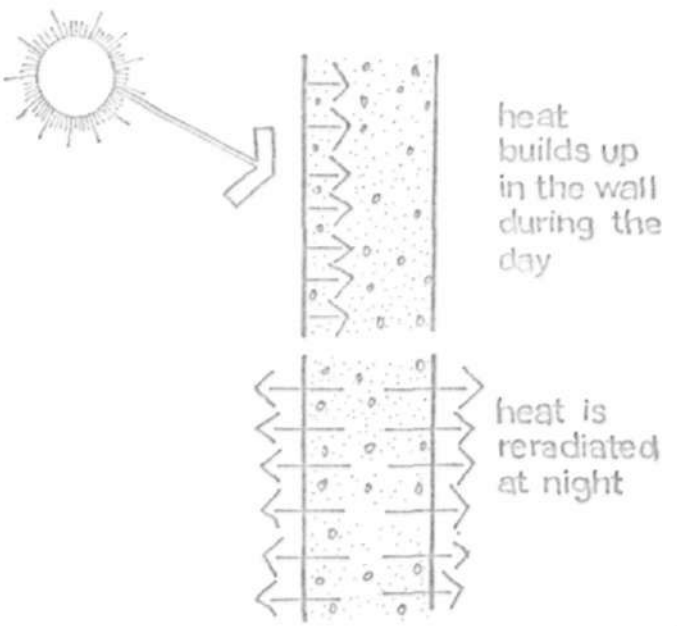
WALL TREATMENT.

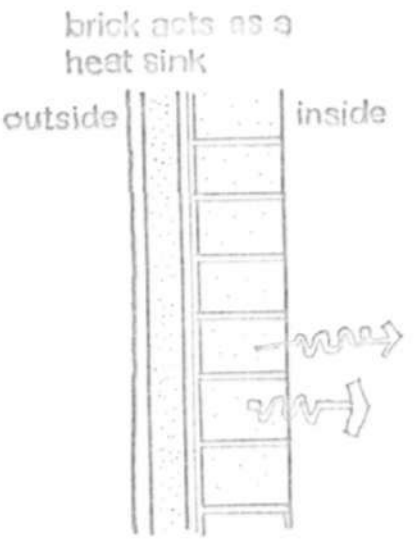


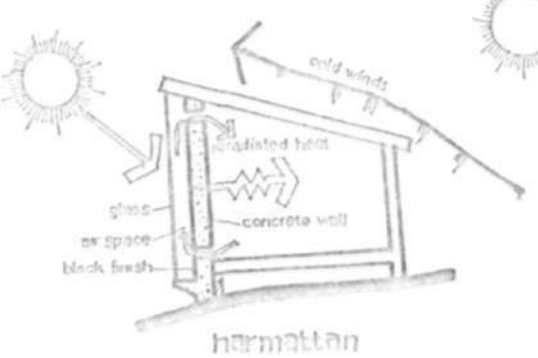
insulation reduces heat gain



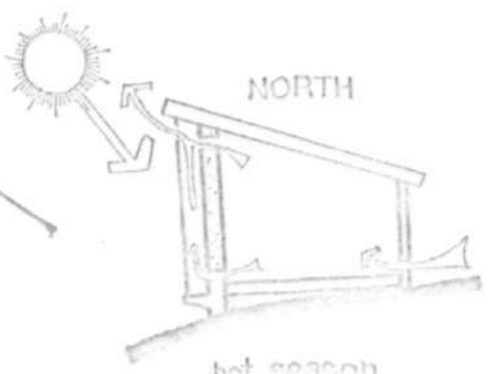
thermal breaks in the unit reduces heat transmittal







harmattan



hot season cooling

The thermal mass of building materials is a very important property which must be considered in the total design process.

Certain materials such as brick, block, stone and adobe can store large amounts of heat. In their traditional position on the exterior of a building, these materials in summer will absorb heat for long periods of time before allowing it to flow to the interior

This produces the "time lag" effect and completely alters the heat flow value.

A house designed by the French engineer Felix Trombe integrates the thermal storage capacity of concrete into a flat plate collector. Components include a thick concrete wall facing south and painted black, plus a sheet of glass covering the wall to decrease convective heat losses and to form an air chamber between the wall and the glass. Vents at the top and bottom of the wall connect the air chamber to the adjacent room. As the sun warms the wall, the air next to it heats up and rises, passes through the top vent into the room, and allows cold room air to enter the bottom vent by displacement. The cold room is warmed as it passes next to the wall and exits the collector at the top. The concrete wall also absorbs heat which is conducted directly into the room.

By opening a vent between the glass and the outside, the collector works as a ventilator in summer. Air warmed by the sun flows up the collector and out the vent. Cool air enters the room by displacement through vents

located on the north side of the building.

Roofs can also be designed to retain or reflect heat energy. Harold Hay has successfully tested a system which uses sealed clear plastic bags filled with water, backed with black plastic, and located on a roof to store heat (fig.13). The bags are supported by a structural corrugated metal roof through which heat can be transmitted. During winter days the sun heats the bags. Most of the heat is stored in the water and a portion is conducted through the roof and radiated to the room below.

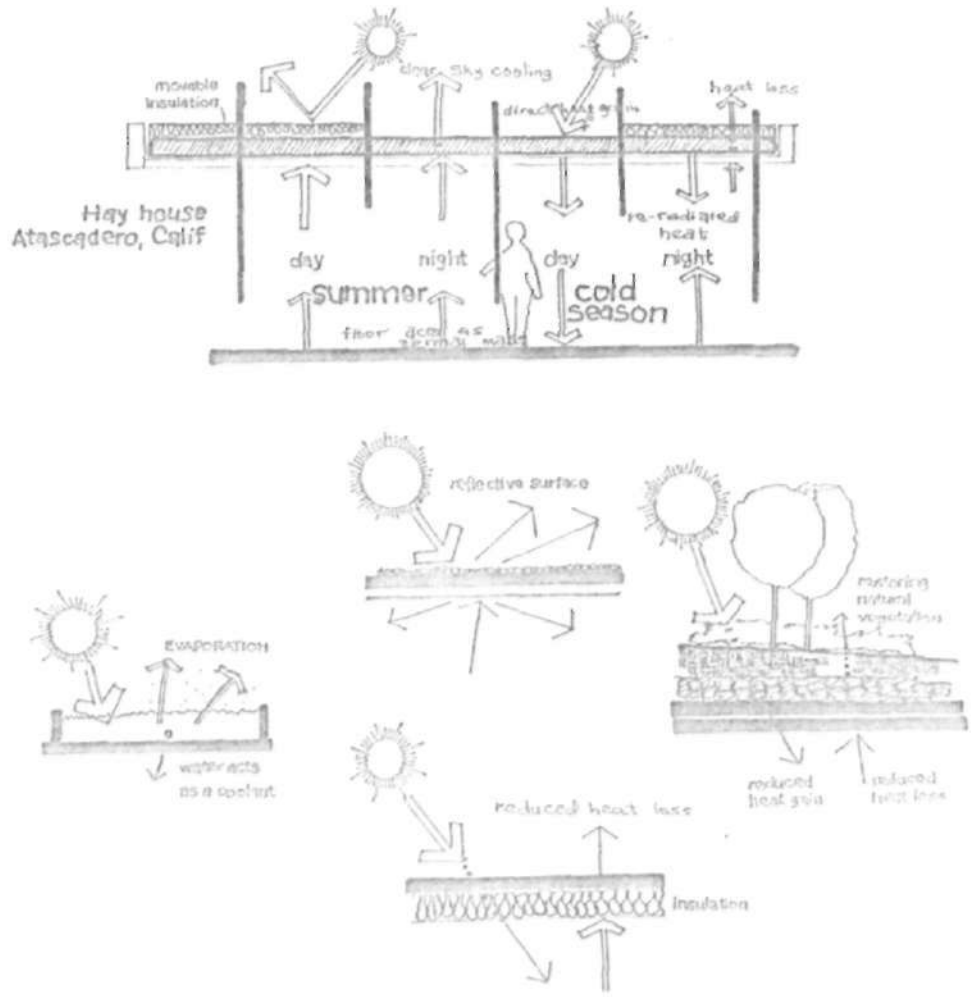
During winter nights the bags are covered with a movable insulated panel and the heat stored during the day radiates downward into the space.

During a summer day the insulation reflects the heat of the sun, and at night any heat stored in the water is radiated upward to the sky.

The presence of water on a roof can help moderate solar heat gains into a building by acting as an evaporative coolant. Simple ponding on the roof can also cool its surface and may extract heat from the interior. In the harmattan, however, a roof pond may lose more heat by evaporation in 24 hours than it gains during 8 hours of day light.

A mass of water may be incorporated into a building design as an open pool, swimming pool, or closed tank to act as either a stabilizer of internal temperatures or as a reservoir of thermal energy.

FIG 13
ROOF TREATMENTS.



There are a number of modifications to roofs which improve energy conservation. Some of these are presented below.

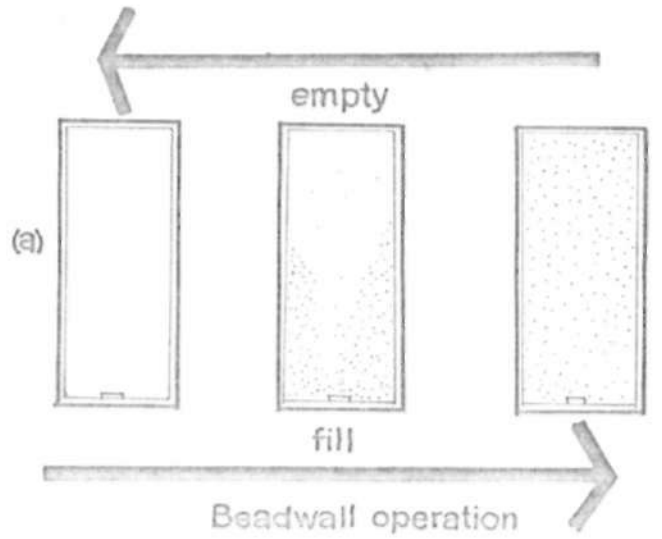
1. Increase the insulation in the ceiling. A heat resistance value of 30 (R-30) should be a minimum standard for the insulation in the ceiling.
2. If possible, increase the mass of outer walls. An application of burnt brick facing slips would increase the thermal inertia and time lag of the wall.

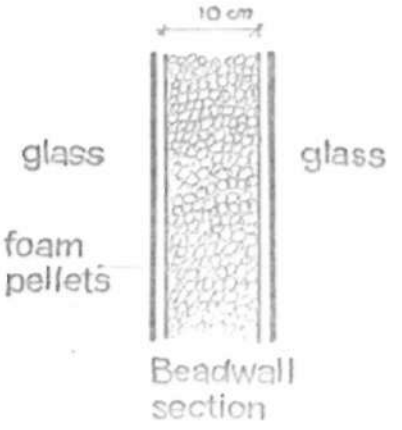
2.3.4 WINDOWS (fig.14)

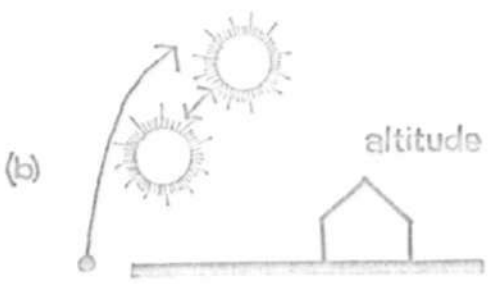
A great deal of heat is gained from a building through windows and other openings. The location of windows on a building will have an influence on their size, shape, and type. On the West and South sides of a building it may be advantageous to use glass with a reflective surface to shield out the intense summer sun.

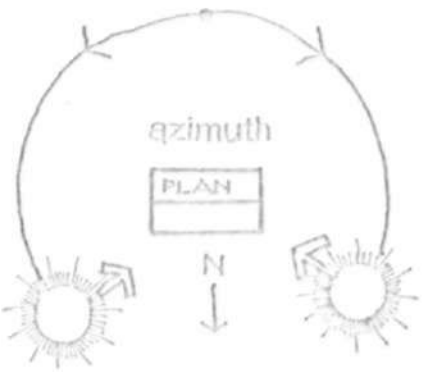
A true dead air space is a good insulator but losses its effectiveness when convection currents propagate in it. One interesting system which uses a material other than air was patented by Steve Baer of some works and is called "Beadwall". This system has two panes of glass spaced several centimeters apart.

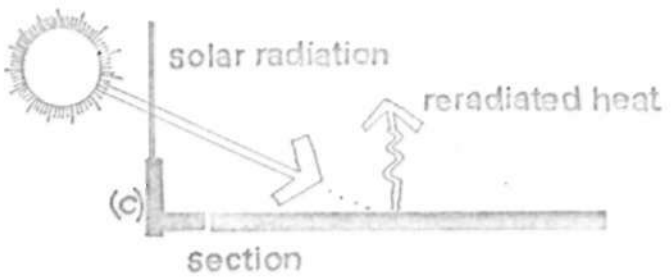
FIG 14
WINDOW TREATMENT.

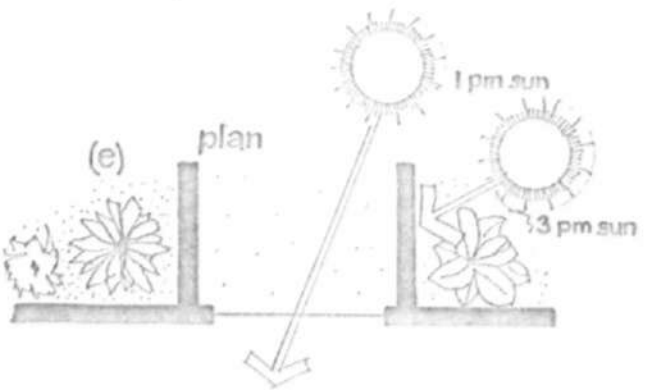




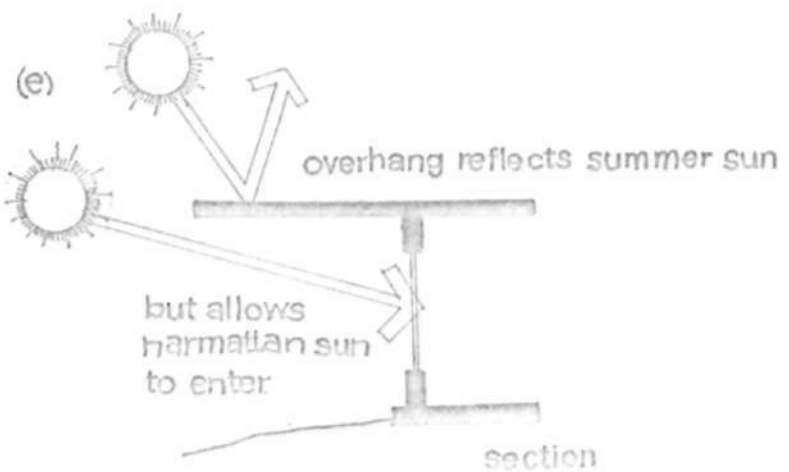








wingwalls can block out sun at certain times of the day



During the day the space or chamber between the glass contains air only (fig.14a). At night, expanded polystyrene pellets are blown into the chamber, displacing the air and forming a heat barrier.

While determining the size and placement of windows, many things should be considered. One of the more important variables is the position of the sun, which is continually changing, not only throughout each day but seasonal as well. Two angles are therefore needed to specify the position of the sun in the sky: one, the azimuth angle which is a measurement in degrees of the sun's position in plan view; the other is the attitude, which is a measurement in degrees of the sun's elevation above the horizon (fig. 14b). At a given date and time, both the attitude and azimuth differ according to earth latitude.

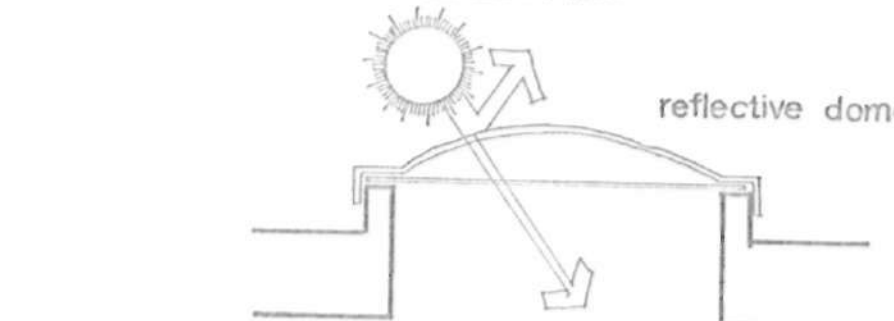
Direct solar radiation can be intercepted and stored by the interior floors and walls of a room, then re-radiated to the room. Windows which extend to the floor line allow the floor to be heated by direct radiation (fig.14c). The heat will be absorbed and stored in floors of massive construction (concrete, masonry, rock, etc.) and released when room temperatures start to fall.

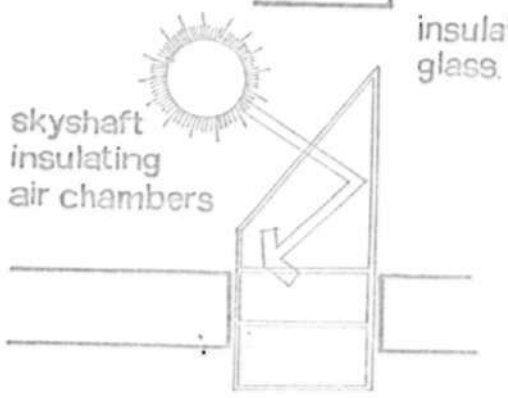
Another device which will allow light to enter a space, yet decrease internal direct solar gains during all seasons that might overheat the interior, is the skylight. Normally, a great deal of heat is lost through skylights, because the hottest air will be at the highest point in a room, which is generally the location of a skylight (fig.15)
"Skyshafts", as developed by R.L. Crowther, are composed of several sealed air chambers which are lined with white reflective sides and clear lenses at the top or horizontal positions. These provide an interior space with diffuse lighting.

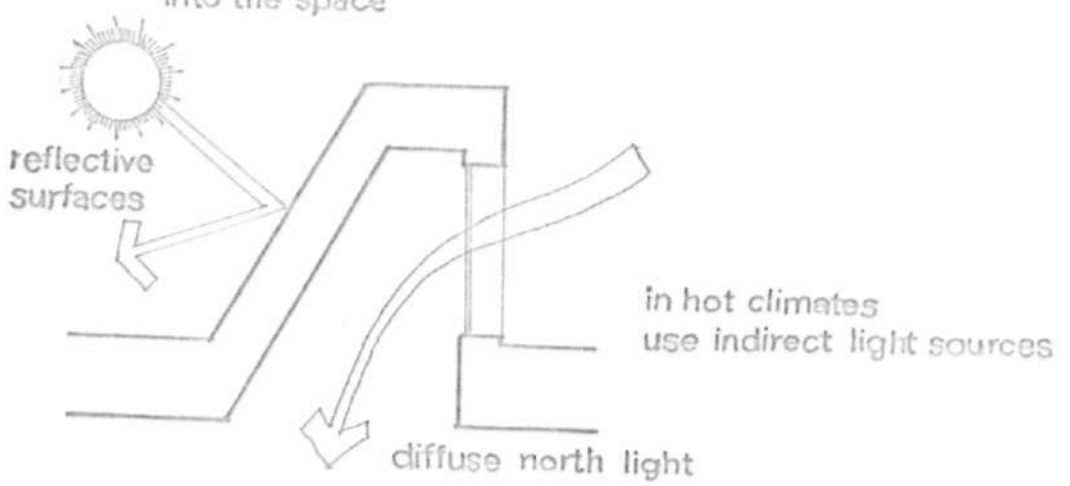
In hot climates, conventional skylights should be used sparingly, as summer heat gains through them can be disastrous. A north-facing monitor windows, would be a more protected light source in such regions.

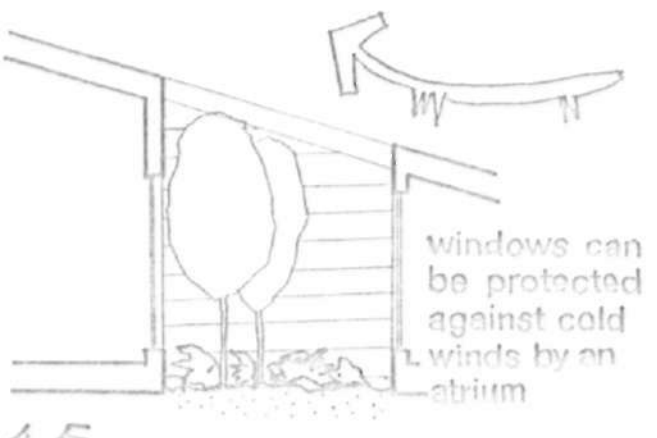
Another feature which will provide natural illumination to rooms not adjacent to the exterior of a building is an atrium (an open shaft or hole extending vertically the full height of the building, forming an interior courtyard at the bottom. The walls of the courtyard may be surfaced with relatively large window areas to allow as much light as possible to enter adjoining spaces which, without the courtyard would be closed to daylight.

FIG 15
SKYLIGHTS.









SOME SUGGESTIONS FOR IMPROVING WINDOW AREAS FOR ENERGY CONSERVATION ARE PRESENTED BELOW:

1. Open windows on warm but not/~~hot~~ days to allow natural ventilation, before resorting to solar air-conditioning.

2. Attach external shading devices such as overhangs, sidewalls, recesses; awnings, or lowered sun screens to reduce solar heat gain.

3. Coat west facing windows with reflective films, and/or install minor cromed venetian blinds inside.

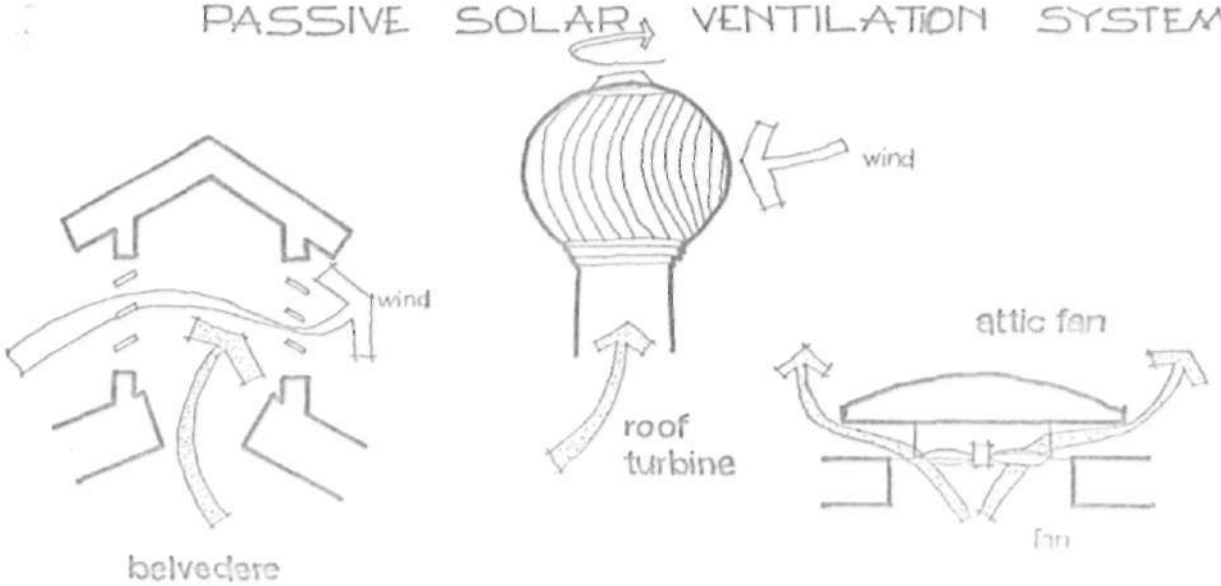
2.3.5 <u>VENTILATION</u> (fig.16)

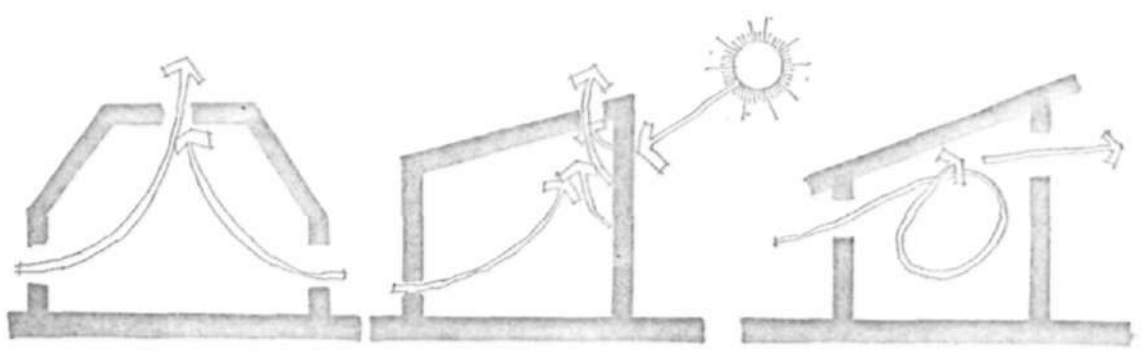
As air moves or circulates it gains heat from objects warmer than itself and loses heat to colder ones. Whereever two air masses of differing temperature meet however, the larger will prevail in its effects. During cold weather it is therefore important to prevent air from carrying heat out of a building, while during the summer maximum ventilation is encouraged, unless solar air condition is used.

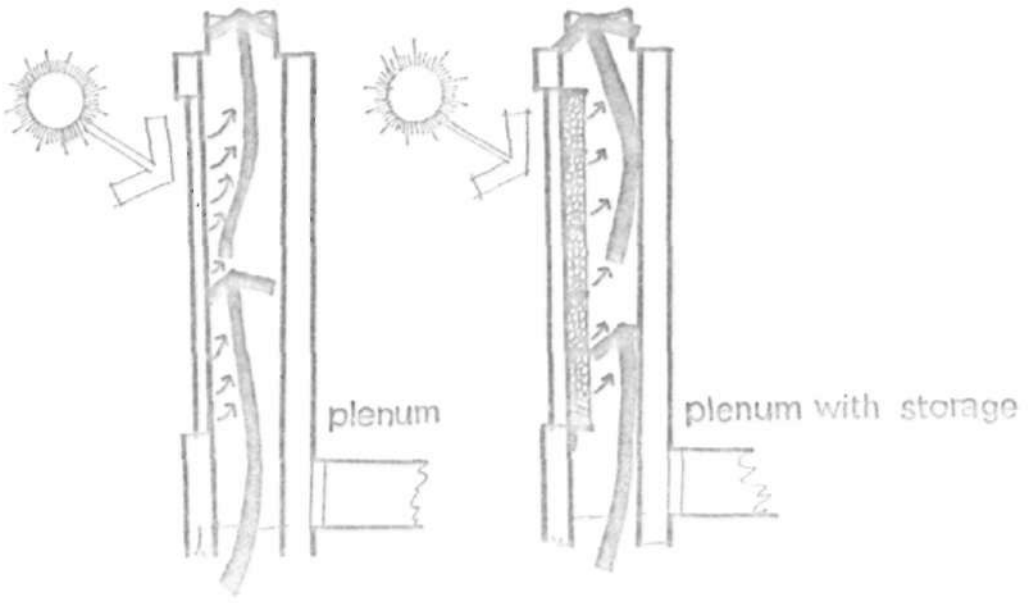
Ventilation should be minimized during harmattan months and encouraged during warm months. However, minimum ventilation standards should always be met to provide adequate air supply. (A little but well established fact is that with all windows and doors closed, a typically constructed building is provided all necessary air changes purely by infiltration).

FIG 16

PASSIVE SOLAR VENTILATION SYSTEMS







Natural ventilation of a building will initiate passive cooling during summer. The exhaust of excess warm air and the intake of cool air help to lower interior temperatures. To facilitate the exit of warm air, dampered vents should be located at high points in a building.

The motion of outside air can often be used to induce interior air movement without the aid of fans. Wind can be directed in such a way that pressure changes result which move inside air.

The heat of the sun can be used to induce natural air movement in a building. If not properly ventilated, summer time heat will eventually build up in any space. The natural rising of warm air can be used to ventilate an area and exhaust the accumulated heat. Solar heated plenums are effective passive systems for ventilating a building. The sun heats the plenum and raises the temperature of air behind a cover. Warm air rises up and out of the plenum, allowing cooler air to enter the building by displacement. The plenum can be equipped to induce air movement even after the sun has set. This is accomplished by incorporating gravel or some other heat storage material into the plenum volume, for day time heat absorption and retention, and dispersal of heat the following night.

Solar plenums are most effective on west exposures, followed by south. In these locations they make use of the day's highest ambient temperature, maximum solar angle of incidence, and latest radiation period before nightfall.

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3.1 Introduction

3.2 NEPA'S GROWTH

3.3 BACK-UP GENERATION

3.4 PHOTOVOLTAIC PLANTS AND THEIR COST-EFFECTIVENESS

3.5 CONCLUSIONS

What a man does - that he has. You may find other things on him but they are not his.

CHAPTER 3

COST-EFFECTIVENESS OF SOLAR ENERGY

3.1 INTRODUCTION

So far, the centralized supply of power in Nigeria was regarded as a sign of progress. The construction of huge power stations that are based on gas, coal, fuel oil and water was the consequence of this conviction. This belief in progress should now be abandoned. Large-scale power station technology is depicted as hampering rather than promoting economic growth of the developing, nations, Nigeria inclusive. It is high time the nation embarked on more effective ways of supplying energy and, for example, to start building small decentralized power stations.[1] In Nigeria, the supply of electric power is basically the responsibility of the autonomous, federally-owned National Electric Power Authority (NEPA). Less than 5% of the country's electric utility supplies are provided by small, independent, state-owned systems.

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1. World Watch Institute, Washington. U.S.A.

3.2 NEPA'S GROWTH

The National Electric Power Authority's system has grown rapidly in recent years, at an average annual rate of 15%.[2] NEPA'S system is reasonably balanced at this time, consisting of one major hydroplant at Kainji with a nominal capacity of 760 MW, a gas-fired steam plant at Sapele with 696MW, a 30MW coal-fired steam plant at Oji River, and various gas turbine installations with a total capacity of 922MW. One small 40MW gas turbine plant at Ijora near Lagos uses gas oil as main fuel. Also, there are several small diesel stations with a total of 9.7MW. The total installed capacity by March 1983, was 2,800MW.

NEPA'S transmission network consists of about 3,440 circuit-Km of 300Kv transmission lines, eight main step-down sub-stations of 330/132 Kv and about 3,800 circuit-Km of 132 KV lines and 60 substations which feed the subtransmission and primary distribution system at 3.3 and 11 KV.

About 46% of total sales[3] in 1980 (4916 GWh) were made to the residential sector, 35% to industry and 16% to the commercial sector.

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2. Guidelines for a comp. & nit.

Sales to municipalities and exports accounted for the rest. Overall, compared to the total population of about 100 million the system is still very small.

There is a considerable difference between the installed capacity and the actual available peak power. In March, 1983, the latter's value was as low as 1200MW. This wide reduction in the actual available power is due to frequent breakdowns, lack of spare parts, slow repairs,and unreliable supply of some of the needed fuels.

Table -1 shows the estimated cost per kwh electric generation at 1982 Naira value, using various plants. Given the low economic costs of natural gas, gas turbines, combined cycle plants and heavy government subsidy ——— "Total energy costs in countries of the Third World amount to 50 billion dollars a year. That is about one quarter of all public expenditure. These are due to interest payments on plant investment which exceed earnings from the production of energy".(4) ——— Show the lowest average generating cost of k2.35 per kwh, gas-fired steam plants are neat, with k3.08kwh followed by coal-fired steam units with k3.22 - k4.23 per kwh respectively. Hydro plants, because of their high initial capital costs and long construction period, are k4.69 per kwh. The cost of new transmission and distribution network has been estimated at k.2.27 per kwh.

TABLE - 1
ESTIMATED AVERAGE COSTS PER kWh OF ELECTRICITY GENERATION
FOR VARIOUS PLANTS
(₦1982)

Category	Hydro	Steam-Gas	Gas Turbine	Gas Combined cycle	Coal Underground	Coal Openpit
Basic Capital Costs (₦/kW)	1340	536	234.50	335	636.50	636.50
Construction Time (Years)	8	4	1	3	4	4
Capital Cost Including Interest During Construction (₦/kW)	1915.50	621.80	234.50	369.80	738.30	738.30
Operation and Maintenance per Year (% of Capital Costs)	1	4	6	6	5	5
Heat Rate (BTU/kWh)	-	10,000	12,000	8,000	10,000	10,000
Fuel Cost Per Unit (₦/Million BTU)	-	1.00	1.00	1.00	1.94	1.45
Useful Life (Year)	50	30	15	15	30	30
Annual Capital Cost (₦/kW)	193.20	70.98	30.83	48.60	78.34	78.34
Annual Operation and Maintenance (₦/kW)	13.40	21.44	14.07	20.10	25.46	25.46
Annual Fuel Costs (₦/kW)	-	44.03	52.82	35.22	85.03	63.24
Average Generating Costs (k/kWh)	4.69	3.08	2.21	2.35	4.29	3.82

Interest rate: 10%; Average load factors, all plants: 50%

Overall costs of electricity represent a relatively modest percentage of total production costs. However, the costs of electricity not supplied due to outages is likely to have raised the total imputable costs of electricity by a substantial margin. Unfortunately, no data is available to give an indication of the actual losses suffered by users from both outages and voltage fluctuations.

The growth in NEPA'S electricity production and demand is estimated to be 12.4% between 1985-90, 10.9% between 1990-95 and 9.1% to the end of century. A number of hydro, gas turbine, gas-fired steam, and combined cycle plants are under-construction and planning to meet these power production and demand. A total of 12.749MW generating capacity with 57,700GWh required generation has been forecasted by the year 2,000. NEPA needs more than 12 billion Naira to meet the cost of generation, transmission, and distribution of the additional facilities, apart from the funds needed to bring its present systems to normal level. With all these implemented, it is still believed that only 20-25% of the population will have access to electricity by the turn of the century. Majority of rural and remote areas will still be left out of the national grid.

With the increasing const of electricity generation, transmission and distribution, and the present inflation rate, the cost per kwh will rise considerably in the next 15 years.

3.3 BACK-UP GENERATION

The electricity service supplied by the national grid is proving to ebe grossly inadequate. Forced outages, service curtailments, and damaging voltage fluctuations are daily occurences they are the results of insufficient generating capacity and frequent failures of transmission and distribution facilities. Most users of electricity are quite aware of the high costs of supply interruptions, and those who are financially able to do so have protected themselves by installing stand by generating equipments. Use of such standby generators is widespread in all sectors of the economy. Allowing for diversity between consumers and a margin of capacity, the present installed standy capacity is likely to be 1200-1500MW. The additional costs of owning and operating these equipments have been estimated at ₦124 per KW per year. The use of such standy generators is likely to continue for industrial and commercial operation, as well as in the residential areas.

Further, the capital, operation, and maintenance cost of these standby generators is rising sharply due to the general economic trends and the advent of the second tier foreign Exchange Market (SFEM) in the country.

Many large industrial undertakings are planning to install their own generating equipment in-house, making them wholly or partially independent of NEPA supplies. About 1,000 MW of self-generating equipments are likely to have been installed from 1985 to date. This would have a serious effect on NEPA'S system loadfactor, increasing the utility's average production costs per Kwh.

3.4 PHOTOVOLTAIC PLANTS AND THEIR COST EFFECTIVENESS

There are few multi-national companies in this country which market imported photovoltaic modules and systems. Studies so far carried out show that photovoltaic systems presently have considerable potential in Water Pumping, T.V. viewing centres, communication systems and railway signalling, street lighting, and remote home power systems, particularly for rural and remote areas of the country. Such photovoltaic power systems may never come true until one can justify, apart from other parameters, their cost effectiveness.

To estimate the cost of electricity per Kwh for photovoltaic plants by the year 2000, four possible options have been considered.

OPTION A. The photovoltaic modules and systems are imported, just as is the case at present, without Government's control and backing. Figure below(5) represents the cost projection for modules and systems in the European market at 198 E.C.U. level.

Cost Projection for Modules and Systems in European Market

The ratio of Nigerian and European cost per peak watt installed is about 2.66 as at 1985. Using the same ratio for the year 2000, the cost per peak watt installed in Nigeria would be N6.78. The specific operating cost has been estimated at N0.15 per peak watt due to inflation, etc, while the improved solar cells by that time might be able to give an annual average coversion efficiency of 10%. Taking other parameters as in appendix A, the cost per Kwh would be N0.36.

OPTION B. The photovoltaic modules and systems are imported with Government's full control and backing. Giving 40% increase due to cost of transportation, profit margin, etc., from the European market, the cost per peak watt installed in Nigeria would be N2.63 at the 1985 value of the Naira. The cost per Kwh in this case would be N0.19.

OPTION C.

For this option, it is assumed that the components of photovoltaic modules and systems will be imported with Government's control and backing and they will be assembled here. For this purpose, a 5MWp capacity assembly plant has been thought appropriate for Nigeria by the year2,000. For such a case, the installed cost per peak watt has been estimated at ₦5.00 which is high due to the capital investment in the assembly plant. Operating cost has been put at ₦0.13 per peak watt because it is believed that with local assembling unit, maintenance of photovoltaic modules and systems could be cheaper. Unit cost in this case would be ₦0.27/Kwh

OPTION D

The last option considered is the complete local manufacturing of the photo cells modules and systems locally by the year 2000. Again, due to heavy capital investment, for such an option the cost per Wp installed has been taken at ₦6.00. Operating cost per peak watt has been further reduced to ₦0.11. It is believed that due to the new nature of industry in Nigeria, the annual average conversion efficiency of modules may be less than the imported ones, say 9.5%. So, the cost per Kwh in this case would be ₦0.32.

3.5 CONCLUSIONS

From the above results of projected unit cost, photovoltaic modules and systems will not be cost competitive with present national generating systems if the latter will provide regular and stable supply and if the huge government subsidies are not taken away. According to the World Watch Institute, Washington, total energy costs in the developing countries amount to 50 billion dollars a year. That is a quarter of all public expenditure. However one can say that by the turn of century, the cost per Kwh from small gasline and diesel generators may be as high as that from photovoltaic plants. So, one could say that stand-alone photovoltaic systems and modules would be cost effective for locations where heavier investments (heavier than NEPA'S subsidies) would be needed to extend tranmission lines of NEPA.

Further, among the options above, option B seems to be the most economical. It must, however, be pointed out that all projections above are subject to considerable fluctuations. What will actually transpire will strongly depend upon:

- The local technical progress in the field of photovoltaics
- The local industrial building for materials, cells, modules and complete systems.
- The local market development of photovoltaic technology.

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4.1 Introduction
4.2 HAY HOUSE
4.3 HAYES ARBORETUM SOLAR GREENHOUSE
4.4 FREESE HOUSE
4.5 UTA DISCOVERY 76 HOUSE
4.6 CHERRY CREEK RESIDENCES - 419
4.7 CHERRY CREEK RESIDENCE - 500
4.8 SUBURBAN SOLAR HOMES.

Solar Architecture is man's great sense of himself embodied in a world of his own making. It may rise as high as the sun - the source. Great architecture is great life.

CHAPTER 4

SOLAR ARCHITECTURE - CASE STUDIES

4.1 INTRODUCTION

Hundreds of millions of people in the world today live in poor housing under adverse climatic conditions that stress their undernourished bodies towards the limits of human endurance and occassionally beyond. The poverty of these people severely restrains their ability to procure the energy required to provide healthful climatic conditions within their homes. Yet their ancestors survived, and often lived comfortably, for centuries under the same climatic conditions in dwellings of traditional design. They were able to do so because they made use of energy available locally in the environment. People living in hot arid climates were faced with problems of high daytime and cool night time temperatures with very little humidity. Solution to these problems relied on energy from the sun, wind, biomass and the innovative, architectural structures and forms that were developed to make use of this natural energy.

Solarchitecture represents the best thinking of architects, engineers, and inventors, and judgement on the solar houses should be based on the following criteria:

- Is the solar system effective?
- Does it provide the needed energy of the house?
- Is it easy to operate?
- Is it durable?
- Is it cheap? More exactly, is it likely to be truly cost-effective? (i.e. considering the first cost, operating cost, and maintenance cost)
- Is it aesthetically attractive? Is it generally compatible with the accepted style of building design?
- Is it of an unusual and technically interesting type that may now or soon show great promise?

Though the case studies chosen are from temperate regions, much care has been taken to include systems with very innovative summer cooling systems which can be applied in this country.

4.2 SKYTHERM SOUTHWEST HOUSE (HAY HOUSE) (Fig.17)

4.2.a BUILDING: This is a one-storey, split-level house, 11.5m x 9.6m located at Atascadero (midway between Los Angeles and San Francisco), latitude 35½°N.

There are seven rooms, but no basement or attic.

FIG 17
HAY HOUSE.

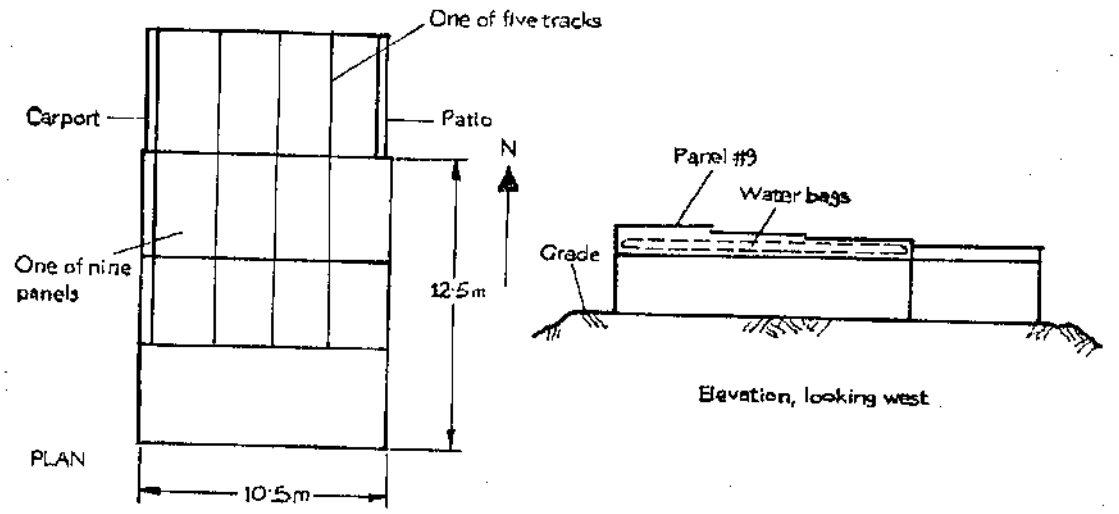
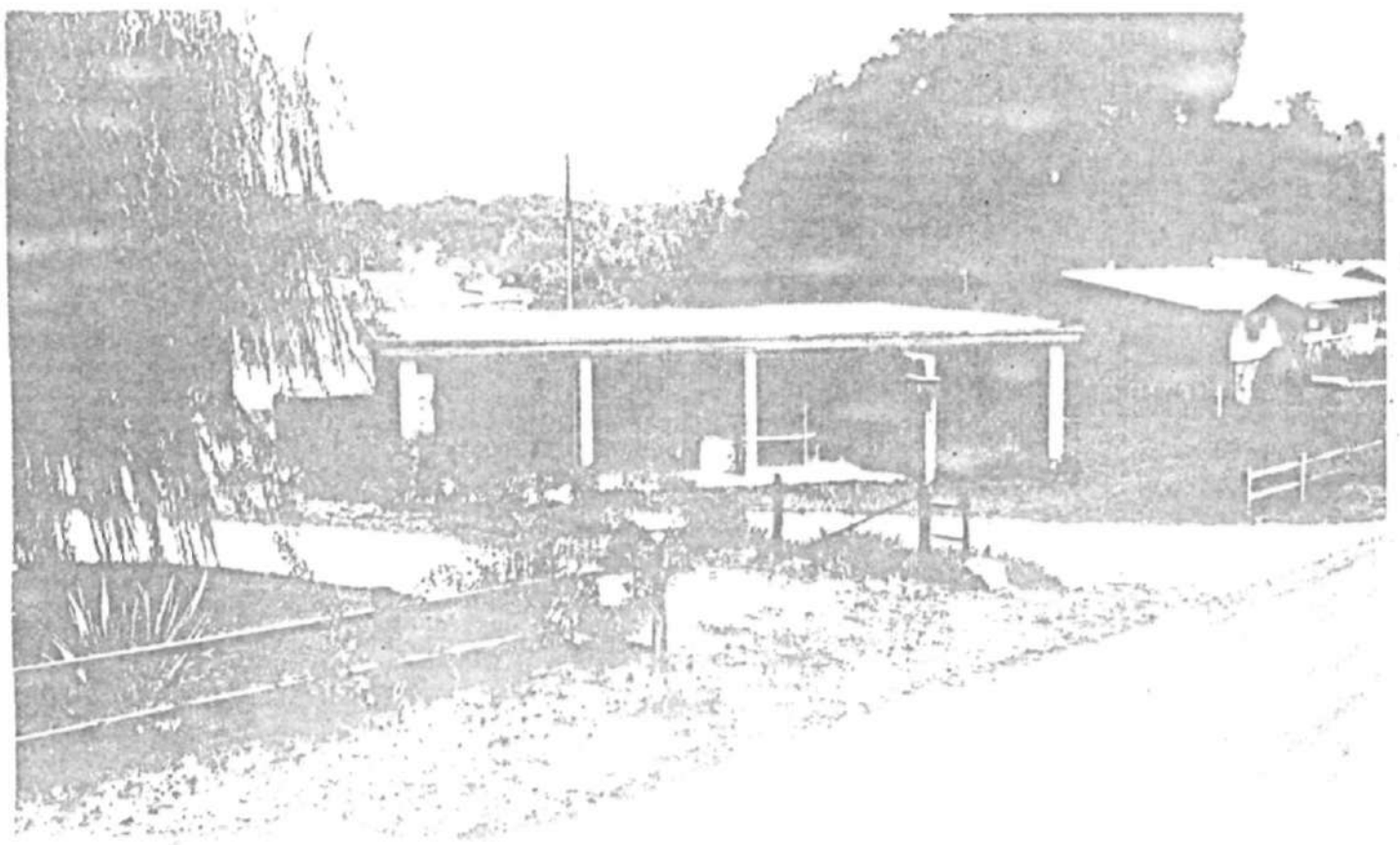


Diagram shows cold-night configuration, with the nine insulating panels in place above the water bags. (During day, panels are stacked above carport and patio.)



At the north end there is a patio and carport. The outer walls and partitions are of concrete blocks; the blocks of the partition walls are sand-filled, and many blocks of the north wall are vermiculite-filled. The solar heating system employs a combined collector and storage system on the horizontal roof; the roof serves also as heat dissipation system.

4.2.b PASSIVE SOLAR COOLING SYSTEM

During the daytime in summer, solar radiation strikes a set of covered side-by-side, water-filled bags covering practically the entire roof of the house. (but not the carport roof). There are four bags, each 12.5 x 2.5m, with the long axis running north-south. They lie in the four alleys, or bays, between five spaced north-south tracks. Each bag is of transparent 0.20 mm polyvinyl chloride (pvc) sheet. The depth of water in each bag is 23cm and the total quantity of water is 25,200 litres (26 tons). Beneath each bag there is a non-selective-black sheet of polyvinyl-chloride or polyethylene which rests on the metallic ceiling of the rooms below. The ceiling consists of 3.6m spans of ribbed sheet steel.

The water-filled bags are covered by the insulating panels and gain very little energy.

At night, the covers are moved aside and stacked above the carport so that the bags are exposed to the sky and to the cool night air and lose energy by convection and radiation.

There is no insulating airfilm above the bags and this results in a high rate of energy loss. The bags remain cool throughout the summer; they cool the metallic roof which in turn cools the rooms. The extent of passive cooling is 100%.

4.2.c PASSIVE SOLAR HEATING SYSTEM

On sunny days in winter the insulating panels are uncovered, solar radiation then strikes the bags. Above each bag there is a transparent sheet of ultra-violet-resistant PVC that is sealed along the edges of the bags and is held-by gentle air pressure from below-about 5 cm above the bags, thus providing some thermal insulation.

No antifreeze is used; the water remains warm all winter. Heat flows downwards through the thin metallic ceilings into the rooms. Much of the heating is by radiation. The heating is sufficiently uniform throughout the house that no fans are required. The bathroom is heated by conduction through the walls and convection of air through the doorway. The thermal capacity of the massive walls and partitions supplements that of the 26 tons of water.

Throughout the winter nights and summer days the bags are covered by a set of nine large, rectangular, horizontal panels of 5-cm-thick polyurethane foam. Panels 1 through 8 inclusive are 4m by 2.5m and panel 9 is 11m by 4m. Each panel is supported by a set of 1-cm diameter, nylon-rimmed, ball-bearing-type wheels which run on horizontal, north-south, positive-guide rails of extruded eluminium. The extrusions are specially designed to provide three levels of wheel runway, to facilitate stacking.

During sunny days the panels are stacked, three deep, just above the carport at the north end of the building. The panels are moved automatically by means of a ¼-hp motor and sprockets and chains; these propel panel 9 (the large, south most panel) which in turn propels panels 5,6,7 & 8: and these is turn propel the northmost panels 1,2,3 and 4. Alternatively, the panels may easily be moved manually, since they are lightweight. Seals prevent cold air from blowing between the panels and the bags.

In winter the panels are closed automatically whenever the energy-collection conditions (intensity of radiation and outdoor temperature) become unfavourable, as determined by a small model collector-

dissipator consisting of an air-insulated horizontal black plate.

In summary, the water-filled bags collect solar radiation on sunny days, avoid losing energy to the outdoors at night,(thanks to the insulating covers), and continuously distribute heat downward, through the thin metallic ceilings, into the rooms.

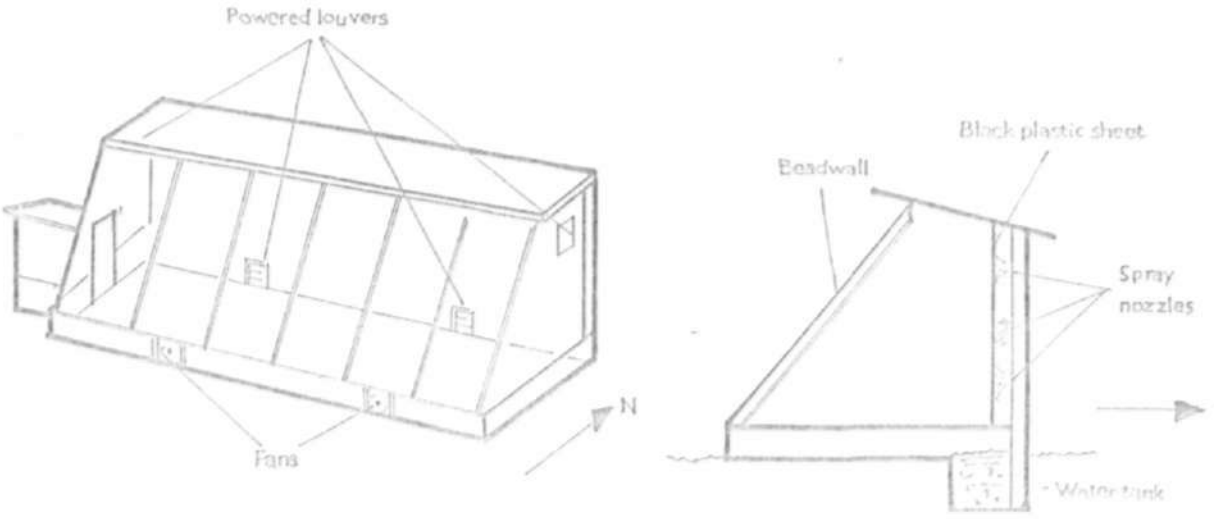
4.2.d PROBLEMS AND MODIFICATIONS

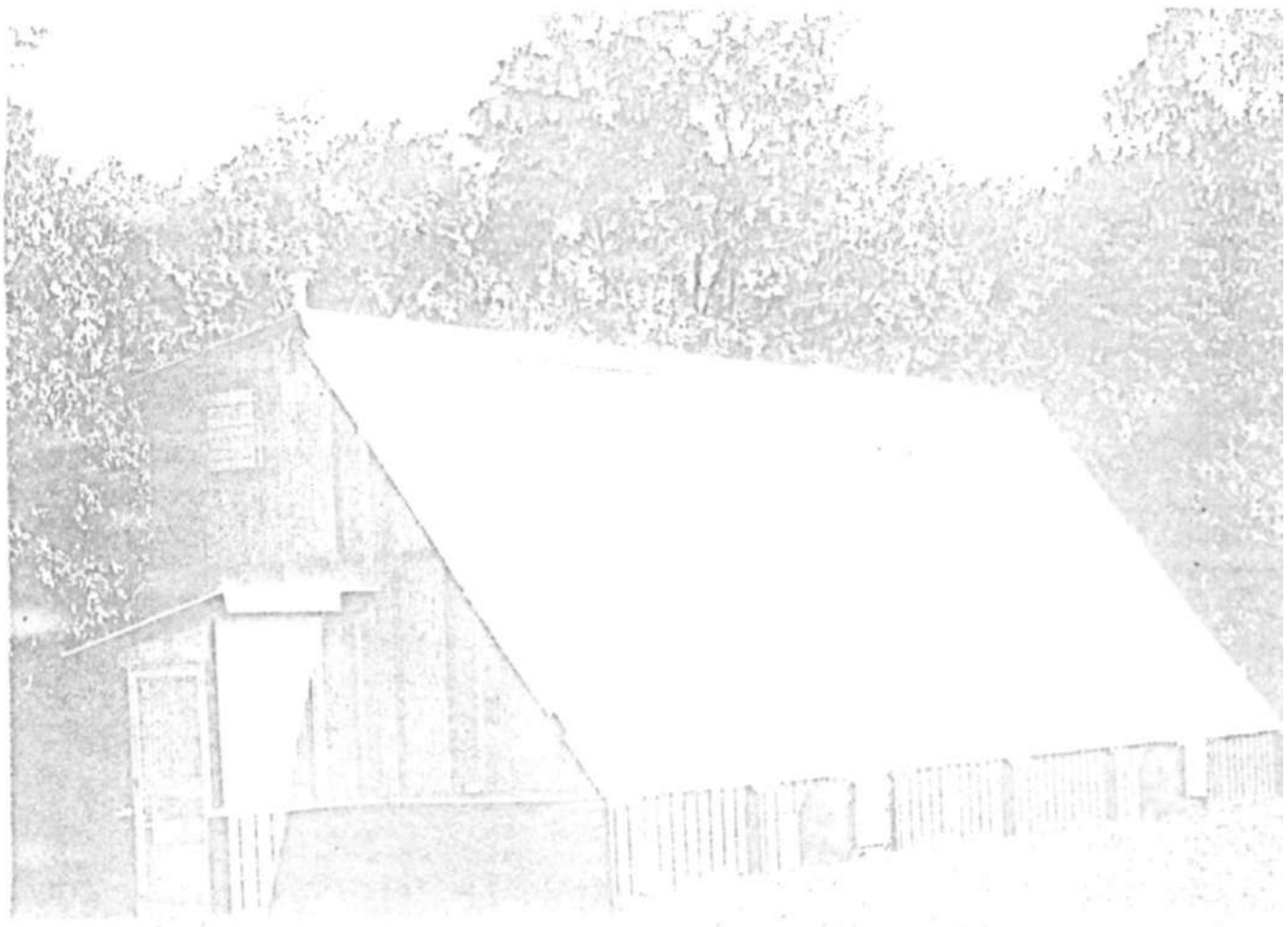
Initially, there were some small leaks in the water-bag-and-roof system. These were corrected and there have been no leaks subsequently. Several minor problems arose in connection with the large horizontal insulating panels: problems concerning edge seals, thermal losses through frame members, drive systems, and controls. These have been corrected. New designs of panel systems have been proposed recently.

4.3 HAYES ARBORETUM SOLAR GREENHOUSE

In this solar Greenhouse the black absorbing surface is close to the north wall; that is, the useful space is been the glazing and the black absorbing surface. Heat is picked up from this surface by a spray of water.

FIG 18
HAYES ARBORETUM SOLAR GREENHOUSE.





4.3.a BUILDING

A steel-framed, 16.5 x 6.5m greenhouse, which faces exactly south (fig.18). The south face, which slopes 53° is 16.5m long and 6m high. It consists of Beadwall. During the day, solar radiation passes through the sheets of Tedlar-coated 5-grms reinforced fiber glass and through the 5-cm space between them. At night this space is filed with 2mm- diameter beads of polystyrene foam. The concrete-block foundation walls and the north wall are insulated with zonolite and 2 or 5-cm of styrofoam. There is no attic, basement or garage.

4.3.b COLLECTION

Much of the radiation entering the building strikes a vertical 0.06mm sheet of black nylon-reinforced polyethylene that is suspended 50cm from the northwall. Water (with no anti-freeze) is sprayed southward onto this sheet by nineteen nozzles affixed to the northwall. A ½-hp centrifugal pump is used, and the flowrate is variable the water that trickles from the lower edge of the sheet is discharged into the storage tank.

Some solar radiation strikes the growing plants and some strikes the floor, which consists of a 10cm slab of poured concrete resting on 1 meter of gravel.

4.3.c STORAGE

The 22,800l of water is in a rectangular poured-concrete tank, 16m x 1.2m x 1.2m high, situated beneath the absorber sheet. The tank walls are 30cm thick. The north side of the tank is insulated with 5cm of styrofoam, and the bottom is similarly insulated. On the south side there is no insulation; heat can escape into the concrete floor and into the gravel beneath the floor. The safety cover of the tank is made of wooden boards and has no added insulation. Heat from the tank is distributed to the environs of the potting benches by 60m of finned tube running under the benches. The water is circulated through the tube by a small centrifugal pump.

4.3.d COOLING IN SUMMER

Alternate pairs of beadwall panels are kept filled with beads at all times to provide partial shade.

4.3.e PROBLEMS AND MODIFICATIONS

Initially, the beadwall panels failed to perform properly. The difficulty was soon corrected.

4.4 FREESE HOUSE

Water-filled plastic bags in attic receive solar radiation via sloping beadwall roof. (fig.19)

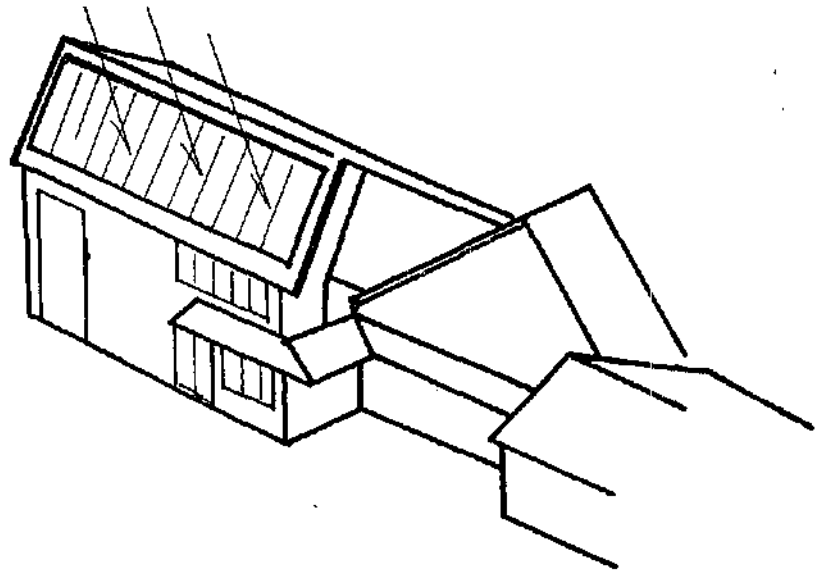
4.4.a BUILDING

The building, which is 11m x 6.5m wide, has two floors, an attic, and a crawl space, but no basement. The cooled area is 125 sq. metres. The ground floor contains the living room, kitchen, and laundry, and the first floor has one bedroom, a large study, and a bathroom. The walls are insulated with 15cm of fibreglass and the roof contains 30cm. The foundation walls, of granite, are insulated on the inner faces with 5cm of urethane foam. The windows are double-glazed.

4.4.b SOLAR HEATING SYSTEM.(fig.19b)

The solar heating system is largely passive. Solar radiation enters the attic via the south face of the roof, which slopes 60 degrees and is doubleglazed with Kalwall sun-lite. The glazed area (23 sq metres) is 11m long by 3m high. The two glazing sheets are 10cm apart and are part of a Beadwall system. On sunny days in winter there is only air between the two sheets, and radiation passes through freely and strikes a large horizontal array of thirteen water-filled black vinyl bags resting on the attic floor.

FIG 19(a)
FREESE HOUSE (VIEWS)



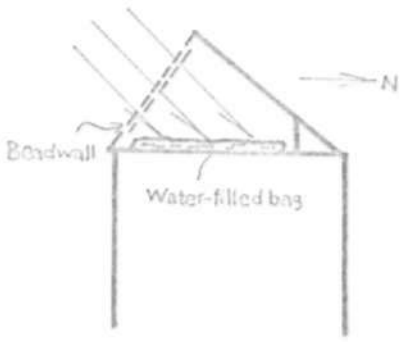


The total amount of water is 8000l, weighing 9 tons. Each of the bags is approximately rectangular and is 2.6m x 2m by 18cm high. Warm air from the space above the bags is sent, by a blower, downward into the crawl space beneath the ground floor and thence upward into the ground floor rooms via five vents. The return air flows up the circular stairwell and into the attic. Some attic air is sent downward directly to the first floor study and, indirectly, to the bathroom. At the end of a sunny day a small blower blows a large quantity of 2mm diameter polystyrene foam into the space between the two sun-lite sheets, to provide insulation equivalent to 10cm of fiberglass. The above-described solar heating system, which is mainly passive but partly active, is supplemented by purely passive solar heating provided by the large vertical window areas on the south face of the building.

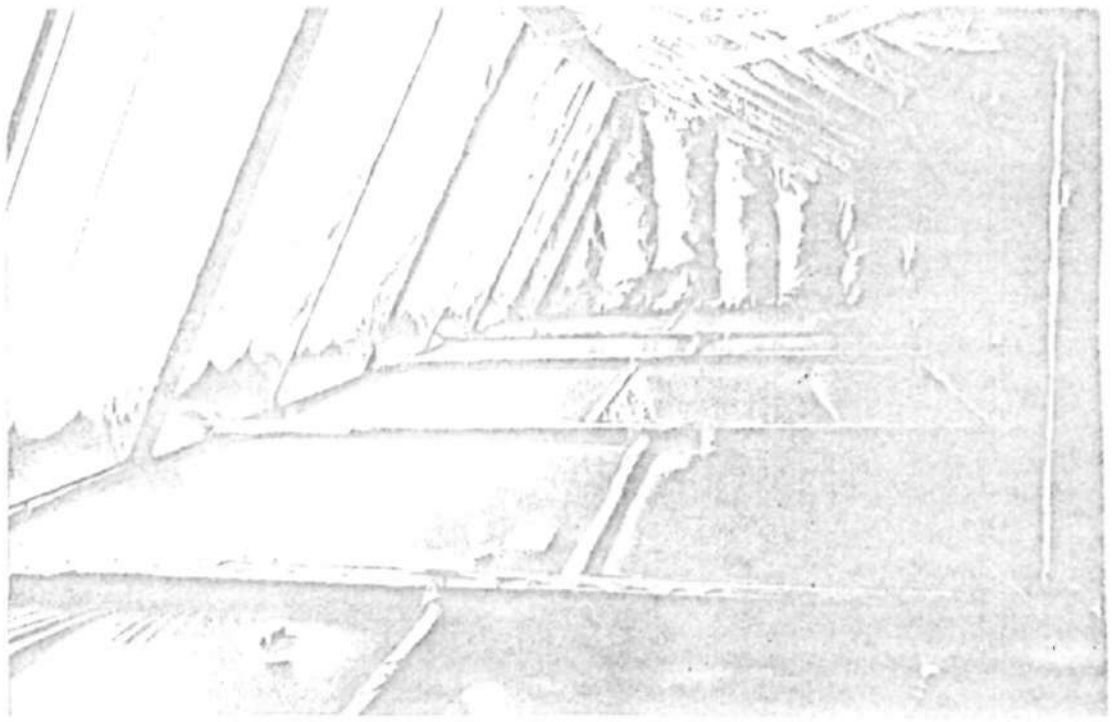
4.4.c COOLING IN SUMMER

Operating of the Beadwall roof and the attic storage system is reversed, to provide cooling. The Beadwall remains filled with beads, to exclude solar radiation, and during

FIG 19(b)
FREESE HOUSE (DETAILS.)



Partial cross section looking west



the night, cool outdoor air is circulated through the attic by means of a blower in order to cool the water-filled bags. Cool air adjacent to the bags is circulated, via the crawl space.

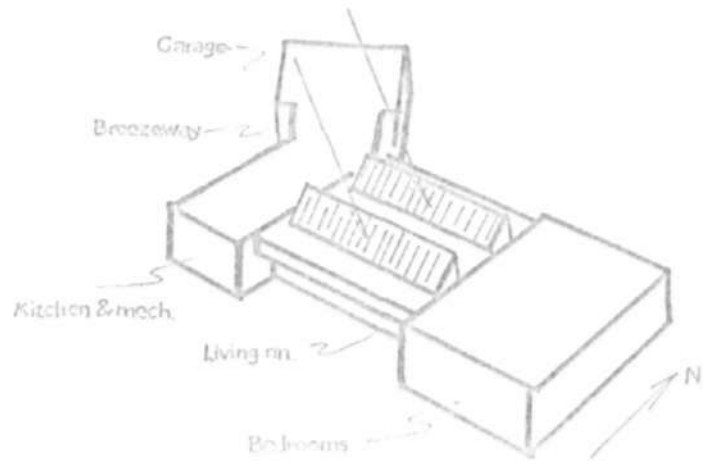
4.5 UTA DISCOVERY 76 HOUSE. (fig.20)

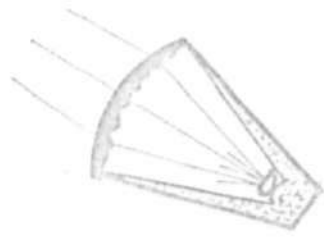
75% solar heating and 60% solar cooling provided by 42 Northrup tracking, concentrating collector boxes.

4.5.a BUILDING:

A 3-bedroom house, with a breezeway and two-car garage at the northwest cornerand no attic or basement. In constructing the house, much use was made of a new kind of material called Tectum 11, when provides structural strength, thermal insulation, and absorption of sound. It is composed of wood fibers and also incorporated 3.5cm of urethane foam. The aggregate area of windows in the central parts of the south and northwall is $18.58m^2$ while the area of east and west windows is negligible. All windows are 2.5cm-thick assemblies of two sheets of 1cm glass with a hermetically sealed airspace between them.

FIG 20
UTA DISCOVERY 76 HOUSE.





Cross section of a collector box (not to scale)



A collector box



4.5.b COLLECTION:

The $39m^2$ of collector is distributed in two linear arrays, one 3.5m north of the other. These are mounted on the horizontal roof of the central part of the building. Each array is 16m in east-west dimension and 3.5m in north-south dimension. Each array includes twenty-one Northrup collector boxes, each of which is 3.5m long, 30cm wide and 30cm deep. The boxes are 70cm apart on centres, and each is tilted with its north end higher than the south end, the typical slope being 27^{o}. The top of each box is a 3.5m long, 30cm-wide cylindirical plastic fresnel lens with 30cm focal length. About 30cm below the lens is the absorber: a 3.5m-long, 5cm-wide flattened copper tube with selective black coating. Coolant (water) enters the tube at one end and leaves by the other. The boxes are slowly turned to track the sun; they rotate about the longitudinal axis and are linked together mechanically so that one tracking motor can control many boxes.
The total angular range of tracking is 140^{o}.

4.5.c STORAGE:

The 12,000 litres of water is stored in three 5,000 litre tanks situated in the garage. Each tank is a vertical cylindrical tank of fiberglass and plastic and is insulated. The group of three tanks is enclosed in an insulated housing. Heat is delivered to the rooms by a forced-air system.

4.5.d COOLING IN SUMMER:

Use is made of a 3-ton Arkla-servel lithium-bromide absorption cooling system, powered by 90^{0}c water from the solar heating system. The solar heating system is expected to provide about 40% of the power needed for cooling.

PROBLEMS AND MODIFICATIONS:

Initially the solar-powered cooling system was inoperative because of faults associated with the vacuum pump used. Repairs have been made. Some of the first collector boxes were not fully waterproofed; the difficulty was soon corrected. An insulated housing was provided for the three storage tanks because the insulation on those tanks was not adequate.

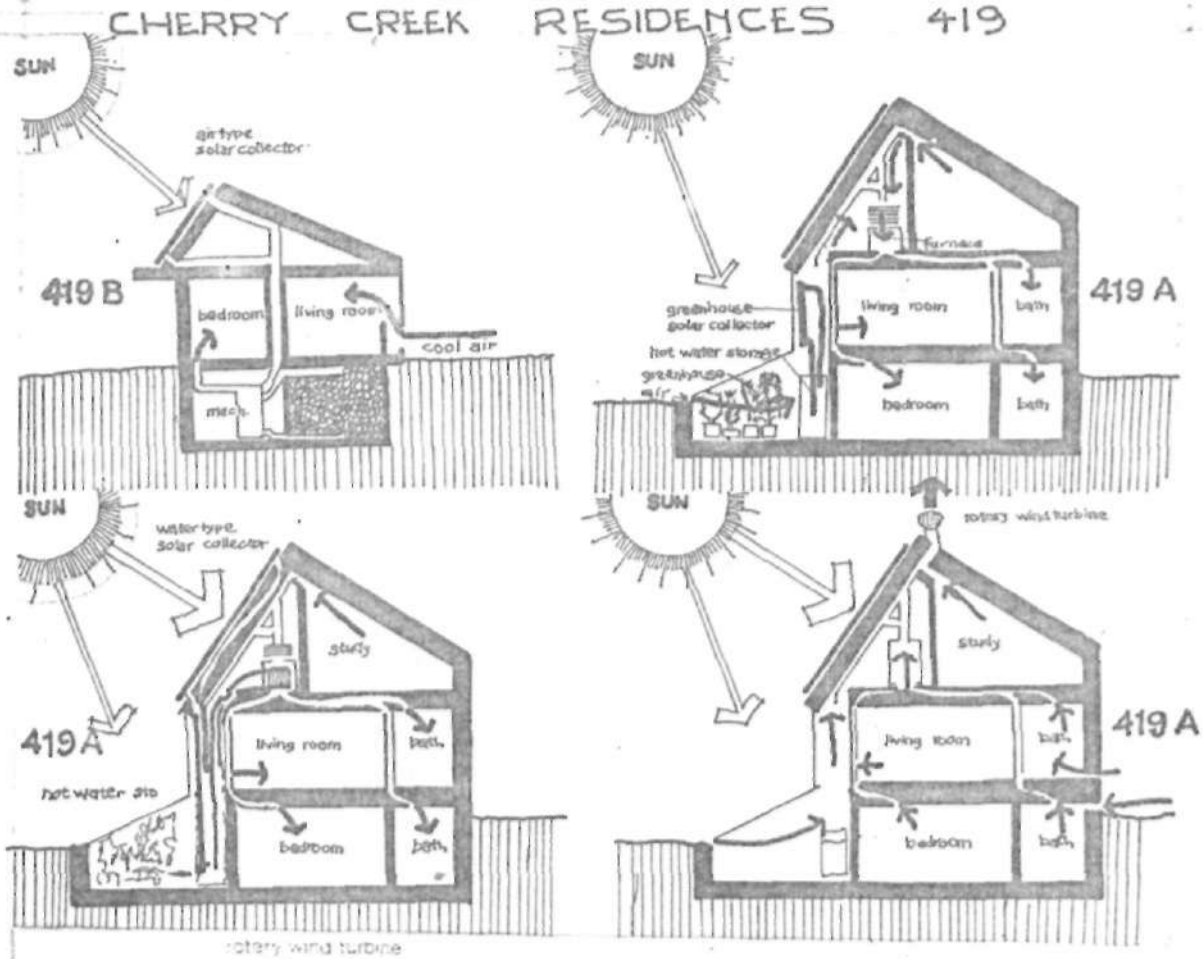
4.6 CHERRY CREEK RESIDENCE -419 (fig.21)

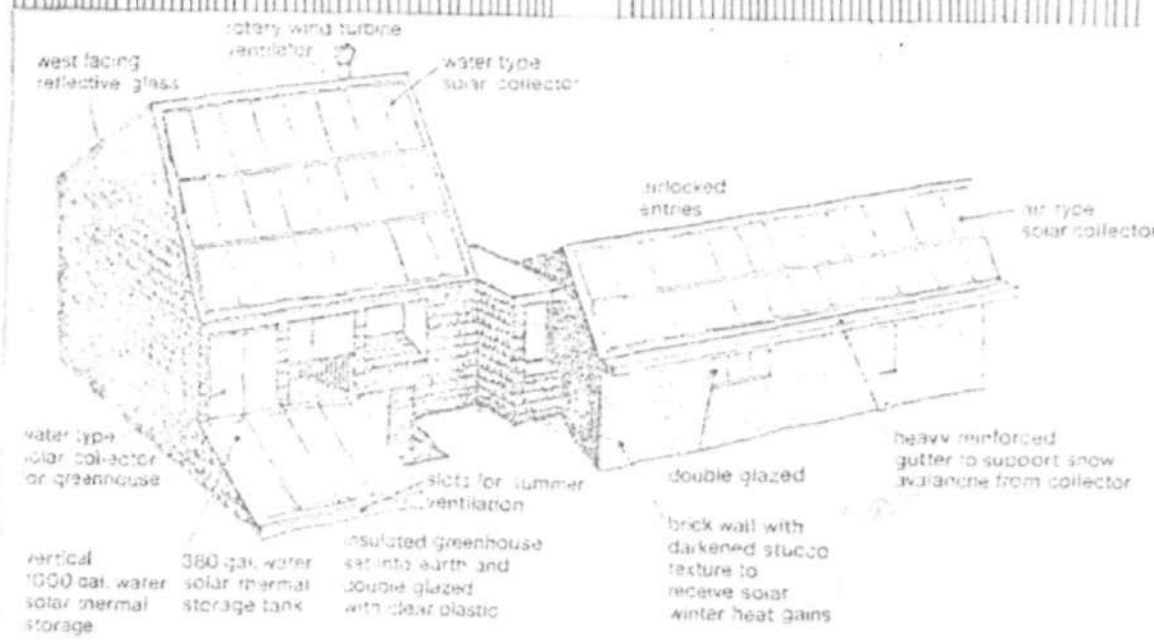
4.6.a The '419 A' building is a 390 m^2 residence on a 9 x 9m foundation. It is intended as a prototype for either on-site or modular construction for townhouses, cluster housing, or single family use. Arrangement has a plan with bedrooms and greenhouse on the lower level; living, dining and kitchen on the main level; and studio at the third level. Full bathrooms, including shower, are located on the lower and main levels.

The primary entry faces east away from north and north west winter winds and is an airlock, doubled door, unheated vestibule. Glass area is limited, yet provided visual openness, attractive outdoor vistas, and natural illumination. Walls and ceilings are shaped and painted to function as light fixtures without glare. All windows are fabricated from clear plate, double glazed, insulating glass. The window position and size is calculated to receive direct winter solar gains but exclude them in the summer.

FIG 21

CHERRY CREEK RESIDENCES 419





data

data

The hood over the kitchen range recirculated the air through a charcoal filter for cleaning and deodorization. The bathrooms have recirculative fans with citrus base filters that deodorize the air and w kill the bacteria. These systems prevent direct internal heat losses that occur through externally vented fan systems.

During spring, summer and fall, ventilation is provided by means of a roof turbine. Cooling is provided on hot days by a 5400 cfm evaporative cooler, combined with the roof turbine fan exhaust system. 90% of all cooling requirements were met with this system.

Fresh air is provided in winter by the solar heated greenhouse and from return air that passes through an electrostatic and charcoal filter system.

Outer walls of the house are 20cm wood studs with 19cm of rock wool insulation, an outer 2cm thick insulating sheating board, 1.5cm of plywood sheathing, and sawdust to trap air. Internal 4mil pliofilm acts as a continuous vapour barrier on the entire interior and is covered with 1.3cm interior drywall. The 'U' factor of this wall is less than 0.025, and due to its thickness provides a higher thermal mass, for retention of interior energy, than conventional frame construction. The roof construction is similar to that of the walls.

The 52 sq. metres solar collector, is a flat plate water type south facing roof collector set at a 53° angle. Each double glass cover plate is 3mm thick. The interior coating is flat black. A reinforced gutter and top member are provided to support a movable ladder for collector access and to act as a snow trap. Heated water is piped from the roof top solar collector to a 4000 litre vertical fibreglass insulated storage tank. At night and when freezing conditions exist, the water is automatically drained from the collector into the insulated tank. This prevents damage to the collector resulting from the expansion of water upon freezing.

The solar collection system is used to heat domestic water. Over 95% of all hot water is provided in this way. It is projected that 96% of all heating requirements will be satisfied by the solar collection system in conjunction with the energy optimized design.

4.6.b THE '419 B' building is the result of extensive remodelling of an older 102 m^2 residence. It also has an 83.6 m^2 basement . To improve the total thermal characteristics of the house, the basement is utilized as a thermal reservoir, to moderate the heating and cooling needs of the house by means of direct transfer grilled floor openings.

The old coal bin is re-used for solar thermal storage. It is filtered with a layer of open concrete block covered with wire mesh to serve as a lower manifold, and filled with 20 cubic yards of large gravel. A new insulated north wall was constructed the length of the house that shields the north from winter storms and winds, as well as converting the old uninsulated 20cm brick wall to an interior thermal inertia wall. The new north wall extends out from the old wall approximately 1m, allowing for moderate day and cool nocturnal temperatures to be drawn in through recessed, insulated air vents. The south roof angle was altered to 53° for effective use of an air type solar flat plate collector. 15cm of insulation was added to the roof to supplement the 10cm of existing loose fill insulation.

The main entry faces east and is an airlock double door unheated vestibule. A floor grille to the basement near the entry picks up cold air intrusion. The old front entry door is replaced with a new weather stripped door, and the old porch converted to a solar patio. Small, old northside windows are replaced with insulated weathersripped solid panels which can be opened for natural ventilation. On the south side of the living room, a new slim shade double glazed window has been provided and is protected by a roof overhang.

Two east windows with sun control, heat absorbing gray double glazed windows extend to the floor and replace the old double hung windows. The west window in the bathroom was replaced with double glazed reflective glass, to eliminate outside air infiltration and decrease west solar radiation approximately 78%.

Bathroom and kitchen fans are the recirculating type to decrease heat losses. The exterior of the house was completely refinished with cedar wood shakes on the roof and sidewalls, adding extra insulation to them. Other sidewalls are finished with new stucco.

The 36sq metre solar collector, is a flat plate air type collector. Each double glass cover plate is 3mm thick. the interior coating is flat black. A reinforced gutter and top member is provided to support a movable ladder for collector access and to act as a snow trap. Solar heated air is forced through a duct system to the thermal gravel storage bin in the basement.

During daytime periods of full or diffuse sunlight, solar heated air through the gravel storage bin and the existing furnace before being delivered to the house. During overcast periods or at night, the forced air system will draw solar heated air from the gravel storage bin.

Natural gas is the back-up fuel source. During seasons when the house needs cooling, cool daytime and nocturnal air will cool the gravel bin, and cool air will be delivered as needed through the house by means of the existing forced air system.

It is projected that 85% of all heating requirements will be provided by the solar collection system in conjunction with energy optimized features. Cooling is provided by natural ventilation.

4.7 CHERRY CREEK RESIDENCE - 500 (fig.22)

This is a 242 m^2 residence with a 116 m^2 apartment, designed to optimize energy conservation and utilize passive solar collection. The entire building is designed to function as a solar collector in the winter and prevent solar gains in the summer. Heat storage is provided by the thermal inertia of floor and walls.

The principal entry for each unit is recessed to protect it from prevailing winter winds. All windows are double glazed, fixed glass. Window areas are kept to a minimum, yet their shape and location maximize interior daylight. Natural illumination is also provided by double plastic, heat absorbing skydomes and special skyshafts with near zero thermal loss.

Solar gain through southern exposure is maximised during winter and minized during summer, by calculated window recess depths and outdoor deciduous vegetation combinations. The southern windows of the dining room function as two-stage winter solar collectors, with the lower unit active from September 1 until April 1 and the upper unit from October 15 to February 15.

5.4 THE SITE - Climate

To properly consider the integration and orientation of the Habitat on the site, the following macro-climatic conditions were evaluated.

1. The monthly average dry bulb and wet bulb temperatures.

2. The average monthly relative humidity (the percent of water vapour in the air relative to the maximum amount it can hold).

3. The monthly average windspeed.

4. The rainfall amount.

5. The incident solar radiation (insolation) on a horizontal surface.

6. The sunshine hours per day (will help to predict monthly heating bads and storage capacities needed).

WIND SPEED

Average Windspeed = 6.34 Km/h

Wind machines produce useful power between 12-16Km/h wind speed to generate electricity or pump water. Top utilisation speed is 65 Km/h.

This implies that wind machines are not viable at the solar habitat, but roof turbines could be very effective.

The exterior wall colour was selected to balance radiant heat gains and losses on a 12 month basis. The rough exterior wall texture deepens the stationary air film, as a thermal buffer zone. The 'U' factor of the walls, roof, and floor is 0.05.

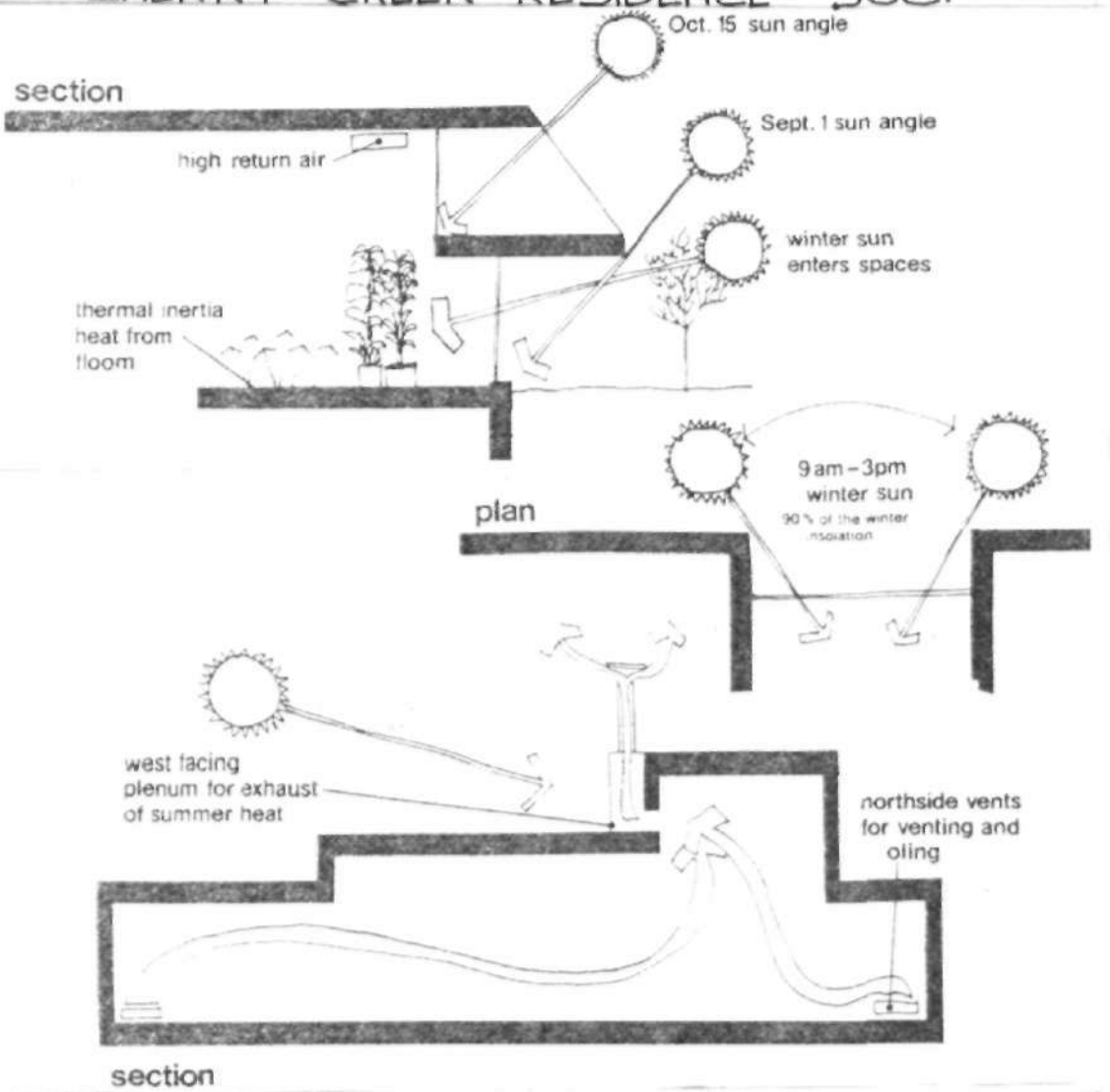
Garage and storage area locations provide thermal buffering of internal living spaces. Modulated ceiling heights are used to direct the hottest air to the highest point in the building, allowing interior air temperatures to be salvaged by high level air returns in winter and low level air returns in summer. For summer cooling, roof plenums heated by the sun, induce upward air motion which allows outside air to enter by displacement through north vents.

The passive systems and energy optimized features of this home provide 65% of the heating and 60% of the cooling. The house is also equipped with conventional heating and airconditioning units. These systems contain electrostatic, charcoal, and fiber filters which allow interior air to be recirculated without the intrusion of exterior air which may be at a different temperature, thereby salvaging thermal equilibrium.

Large interior plants provide oxygen to the air and absorb carbon dioxide. Winter dehumidification of interior air is produced by a water fountain, which raises the perceived temperature.

FIG 22

CHERRY CREEK RESIDENCE 500.



data

CHERRY CREEK RESIDENCE "500"

Floor Area	2600 square feet (+1250 square foot apartment)
Collector Area	None
Solar Collector	None
Solar Collector Supplier	None
Heat Storage	Thermal Inertia of Floors and W
Completed	1972
Architect	Richard L. Crowther AIA

4.8 SUBURBAN SOLAR HOMES (fig.23)

These two suburban homes designed as solar prototypes for a housing development, feature a one-storey, 195 m^2 home and a 93 m^2 bungalow. Both have air type solar collectors and gravel heat storage. The one-storey unit has 32.6 m^2 of collector area and 8 tonnes of gravel storage, while the other unit has 22m^2 of collector area and stonnes of gravel storage.

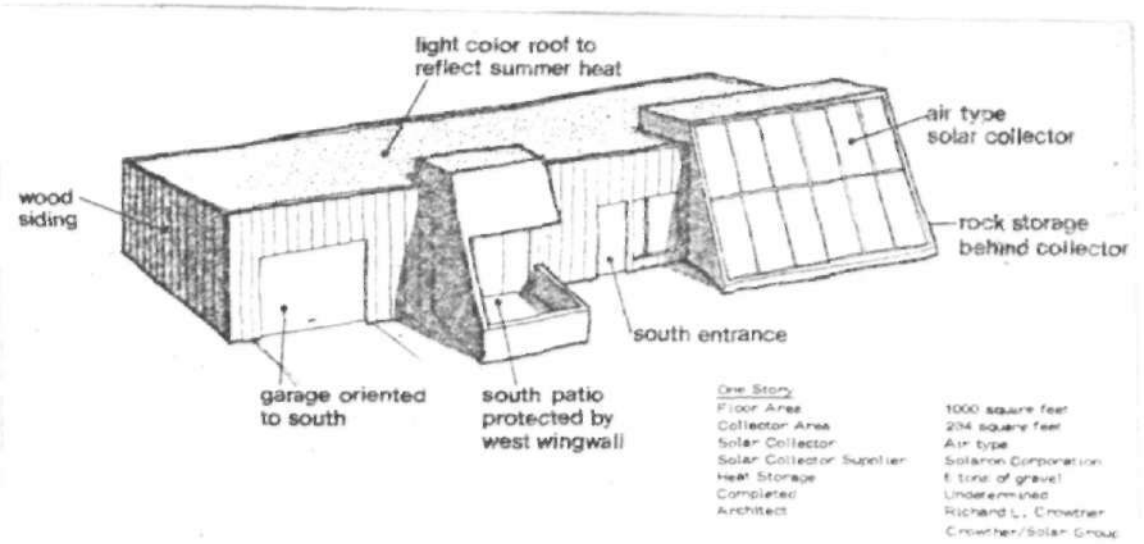
Architectural features of the storey-building are minimal northside windows to decrease heat loss, wingwalls to protect west side windows from wind and sun, and a recessed south entry. Excess greenhouse heat is ventilated through a roof stack in the summer, and used for space heating during the winter.

The bungalow has no west windows and minimal northside glazing. It has a south facing entry and patio, protected from direct afternoon sun by a wingwall. The heat storage area is located directly behind the solar collector.

Both houses have 5cm wood stud walls, insulated with moisture barrier batt type insulation. Dark coloured wood siding increases heat gains when the sun angle is low (winter) and the light colour of roof reflects heat when the sun angle is high (summer). Double glazed, wood frame windows are used throughout.

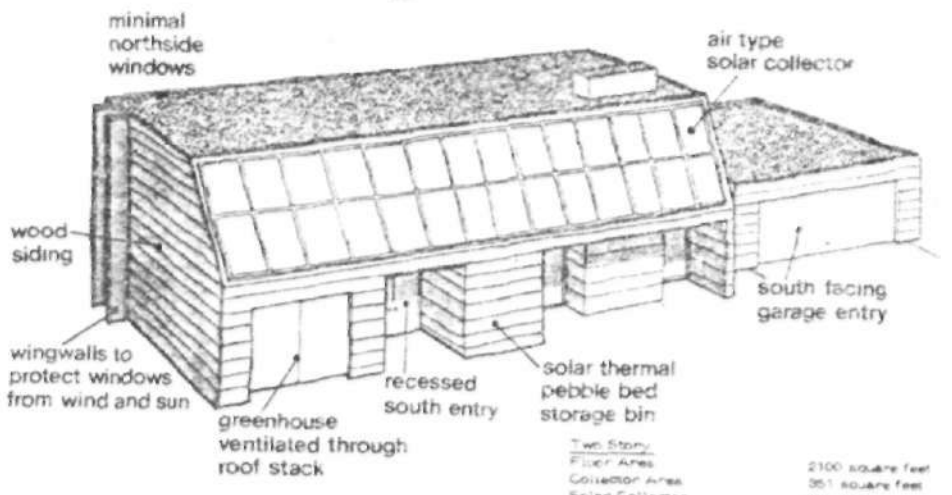
These houses were designed to be economically competitive with other development homes. The solar heating systems are expected to provide 75% of all space heating. Solar heating of domestic water is being considered.

FIG 23
SUBURBAN SOLAR HOMES.



One Story

Floor Area	1000 square feet
Collector Area	204 square feet
Solar Collector	Air type
Solar Collector Supplier	Solaron Corporation
Heat Storage	6 tons of gravel
Completed	Underermined
Architect	Richard L. Crowther
	Crowther/Solar Group



Two Story

Floor Area	2100 square feet
Collector Area	351 square feet
Solar Collector	Air type
Solar Collector Supplier	Solaron Corporation
Heat Storage	9 tons of gravel
Completed	In bidding phase
Architect	Richard L. Crowther AIA
	Crowther/Solar Group

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5.1 SITE SELECTION CRITERIA

5.2 SITE LOCATION

5.3 SITE ANALYSIS

5.4 SITE CLIMATE.

The character of the site is the beginning of a house with character - Man is part of nature- let us build homes that keep him in wholesome balance with the natural world, that give him contact with the life-enhacing elements.

FLW

CHAPTER 5

THE SOLAR HABITAT SITE AND CLIMATE

In order for the solar Habitat to use the natural energy available to it most efficently, it must be planned with consideration given to microclimate conditions, site and building orientation, landscape features etc.

The solar Habitat should have minimal negative impact on its site, (i.e. it should be of the site and not on the site); maximize efficient use of all energy, maximize human effort and comfort, and promote human talents by providing a pleasing atmosphere in which to live and work according to personal inclinations.

5.1 SITE SELECTION CRITERIA

Plans for using solar energy sources require that foresight be used in sight selection. Therefore diligence was exercised in examining the choice of site. In this regard, emphasis was laid on the following site selection criteria;

1. ACCESSIBILITY.
2. PROXIMITY OF SITE TO EMPLOYMENT OPPORTUNITIES
3. DISTANCE FROM EXISTING INFRASTRUCTURE
4. SUITABLE SITE AND CLIMATIC CONDITIONS, SUCH AS RELIEF, INSOLATION. TOPOGRAPHY, NATURAL DRAINAGE, AND SOIL TYPE.

5. COMFORMITY OF SITE TO DESIGNATED MASTER-PLAN LAND USE.

5.2 THE SITE - LOCATION

NAME OF TOWN - KADUNA

STATUS OF TOWN - KADUNA STATE CAPITAL

GEOGRAPHICAL LOCATION - Kaduna town lies on latitude $10^{\circ}41'$ N; LONGITUDE 07° 19'E

CHOSEN SITE - Malali Residential Area.

5.2 (a) ACCESSIBILITY:

Bounding the site are two road proposals which run South-West - North- East, and Northwest - South east. These roads will connect the site to the other parts of the town, the central Business District, and to existing cuttural facilities within Kaduna and its rural hinter lands.

5.2 (b) PROXIMITY OF SITE TO EMPLOYMENT FACILITIES

Being a part of the Greater Malali Area, the site, though not serviced by the Kaduna Transport Cabs, due to its proximity to the Malali villages and Malali low cost, can easily be accessible to transport cabs.



Plate 4

What a site! Boundaries of which are being washed by the ever-present Kaduna River. Maximum use must be made of this River. Good Views, recreational Zone.

5.2 (c) DISTANCE FROM EXISTING INFRASTRUCTURE

Not to negate the Government's drive for provision of infrastructure, a site was chosen which has no infrastructure of any kind.

5.2 (d) The site falls within a designated urban expansion programme for housing. It has not been committed by Government to any lease, and therefore not liable to legal problems of acquisition.

5.3 THE SITE - Analysis

The Habitat site is located in one of the Government Reservation Areas in Kaduna- the Malali Residential Area (fig.24). The site which is zoned for middle to high cost housing is to the East of Malali Village and South of the Malali Low Cost Housing Area, and is bounded to the west by Kaduna River which flows due Southwest of the site.

The site, which is relatively flat, is gently sloping towards the Kaduna River. A well-defined flood plain gives an assurance against any future flooding of site from the site.

The site is about 80.9 hectares.

SITE OF THE SOLAR HABITAT, KADUNA

0 15 60 152 228 304 456
metres

FIG 24

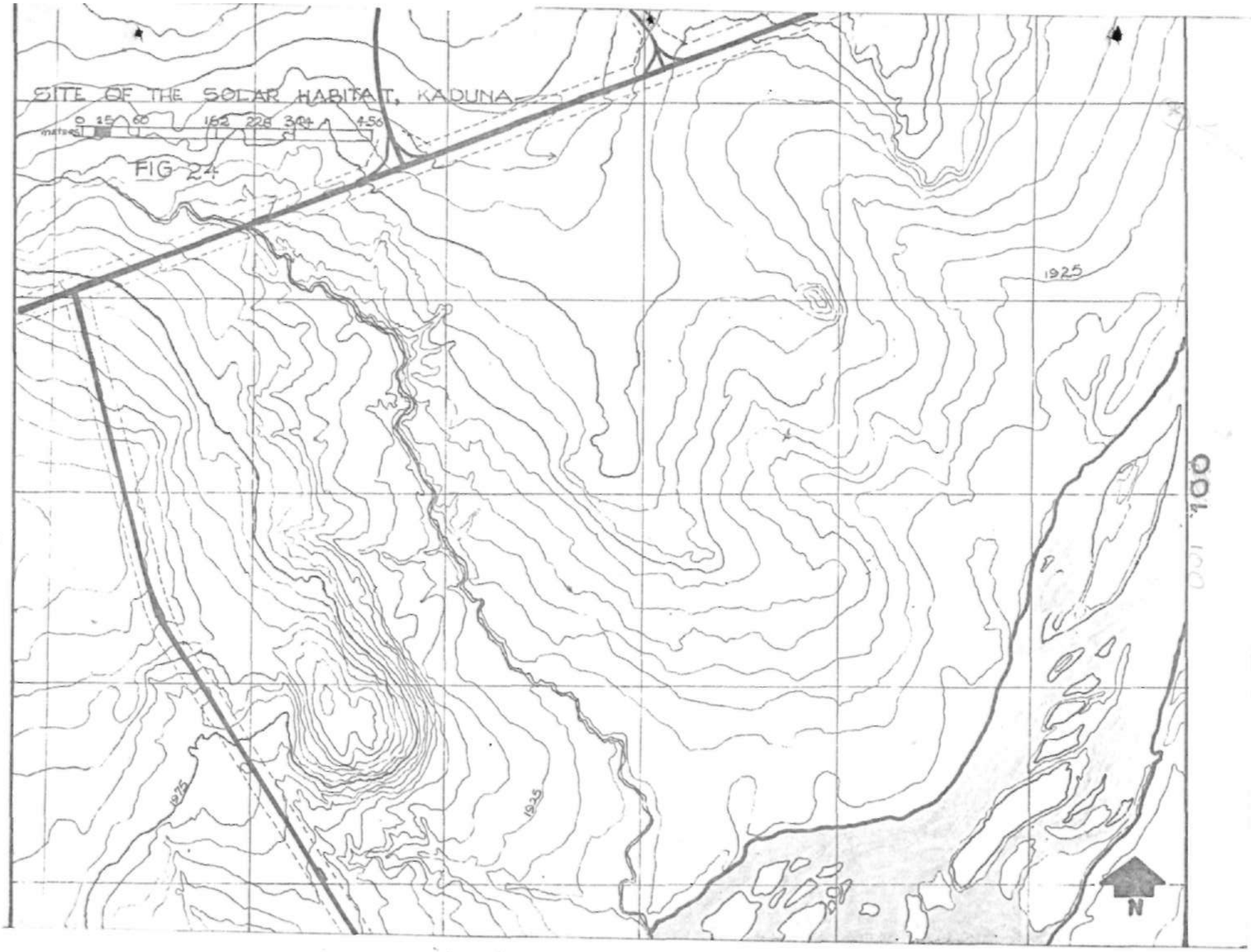


TABLE 2 WEATHER REPORT 1985 KADUNA

Lat. 10° 41' N

Long. 07° 19' E

	Mean Wind Spead KM	Temperature °C		R.H.%	Sunshine	Rainfall
		Max	Min	09 GMT	1982 Hours	(mm)
Jan.	186.31	31.9	15.1	22:	9.0	0.0
Feb.	168.23	36.0	19.0	19	7.6	0.0
Mar.	129.30	35.9	21.1	46	7.3	7.3
Apr.	159.52	36.6	23.5	61	8.8	22.5
May	150.80	34.2	22.6	66	7.5	91.2
Jun.	169.72	30.6	20.4	74	6.9	117.5
Jul.	152.92	28.0	20.2	84	6.1	213.7
Aug.	122.77	28.8	20.0	84	4.7	306.1
Sept	122.77	29.2	19.7	81	5.9	319.0
Oct.	98.66	32.2	19.1	64	6.5	18.4
Nov.	145.44	32.6	16.8	36	7.0	0.0
Dec.	216.42	29.1	14.1	21	8.6	0.0

TEMPERATURE

Average minimum temperature = 19.29°C.

Average maximum temperature = 32.09°C

Comfort Zone in Nigeria = 22 - 30°C.

This implies that for optimum comfort, there should be the use of solar cooling and heating with the active or passive systems to ameliorate the conditions of ambient temperature.

RADIATION AND SUNSHINE HOURS

Average solar Radiation = 16.997 Kcal/day

= 17 Kcal/day

Average daily sun hours = 7.3 hrs.

This implies that 17 Kcal/day of sun shines for 7.3hours every day. This shows that the solar habitat is going to be viable at the. Solar Habitat using photocells, solar plenums etc.

RELATIVE HUMIDITY

Average relative humidity = 54.75%

This means that the atmosphere holds an average of 54.75% of the water vapour it can hold, therefore it still has capacity for 45.25%. This could be used to achieve evaporative cooling at the solar Habitat using such devices as fountains, roof ponds, and water trombe walls.

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2. Kaduna Master Plan. Max Lock.

3. Passive Solar Architecture in Europe. The Results of the "First European Passive Solar competition - 1980" Edited by Ralph M. Lebens. Architectural Press Ltd, London, Halsted Press Division, John Wiley and Sons, 1981.

6.1 INTRODUCTION

6.2 THE ENERGY NEEDS AND THE WASTE PRODUCTION OF THE SOLAR HABITAT.

6.3 THE USE OF SOLAR ENERGY AT EACH INDIVIDUAL BUILDING.

6.4 SEASONAL STORAGE OF SOLAR ENERGY.

6.5 UTILIZATION OF WASTES

There should be as many types of houses as there are types of people, and as many differentiations of the types as there are different people.

Fig.

MOSHE SAFDIE

CHAPTER 6

CONCEPTUAL DEVELOPMENT OF THE SOLAR

6.1 Introduction: Solar energy, wind, sky radiation, daily temperature range, residential organic wastes and waste water may be employed to meet all the energy needs of the solar Habitat. The energy needs of the solar Habitat are estimated. No major change in propies's life-style, except for the low temperature cooking by water vapour, that is introduced. Several methods of solar energy utilization are considered:

1. Central generation of electricity, hot or chilled water and water vapour (for low temperature cooking), and distribution to each building.

2. Local generation of electricity, hot or chilled water and water vapour, and central utilization of residential wastes to produce methane gas for high temperature cooking.

3. Central utilization of city wastes and growth of a plant for its energy values.

4. Suitable design of the buildings to be heated or cooled passively through solar energy and other natural sources, local generation of hot water for washing and water vapuur for low temperature cooking, local generation of electricity and central utilization of residential wastes

FIG 24.

GENERAL REQUIREMENTS — SOLAR HABITAT.

CLEAN AIR

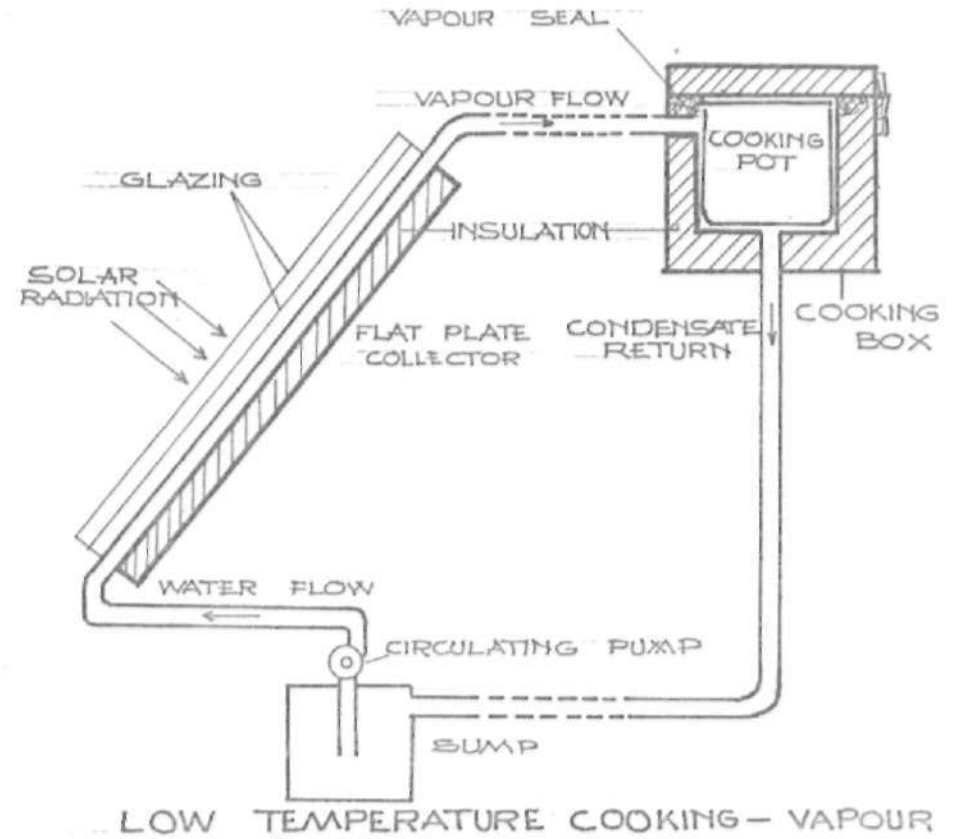
FRESH WATER

THERMAL ENERGY →	RESIDENTIAL	WASHING, HEATING, COOLING, COOKING.
	COMMERCIAL	
	AGRICULTURAL	PROCESS HEAT.

ELECTRICAL ENERGY →	RESIDENTIAL	LIGHTING, ELECTRICAL APPLICATIONS.
	COMMERCIAL	
	AGRICULTURAL	MACHINERY.
	STREET LIGHTING	

CHEMICAL ENERGY →

- THERMAL ENERGY
- ELECTRICAL ENERGY
- AGRICULTURE MACHINERY



LOW TEMPERATURE COOKING — VAPOUR

FIG 25

2. DOMESTIC HOT WATER AT AN AVERAGE TEMPERATURE OF 45°C

With an average hot water consumption of 400 liters/d, per family the energy required in harmattan is estimated at 50,230 KJ/d, in hot season at 41,860 KJ/d.

3. COOKING

The present uses of energy are estimated at 41,860 KJ/d for cooking at low temperatures ($T < 100^{\circ}C$) and at 4310 KJ/d for cooking at high temperatures ($T > 100^{\circ}C$).

The cooking practices using natural gas or kerosène are associated with great deal of losses. Using solar cooking device(show in fig.25) for low temperature cooking, it is estimated that about 60% of the value given above will be necessary. This corresponds to low temperature cooking needs of 25,115 KJ/d for each family.

4. Electrical Energy

The average electrical energy needs of a family including that for lighting, electrical appliances, etc is estimated at 18,000 KJ/d in harmattan and 15,400 KJ/d in hot season.

5. STREET LIGHTING

Assume 20% of electricity used in residences for street lighting = 6,480KJ/d.

6. COMMERCIAL NEEDS

Assume a total electrical energy need of about 25% of that of the residences and thermal energy needs of about 20% of that of the residences for stores, including restaurants, bakeries, and office buildings. The high temperature baking needs of bread is estimated at 9500 KJ/d for each family and the cooking needs of restaurants are estimated to be 15% that of the families.

Table 3. Summarizes the estimated per family energy needs in the solar town. In the above estimates, no industrial, or agricultural activities, but a normal residential town.

	Thermal Energy KJ/d		Electrical Energy KJ/d	
	Harmattan	Rainny Season	Harmattan	Rainny Season
Size of Residence, 100m^2 Heating or cooling Load	188,370	314,000		
Hot water for washing, 0.4m3/d	50,230	41,860		
Cooking at low temperature	25,115	25,115		
at high temperature	4,310	4,310		
Electrical energy			18,000	14,400
Street lighting			3,600	2,880
Commercial: Electrical Energy Heating/cooling	75,350	62,800		
Cooking at low tempe.	3,770	3,770		
Baking & cooking at high temperature	10,145	10,145		
Hot Water for washing	10,045	8,375		

Table... 4 Summary of the Total Energy requirements for the Solar Habitat of 315 families.

	THERMAL ENERGY x10 KJ/d		ELECTRICAL ENERGY $x10^6$KJ/d		LOW T Vapour $x10^6$KJ/d	Gaseous Fuel $x10^6$KJ/d
	Harmattan Season	Rainy Seas.	Harmattan Seas.	Rainy Seas.		
Hot water for washings	18.98	15.82				
House warming	71.19	-				
House cooling	-	118.69				
Cooking, at low temp.					9.09	
at high temp.						4.55
Electrical Energy			8.22	6.57		
Rejected heat which can be utilized η = 20%	32.17	61.97				
Total Thermal Energy required.	129.22	151.63				

6.2.2 WASTE PRODUCTION

The per family production of wastes are estimated as follows:

1. SEWAGE

Solid content	0.4Kg/d
Water	800 litres/d

2. SOLID WASTES

Glass, metals, dirt etc	0.40Kg/d
Water content	0.46Kg/d
burnable solids	0.40 "

6.3 THE USE OF SOLAR ENERGY AT EACH INDIVIDUAL BUILDING

There are many possible methods, the ones more feasible are:

1. For Residential cooling and Heating. flat plate collectors will be employed in an active solar heating system and the hot water will be used for summer absorption- refrigeration cooling. The collector size with an efficiency of 30% and with daily energy storage and transmission losses of 20% is estimated to be $75m^2$ for each building of $100m^2$ floor area.

2. The buildings are designed so as to employ solar energy in a passive or natural way in harmattan, and wind, the sky radiation, and daily temperature range for hot season cooling.

3. For Domestic Hot Water Needs. Flat plate collectors are used. The size of the collectors to produce $0.4m^3$ of hot water at 45^oC and with an average efficiency of 40% is estimated to be $6m^2$ for each residence.

4. For Low Temperature Cooking. Flat plate collectors are used to produce vapour at atmospheric pressure, this vapour is transported to the kitchen for cooking, similar to that shown in Fig.25.

The condensates are cumulated in the cooking chamber and later used in the collectors. For low temperature solar cooking with a 30% collector efficiency and 10% losses the estimated collector area is 4.4m^2.

5. For Electrical Energy. Solar cells along with storage batteries are used. Inverter converts the d.c. power to a.c. and conventional fixtures and appliances are used. Assuming a conversion efficiency of 10% for the solar cells and an energy loss of 20% in the inverter, batteries, etc., the area of solar cells is estimated to be 10.75m^2 for each residence.

6. For cooking at High Temperatures, biogas generated at a central plant is employed.

6.4 SEASONAL STORAGE OF SOLAR ENERGY

While the daily storage of energy is relatively simple to meet, it is the seasonal storage of energy which can result in more economical system. A look at figure 26 shows that an area of 46,500m^2 of collectors without a seasonal storage can not meet the thermal energy needs in harmattan. There is excess energy available during the hot dry season and shortage of energy during harmattan.

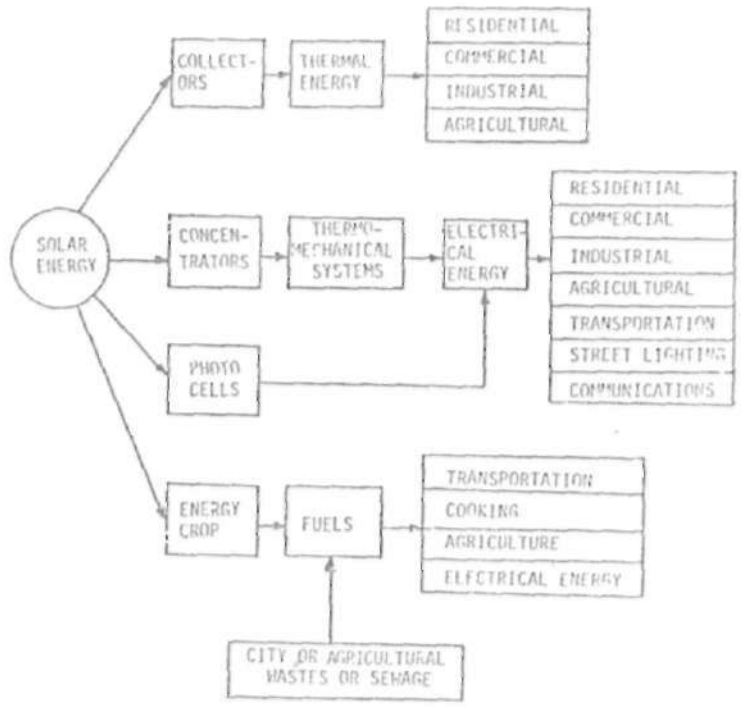


Figure26: Different Methods for Meeting the Energy Needs of a Town by Solar Energy.

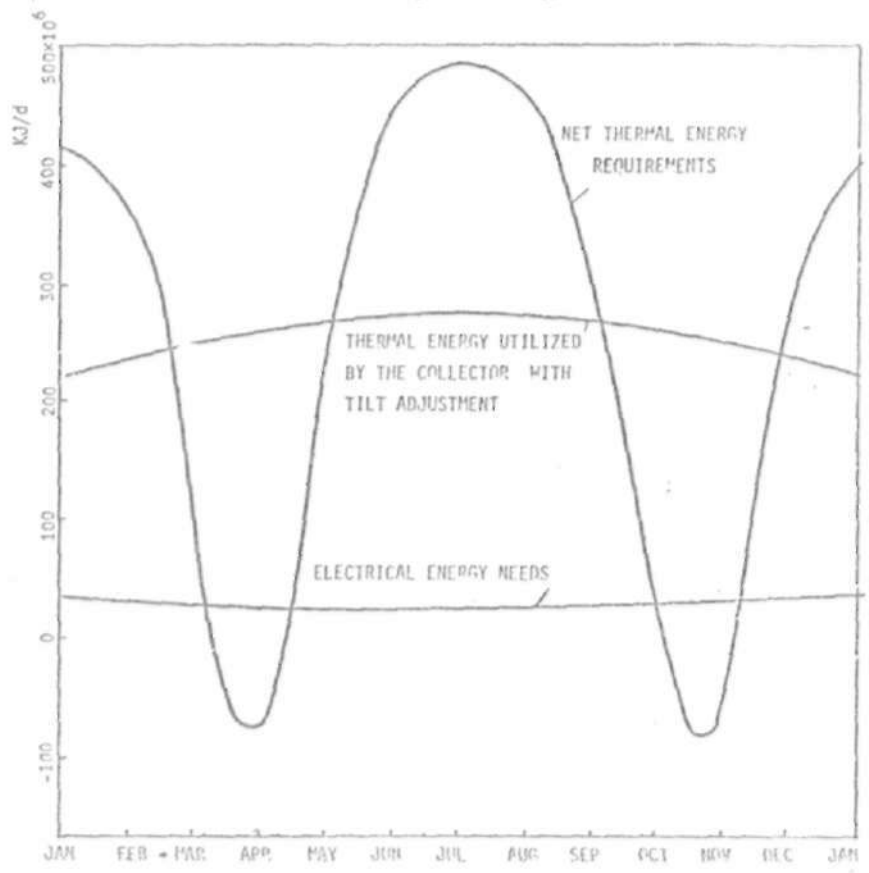


Figure27: Total Electrical and Net Thermal Energy Needs for the Solar Town of 2000 Population and the Thermal Energy which May be Utilized by a Solar Collector of 46,500 m^2 with Monthly Tilt Adjustment.

A 70,000m^2 collector, on the other hand, can meet the thermal energy needs both in hot and cold seasons but should collect no energy in other seasons.

Seasonal storages of thermal energy in the following are possible. Extensive research and development are needed in some of these areas before they can become economically feasible.

1. Produce excess electrical energy in the dry season (between February & April), electrolyse water to H_2 and O_2 and use the hydrogen during the needed seasons. Or, store the excess electrical energy in suitable lightweight batteries.

2. Store thermal energy in phase-changing materials.

3. Make use of excess heat to help grow special energy-rich plants for fuel production and use the fuel in peak seasons.

4. Produce electrical energy and displace water to a higher elevation for a later use.

5. Produce compressed air and store it in aquifers.

At the solar Habitat, Kaduna the second option will be made use of. See Appendix B.

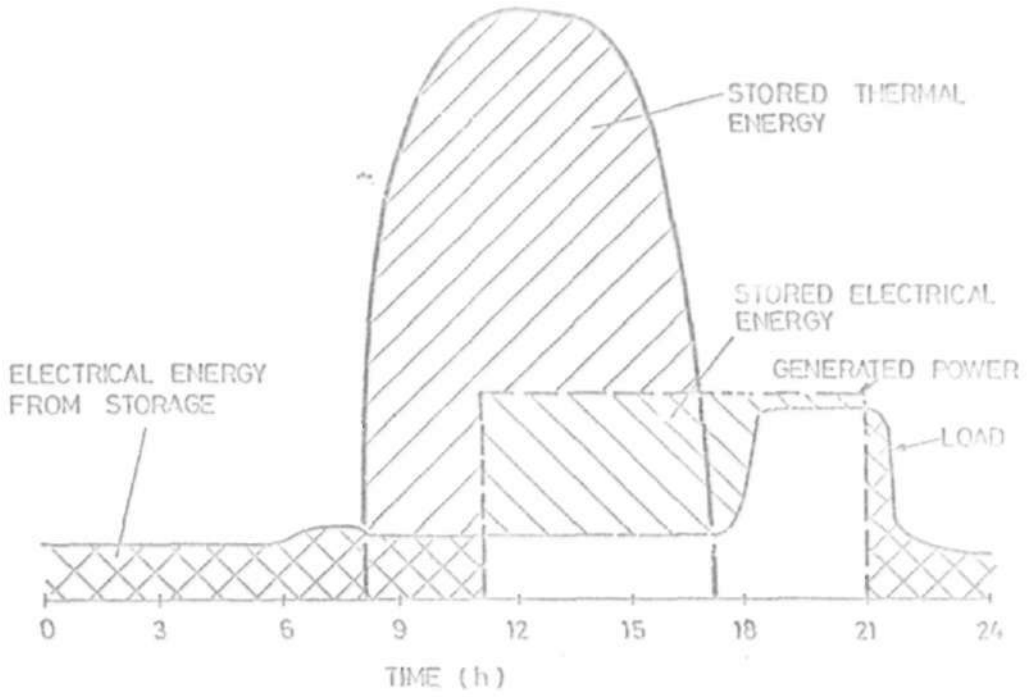


Figure 28: Electrical Energy Generation and Use Pattern Employing Thermal and Electrical Energy Storages

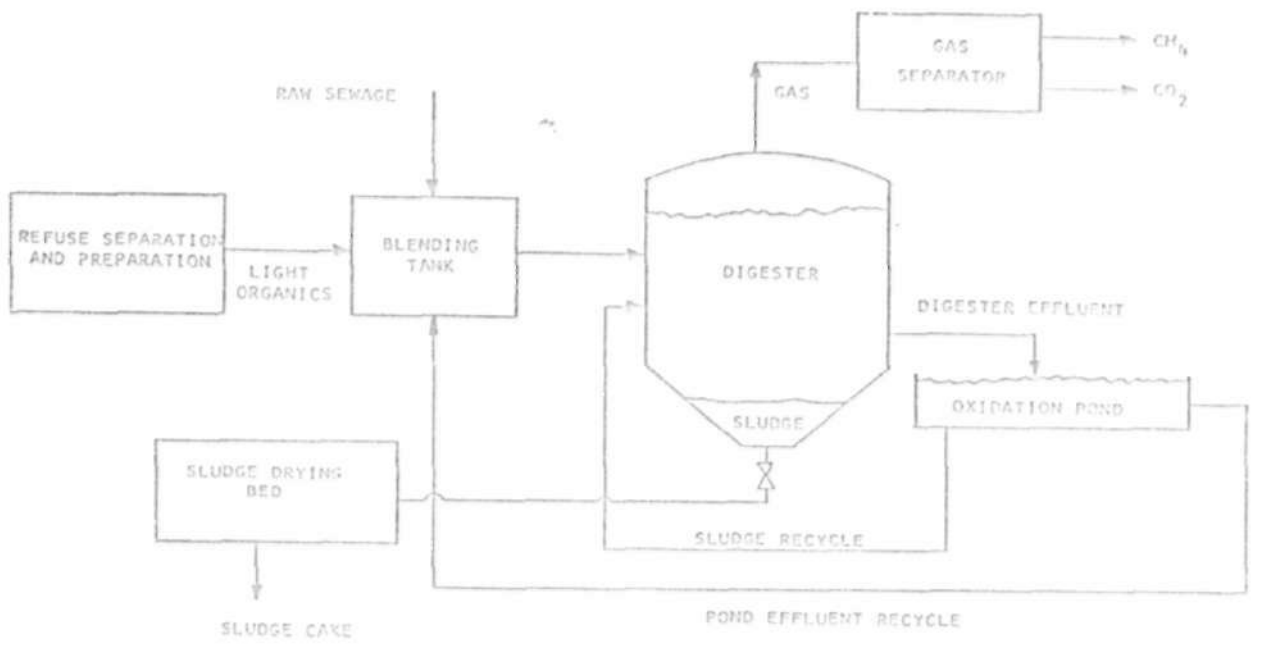


Figure 29: A Schematic Diagram of Solid Waste Anaerobic Digestion Plant.

In addition to utilizing the water contained in the city wastes for agriculture, energy may be produced and waste disposal problems may also be solved.

(a) SEWAGE The solar habitat sewage will be processed to produce methane gas by anaerobic digestion, with a sludge gas production rate of 0.36 to 0.5m^2/Kg of the solid content. The gas is about 55 to 70% methane and the rest is primarily carbon dioxide. This corresponds with an energy production of 8870 to 12,560KJ/kg of the solids (see appendix C). Figure 29 schematically shows a simplified arrangement for such an anaerobic process.

(b) GARBAGE: Solar habitat garbage will be used for their energy content by composting. In this process the nutrients in the waste are retained and the sludge can then be used as fertilizer. (fig.30)

The methane production rate depends on the digester temperature and the retention time. A methane production rate of 0.33m^3/kg of the solid with an energy values of 1260 KJ/kg, is assumed for the digester. This corresponds with a digester methane production efficiency of about 50% (Fig.30).

The total methane gas which may be produced through the sewage and garbage treatment plants amount to 0.93m^3/Kg with an energy value of 3560KJ/kg which can meet about 90.5% of the cooking needs at higher temperatures.

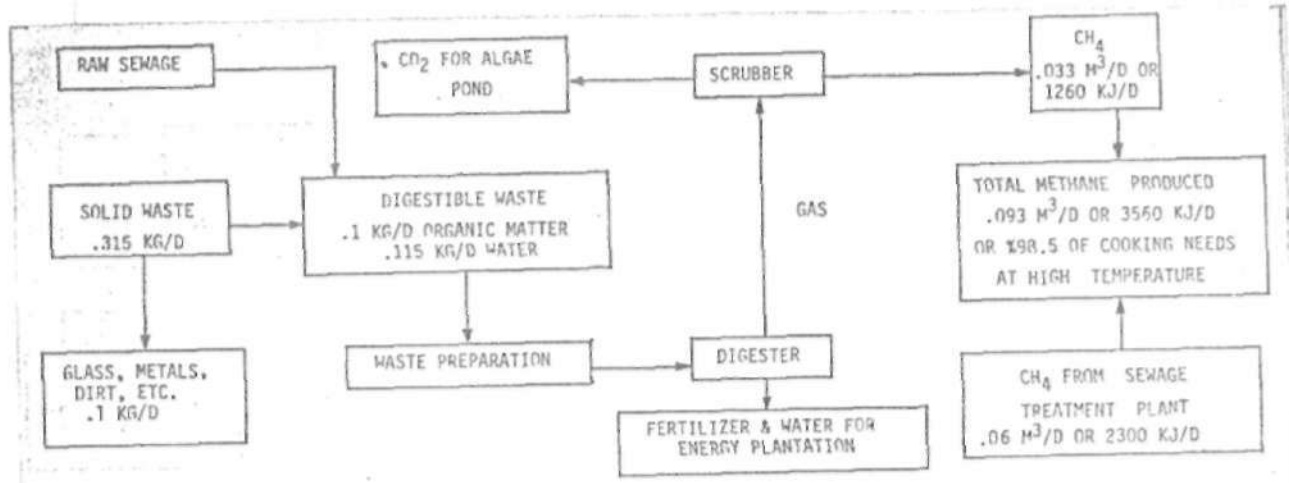


Figure 30 Mass and Energy Balance for the Urban Waste Treatment Plant Producing Methane and Fertilizer for an Energy Plantation. All values are for one person.

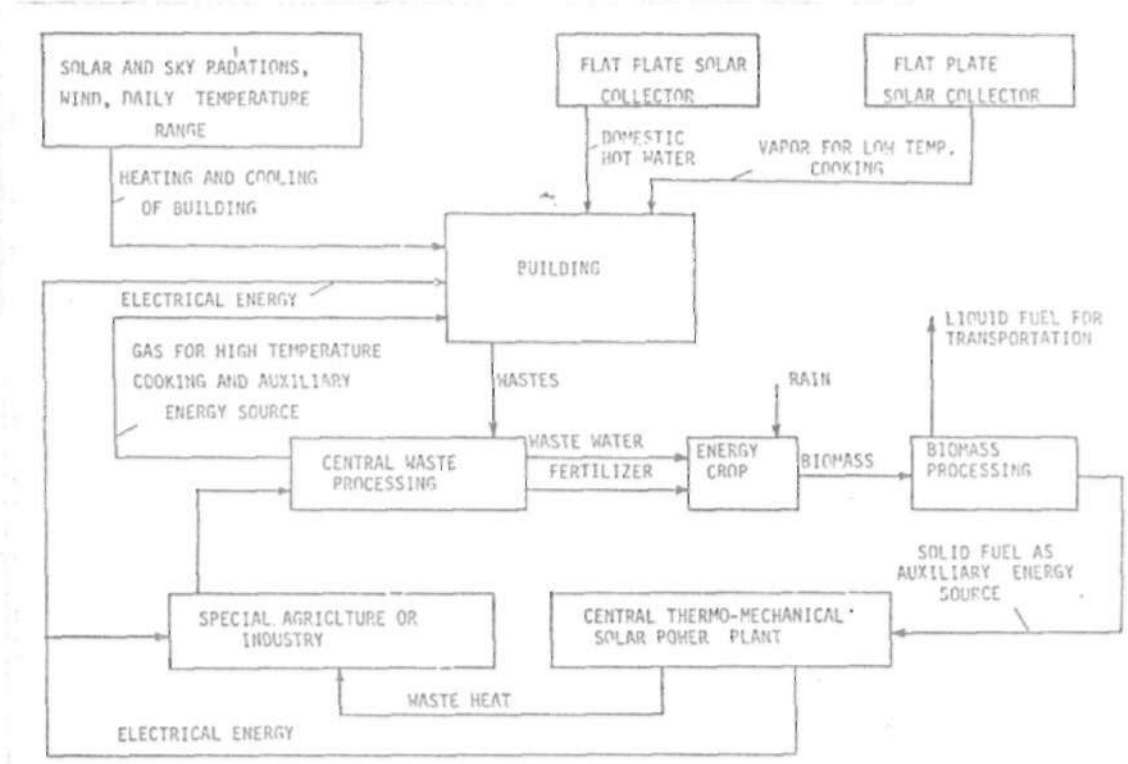


Figure 31: A More Suitable Method of Utilizing Solar and other Natural Energy Sources and the City Wastes for the Solar Town.

REFERENCE

1. Conceptual Development of a Solar Town in Iran by M.N. Bahadori. Published in "Solar Energy Conversion". Ed. A.E. Dixon and J.D. Leslie, Pergamon Press, Toronto, Canada, 1979. Pages 715-756.

2. TOPIC. Issue No. 126. pages 24-25.

The architectural trinity: First, nature of the materials; second, the characteristic architectural element, the 3rd dimension; third, the integral ornament.

FLW.

CHAPTER 7

DESIGN REPORT

1. LAYOUT

2. RESIDENTIAL UNITS
   - (a) Architectural Design Principles.
   - (b) Passive Solar Houses
   - (c) A ctive Solar Houses

3. INFRASTRUCTURE
   - (a) Water Supply
   - (b) Sewage and Storm Disposal
   - (c) Gas Supply
   - (d) Power Supply

4. RECREATIONAL AREAS.
   - (a) Sports Fields
   - (b) Parks and Gardens.

7.1 LAYOUT

The solar Habitat is designed primarily to promote energy consciousness and awareness of the resources of the climatic energy farms.

Despite the constraints of fixed orientation of the buildings, stipulated by the sun path diagram, an attempt has been made to maximise the comforts of the occupants of the solar Habitat by the following spatial allocation.

1. Spatial Allocation:

The purely residential settlement of 375 housing units has the following ratio:

60% of site - Housing = 48.6 ha

10% of site - Amenities = 8.1ha

10% of site - Recreation= 8.1ha

20% of site - Circulation = 16.2 ha.

Total Area of the site = 81ha.

This proposal, which is intended as a low-density housing development with a limit of 62.5 pers/has has the following house-type distribution:

yout

NEIGHBOURHOOD GARDEN

SHOPPING CENTRE

PASSIVE RECREATION

ARTIFICIAL BEACH

LEARNERS POOL

LEISURE POOL

ARTIFICIAL WATERFALL

ACTIVE RECREATION

CUL-DE-SAC WITH P. AWNG

RETAINING WALL

KAIDUNA RIVER

SERVICE UNIT.

VIEW OF WATERFALL AND POOL

10% of housing site - 1-bedroom = 31 units
24% of housing site - 2-bedroom = 78 units
40% of housing site - 3-bedroom = 125 units
20% of housing site - 4-bedroom = 62 units
60% of housing site - 5-bedroom = 19 units
Total = 315 units.

Proposed Net density = $\frac{315}{48.6}$ = 6.42 units/ha

Gross density = 3.86 units/ha.

Population density = 49 pers/ha.

ii. Orientation

Although true south is the most frequent choice for the collector orientation, slightly west of south may be a better choice. Because of early morning haze which reduces the insolation and because of higher outdoor air temperatures in the afternoon, such an orientation can give slightly higher collector efficiencies. Optimum orientation = 10^{o}-15^{o} West of South.

iii. Clusters

The first principle of architecture is for architecture to recognize its own nature, to realize the fact that it is out of life itself; a humane and therefore an intensely human expressions the most human of all the expressions of human nature.

The sun is not static, neither does it run along a major or a minor axis. In like manner, solarchitecture seeks dynamism, and rejects the major axis and minor axis of 'rationalist' architects.

Solarchitecture favours the reflex, the natural, easy attitude, the symmetry of grace and rythm by involving the sun, affirming the ease, grace, and naturalness of natural life.

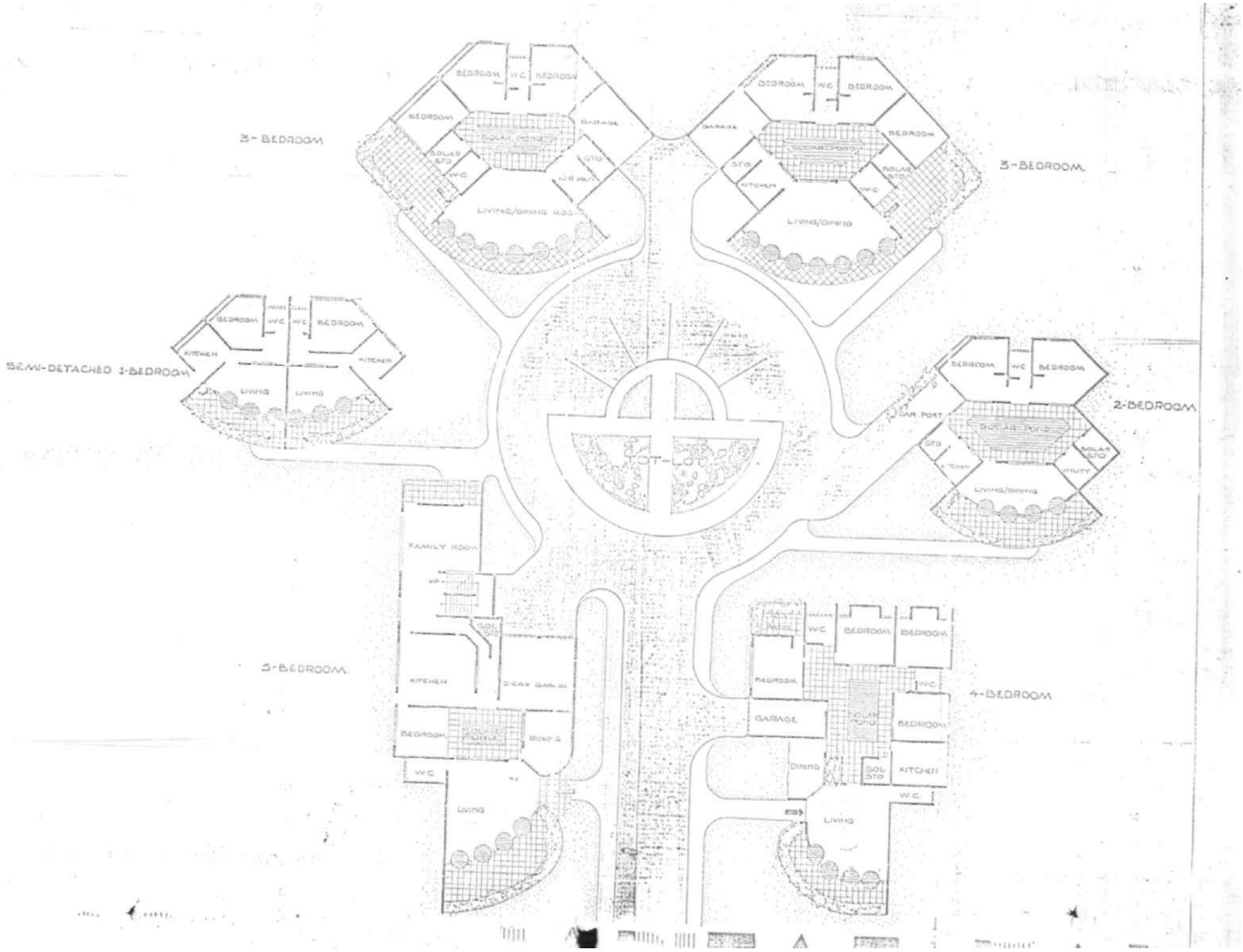
This is architecture of nature, for nature.

To achieve energy efficiency and a required density of houses and at the same time maintaining a humane design, it was decided to create a clustered pattern of streets. By having six dwelling units, it was possible to have tot-lots which broke the patern into a natural and definable system of spaces that are consistent with the objective of creating an acceptable residential community.

All the dwellings face 15^{0} west of south with porches to the south.

Vehicular access to the houses are from the cluster driveway.

Pedestrian spines link dwellings and clusters interlinking the development with the neighbourhood gardens and other facilities.


3-BEDROOM
BEDROOM
W.C
BEDROOM
GARAGE
SOLAR STO
LIVING/DINING ROOM
3-BEDROOM
CARPORT
KITCHEN
LIVING/DINING
SEMI-DETACHED 1-BEDROOM
KITCHEN
LIVING
2-BEDROOM
CAR PORT
SOLAR STO
TOT-LOT
FAMILY ROOM
KITCHEN
BEDROOM
LIVING
5-BEDROOM
PATIO
4-BEDROOM
GARAGE
DINING
SOL STO

7.2 RESIDENTIAL UNITS

There is a clearly defined style growing out of conditions. One may not like it, but, if one has studied architecture as a technology, not as an art, and not merely accepted it as a recipe for cooking then, the solar nature of the whole will thrill and please and edify.

Generally, the users of the habitat require a self-testing habitat where their efforts and their comforts will be complimented by an environment which is the lesson itself. The solar Habitat design is a design for better living, a better design for a richer , fairer way of life instead of being a shallow hang-over from political times to please the masses.

Generally, the requirements of the solar habitat can be sub-divided into two: i. the passive solar houses:- comprising the one-, two-, and three-bedroom houses, and ii. the active solar houses, comprising the four-and five-bedroom houses.

7.2.b. PASSIVE SOLAR HOUSES

A passive solar approach to building design involves more than maximising solar gains. It is a total design approach and thus demands the interaction of many factors including best use of the physical site conditions, control of the complete thermal envelope of the building, cost considerations, thermal and visual comfort, and the life-style of the occupants.

The passive solar home makes use of the materials from which the dwelling is constructed to capture, store and distribute the solar heat to its occupants or store and re-radiate the heat outwards.

Passive designs require consideration of solar and heat flow in every detail and component. Floor plan layout, circulation patterns, window location and the selection of wall and floor materials, all affect how well a passive design will work.

The solar habitat is a solar energy system with many of the components how having dual functions: both the traditional function of providing an enclosure, and the solar function of collecting, storing and distributing heat. Walls which subdivide and enclose space can also store and radiate heat.

Components whose functions were primarily structural, special or aesthetic may double as solar heating and cooking mechanisms.

The plan form was used in order to balance the requirements of maximum heat loss through the external wall and minimum heat gain through the glazed area which has been kept to a minimum.

BRIEF.

A. 31 SINGLE BEDROOM UNITS

USER REQUIREMENT		SPACE REQUIREMENT
A	Living Room	$20m^2$
A	Kitchenette	$12m^2$
A	Bedroom	$14m^2$
A	Bathroom	$4m^2$
	Total Area =	$50m^2$
	Gross Area =	$1550m^2$

B. 78 TWO-BEDROOM HOUSES (2-4 PERSONS/FAMILY)

A	Living/Dining Room	$20m^2$
A	Kitchen/Store	$12m^2$
A	Bathroom	$4m^2$
2	Bedrooms	$15m^2$ each
A	car port	
		$72m^2$
	Gross Area =	$5616m^2$

C. 125 3-BEDROOM HOUSES (4-6 PERSONS/FAMILY)

A	Living/Dining Room	$27m^2$
A	Kitchen/Store	$15m^2$
3	Bedrooms	$15m^2$ each
2	Bathrooms	$4m^2$ each
	Equipment Store	$6m^2$
	Garage	$18m^2$
	Total Area =	$119m^2$
	Gross Area =	$148.75m^2$

The Southern facade is made of water troube wall which is shaped so as to provide maximum heat gain in harmattan and to be shaded in the hot season.

External walls are used to control the temperature within the house by allowing the warm air to, flow through the wall in harmattan and assisting in cross-ventilation in the hot season.

The passive solar residential units vary in sizes from a one-bedroom unit to five bedroom houses

ACTIVE SOLAR SYSTEM

There are two active solar house designs at the solar habitat: the four- and five-bedroom houses, these are based on the water-type collection system.

Water heating is based on the thermosiphon principle of solar water heating. The glazed areas have been organised in order that the insulation will be of manageable proportions and that all elements would be within the normal domestic scale.

Home cooling and heating is based on an integrated system with an external and internal waterwall to transmit and cool the rooms.

BRIEF.

A. 62 FOUR-BEDROOM HOUSES (6-8 PERSONS PER FAMILY)

USER REQUIREMENT	SPACE REQUIREMENT
A Living Room	$24m^2$
A Dining Room	$10m^2$
A Kitchen and Store	$20m^2$
4 Bedrooms	$20m^2$ each
2½ Bathroom	$8m^2 \times 1.0m^2$
Equipment Store	$6m^2$
Garage	$18m^2$
Total Area =	$167m^2$
Gross Area =	$10354m^2$

B. 19 FIVE-BEDROOM HOUSES (8-10 PERSONS/FAMILY)

A Living Room	$30m^2$
A Dining Room	$16m^2$
A Family Room	$20m^2$
A Kitchen and Store	$20m^2$
2½ Bathrooms	$8m^2 * 10m^2$
MASTER BEDROOM	$35m^2$
4 BEDROOMS	$20m^2$ each
A 2-Car Garage	$36m^2$
Equipment Store	$6m^2$
Total Area	$247m^2$
Gross Area =	$4693m^2$

7.3 INFRASTRUCTURE

(a) WATER SUPPLY

The sources of water supply at the solar habitat will be rain water and by underground water by the use of a bore-hole.

The water supply system will consist of two principal levels of distribution scheme. First is the main pipe line loop, and second is the internal distribution network. The internal distribution network is further divided into primary and secondary network. The primary internal distribution network is designed and incorporated in the tot-lot for ease of maintenance and should serve a cluster, it is tapped to the secondary distribution network to supply water to the residential houses and other facilities.

(b) SEWAGE DISPOSAL:-

Average domestic water consumption assumed to be 250l/day. Average sewage production = 0.90 x 250 = 230l/day. .: a maximum of 230l/day of sewage production is adopted.

The design of sewers, including the determination of the required sewer diameter and slope is based on an anticipated maximum and minimum flows.

The magnitude of these extremes is a function of many factors, significant among which is the size of the population contributing to a given sewage flow and the corresponding ratio of the maximum and minimum discharges to the treatment plant.

The sewage scheme for the Solar Habitat is mainly based on gravity. The sewage is taken to the Bioconverter where it is separated and decomposed to methane gas, carbon dioxide and water.

(c) GAS SUPPLY.

Methane gas will be produced at a central bio-converter and distributed to the various clusters and thence to the residential units. The gas distribution is by high pressure network system to all clusters of the habitat.

Gas pipes must be protected against condensation, damp, and corrosion.

(d) POWER SUPPLY.

The design of the electrical distribution system will be based on the capacity of collectors and solar intensity at the solar habitat. Electricity supply will be provided by photo-voltaic solar collectors placed on the roofs of the houses at a slope of 15° to the horizontal and oriented 15° due west of south.

Each house has a room reserved for storage of batteries which store electrical energy in chemical form until required. For seasonal storage, mass of water to act as collector will be used, each house having its own storage system, from which heat will be tapped and converted during periods of extensive cloudiness.

Power supply for street lighting will be collected by photocells at a central point and distributed via underground cables to the lighting points.

The lighting of the roads(access, distributor and artenial) will include high pressure sodium lamps which provide optimal relation of lighting and colour quality versus efficiency. The lightin of gardens and pedestrian paths in the open park will be made by high pressure mercury vapour lamps.

The automatic "on-off" activation will be executed by photo electric relay systems.

7.3 RECREATIONAL AREAS.

(a) SPORTS FIELDS:- Two national priorities are football and basketball. Other games of interest are: badminton, lawn tennis, and volleyball.

To serve the population of about 2,000, a football field, a basket ball court, volley-ball, badminton, lawntennis courts and open spaces are provided and could be used for social gathering such as festivals.

(b) PARKS AND GARPENS.

The solar Habitat proposal has for every household an inner courtyard independent of the porch.

From the courtyard the next open space is the tot-lot and then the neighbourhood park. The solar habitat garden, which is the largest of them all is situated by the Kaduna River and comprises both active and passive recreational facilities, such as foot paths, lawns, park benches, a leisure pool, artificial beach and an artificial waterfall. All these are meant to improve the awareness of the natural feelings of solarchitecture and thus bringing man closer to nature.

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   by S.C. Baipai. Building Research Institute, Kingston, Jamaica. March 1986.

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When we endeavour to make for ourselves an atmosphere in which to live and work according to our own faith and feeling for nature, we are performing a genuine service not only to our time, but especially to the future....

FLW.

Solar Architecture is the scientific art of making the sun express ideas.

KKO.

CHAPTER 8

CONCLUSION

It's the plans we draw,
The schemes we dare,
Our contributions along the way,
that bring into life
Architecture that is bright and fair.

Though the solar habitat design proposal is sited in an urban area - Kaduna - it is not intended as an end in itself. It is intended as a means to an end. As a pilot scheme, situated in a town, it will afford decision makers the opportunity to experience solar housing. See its advantages and disadvantages - and explore ways through which it can be used in our rural areas for the vast majority of our population.

Little is known of what procedure is going to evolve out of this convolute progress to enable the men of ideas, technique, trained and adequate, to get these solar ideas into the form of practical, beautiful buildings for the human joy and use of tomorrow, what is known is that there is a future for our rural areas in the solar system.

APPENDIX A

To comput the cost per Kwh of electricity generated by photovoltaic plants, the most basic procedure would be followed(5). Assuming the full annual electrical output of the system is used, the unit energy cost is given by:

$$\frac{\text{Annual Capital Charges + Annual Operating Costs}}{\text{Total energy output.}}$$

Neglecting inflations, tax credits, etc. a simplified approach gives the relationship:

$$= p = \frac{r.c. + m.W_p}{\eta ave \; Pi}$$

Where p = cost per Kwh; r = interest plus amortization factor; c = total capital cost of system; m = specific operating cost, expressed as cost per peak watt installed; Wp = peak power of photovoltaic array; ave = average coversion of system and p = total annual solar energy incident on the array.

As an example, let us consider a 10Kwp photovoltaic plant for Kaduna town. The present cost of photovoltaic modules per peak watt is ₦11.70. Taking the installed cost as 2.5 times of the modules cost including battery storage, ₦292,500.00 would be the capital cost to install a 10Kwp photovoltaic plant.

Assuming a 20 years amortization period and 5% rate of return, the factor would be 0.0802,(5) and thus the annual capital cost would be ₦23,458.50. The annual operating cost including maintenance has been estimated to be of the order of ₦0.12/^{W}p, and so the total annual operating cost would be ₦1,200.00. Area required for 10 Kwp array would be 106.6m^2, so pi would be 193,815Kwh. Some efficiencies like 4-7% for harmattan cloud cover period, and 10-11% for average clear sky conditions have been found. These figures give an annual average efficiency of 8.8% so, the total annual energy output would be 17,065.72 Kwh.

The unit energy cost would thus be, p = ₦1.45/Kwh.

This unit electricity cost presently has no match whatsoever to other available alternatives.

BIBLIOGRAPHY

The annotated bibliography which follows contains some of the references used in the preparation of this thesis, plus other publications which can be of value for furtherance of research in this field.

The bibliography is divided into major categories to facilitate access to publications presenting specific topics, with comments on some of the entries provided to expedite the selection process.

ENERGY- GENERAL

alternative energy sources.

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2. ENERGY PRIMER. Solar, Water, wind and Biofuels. Portola Institute. Fricke-Parks Press, 1974. 200 pages.

(A collection of articles on solar, wind, water, architecture, and integrated energy systems with a "Whole Earth" style of catalog for energy related hardware and informa-

3. ENERGY BOOK No.1 Natural sources and backyard Applications. Edited by John Previs. 112 pages.

(Collection of articles and information on wind, solar, and biosystems energy generation).

4. NATURAL ENERGY WORK BOOK. Peter Clerk. Visual purple, 1974. 98 pages.

(presents basic concepts related to solar, wind, and other alternative energy source systems.

5. SURVIVAL 2001, scenerid from the future. Henry Voegeli and John J. Tarrant . Van Nostrand Reinhold Company, 1975. 115 pages.

(A book which presents the alternative energy sources; wind, solar, water, wave, and ocean power, using a futuristic standpoint.

ENERGY CONSERVATION.

1. ENERGY CONSERVATION IN ARCHITECTURE.

Part 1: ADAPTING DESIGN TO CLIMATE.

Donald watson in Connecticut Architect, March/April 1974.

2. ENERGY CONSERVATION IN ARCHITECTURE.
Part 2: ALTERNATIVE ENERGY SOURCES.
Donald Watson and Everett Barber, Jr. in
Connecticut Architect, May/June 1974. 13 pages.

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American Institute of Architects, AIA Research Corporation, 1974. 156 pages.

(included in this book are design methods for maximising energy efficiency in building design. Also included are analyses of energy uses in existing buildings.

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(A worthwhile book on the historical analysis of primitive architecture and design concepts. The study includes the development of forms which respond to natural and climatic stimuli.)

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6. THE AUTONOMOUS HOUSE. Design and Planning for self-sufficiency. Brenda and Robert Vale. Thames and Hudson, London, 1975.

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(The design of buildings to respond to the natural forces of the climate and the sun. Examples of many different project sizes and applications).

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(A survey of solar Heated/Cooled buildings in the United States. Included are basic principles of Solar energy.)

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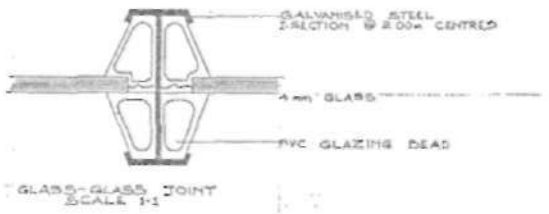
Plate 5



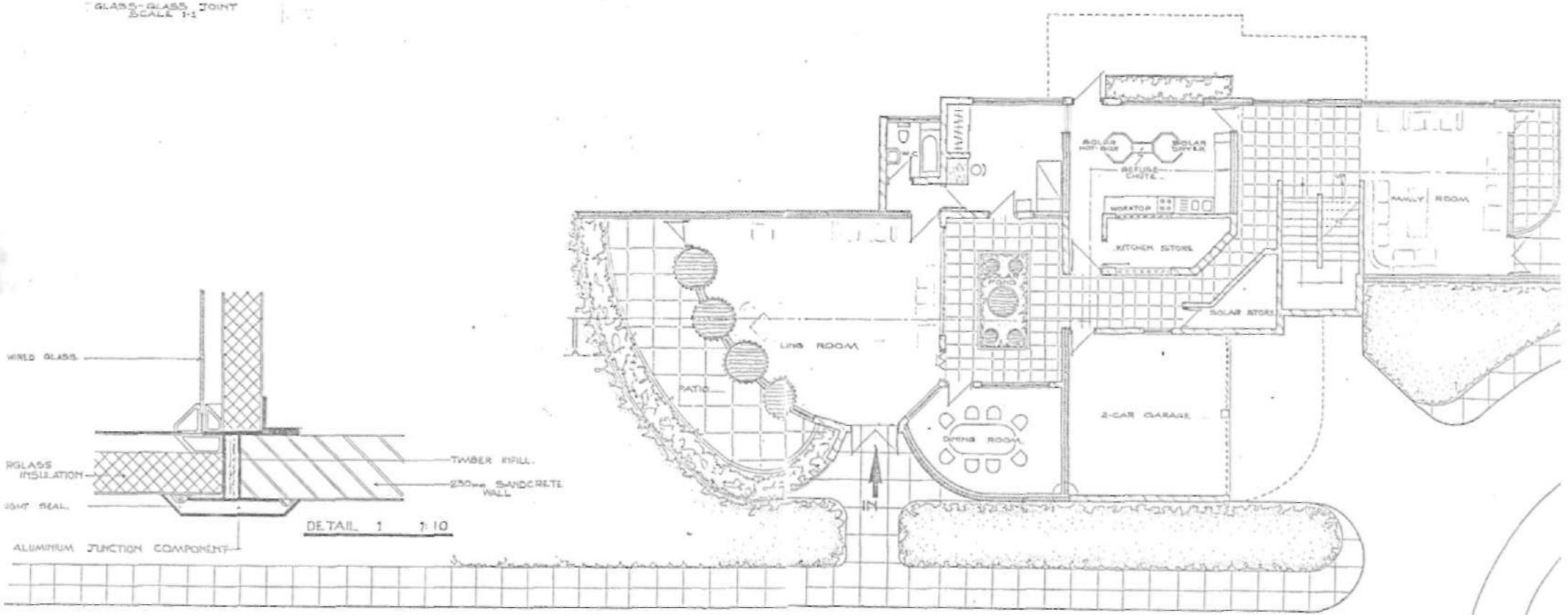
Plate 5

South-Eastern view of the site. Note the vegetation of the site.

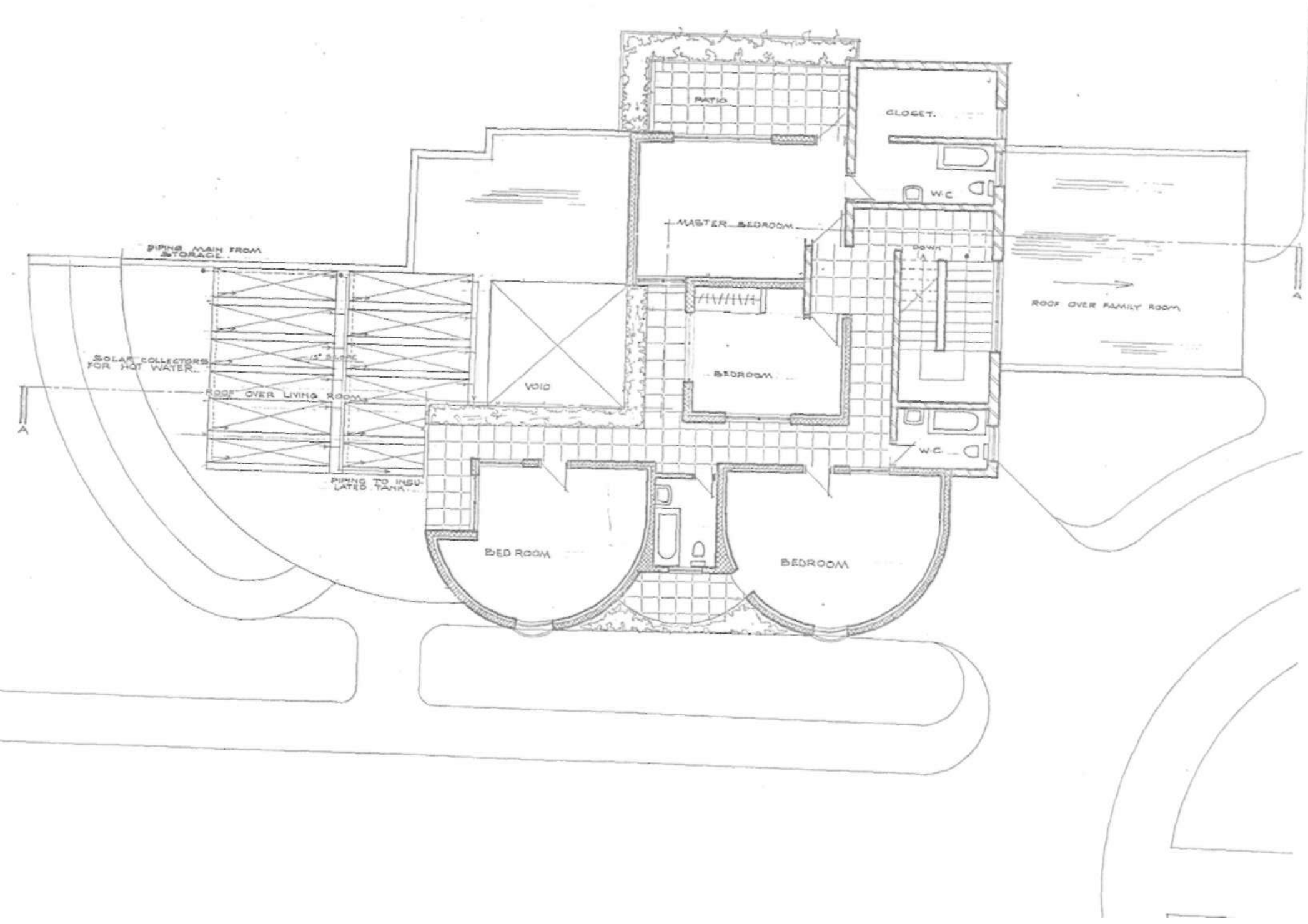
5-bedroom plan

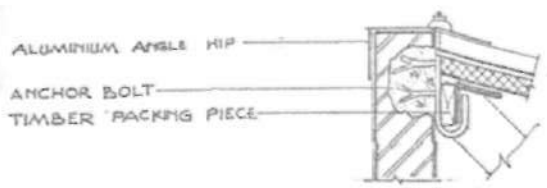


GLASS-GLASS JOINT
SCALE 1:1

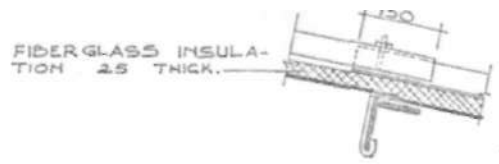


DETAIL 1 1:10

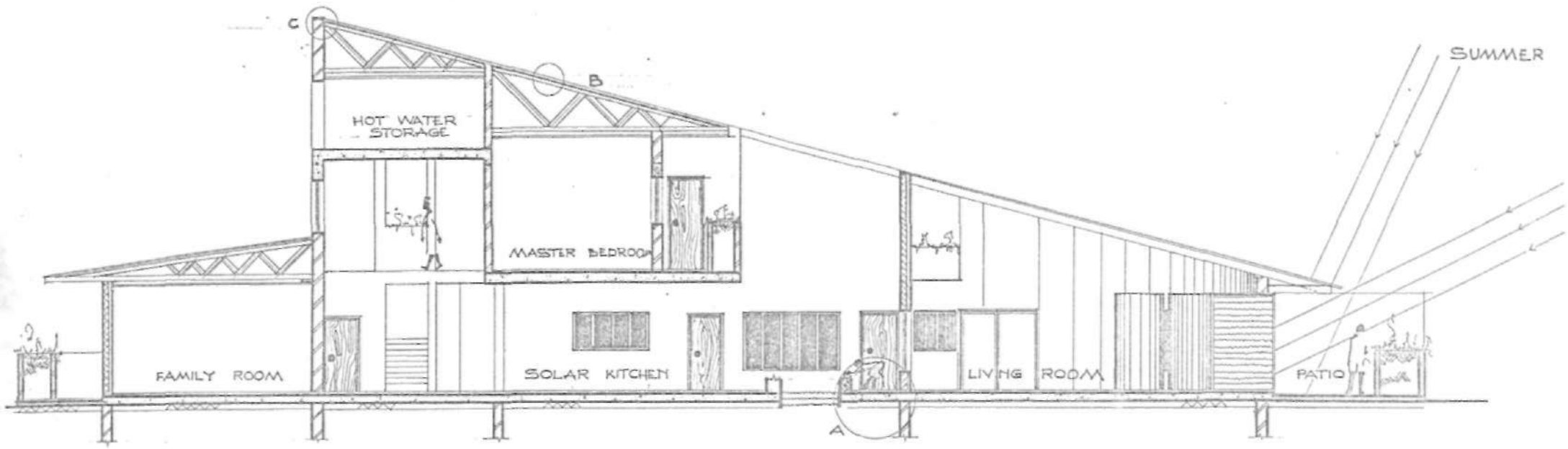

PATIO
CLOSET.
W.C
MASTER BEDROOM
DOWN
ROOF OVER FAMILY ROOM
PIPING MAIN FROM STORAGE
SOLAR COLLECTORS FOR HOT WATER.
ROOF OVER LIVING ROOM
VOID
BEDROOM
W.C.
PIPING TO INSULATED TANK
BED ROOM
BEDROOM
A
A

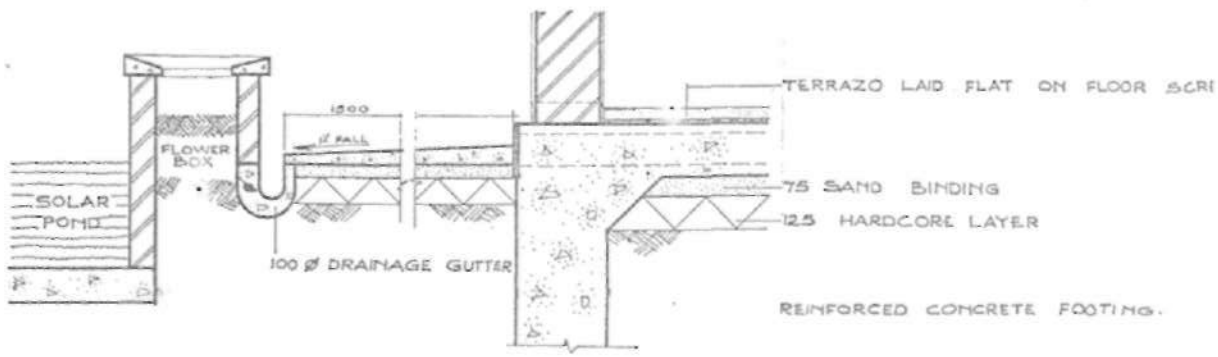


DETAIL C 1:20

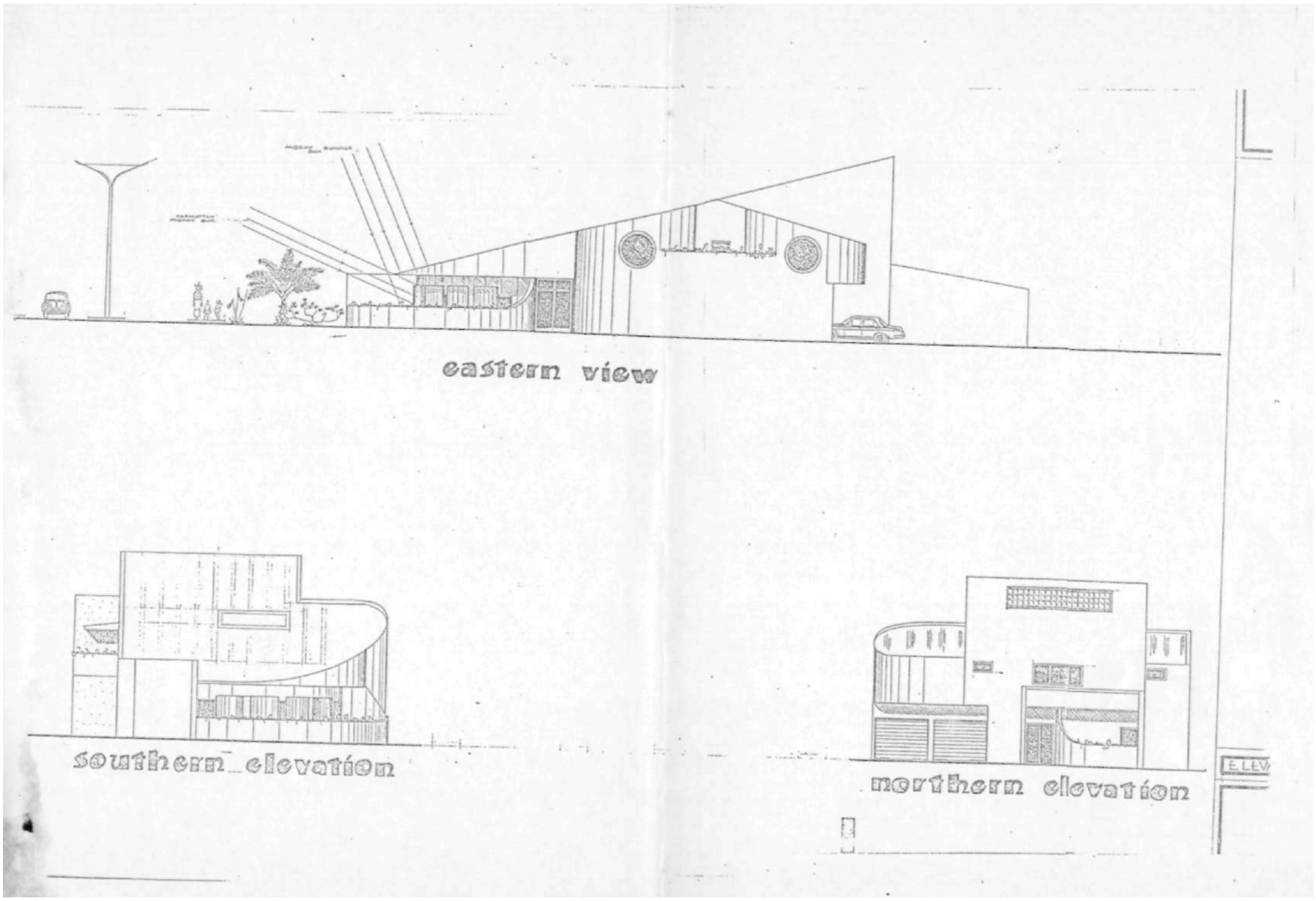


DETAIL B 1:20





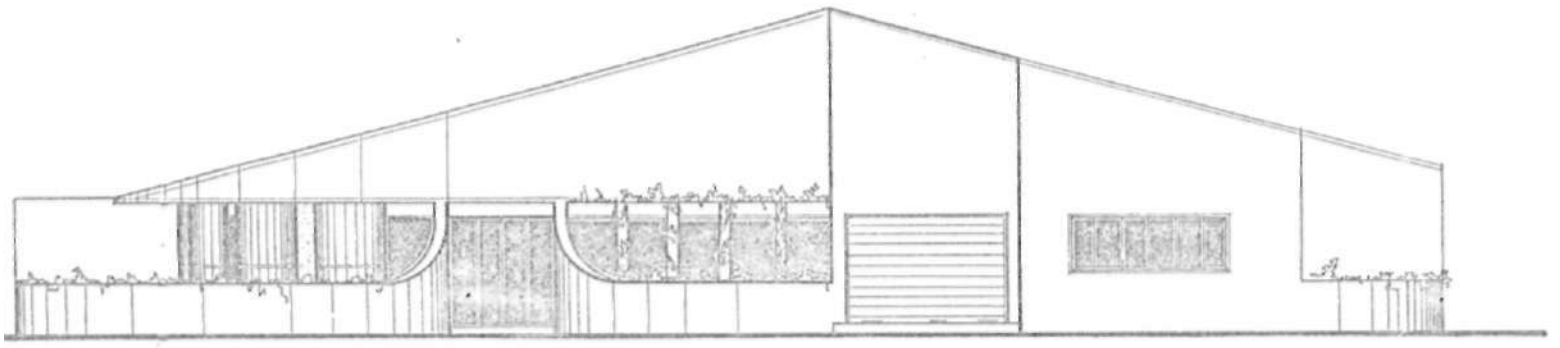
DETAIL A 1:20

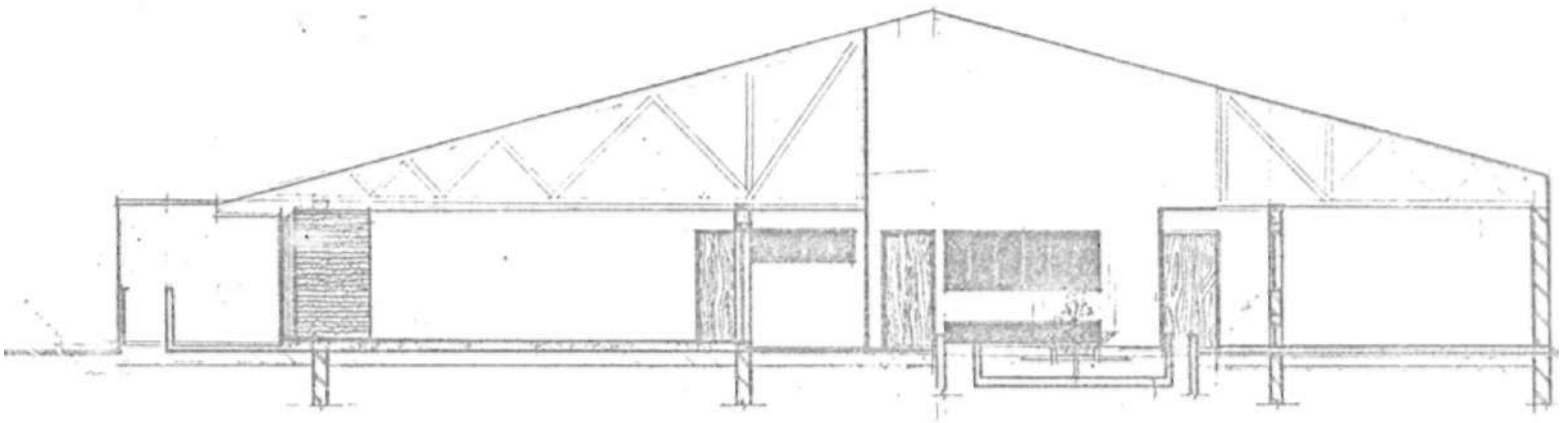


eastern view

southern elevation

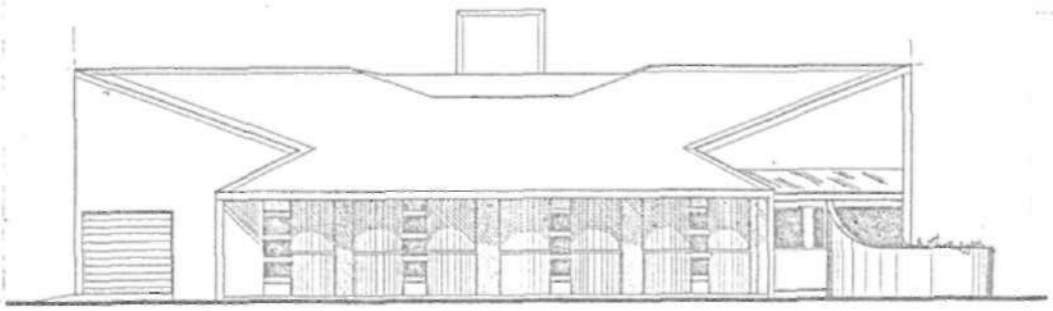
northern elevation



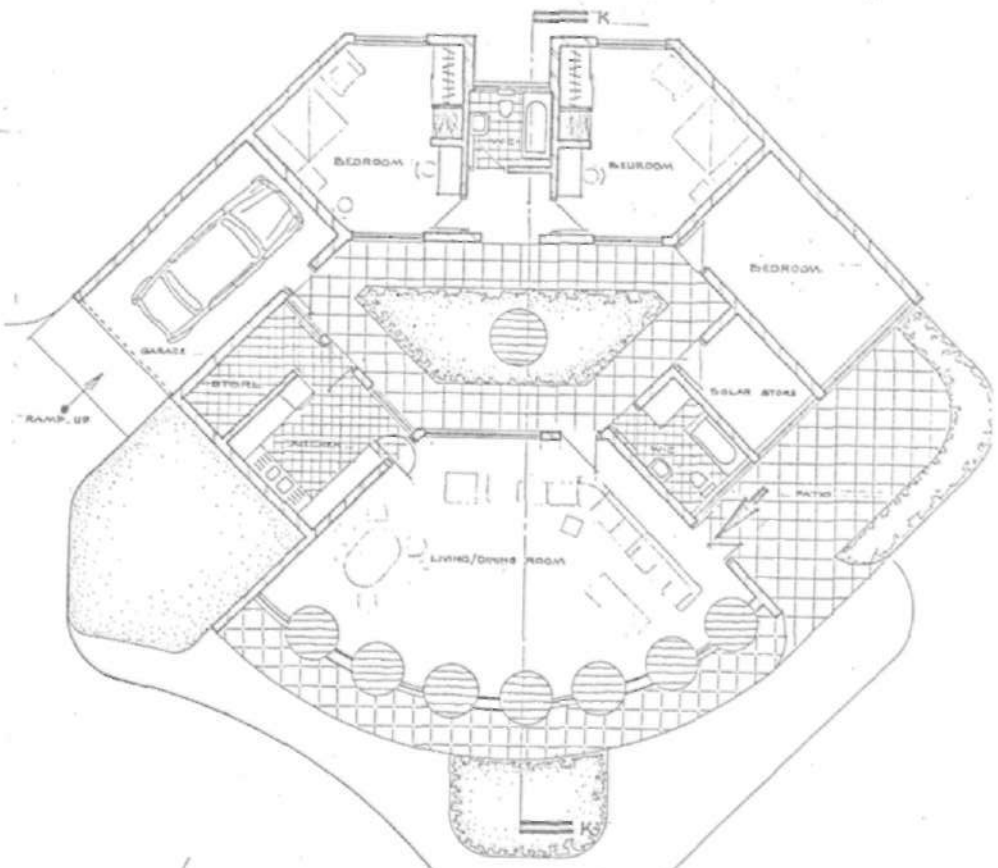


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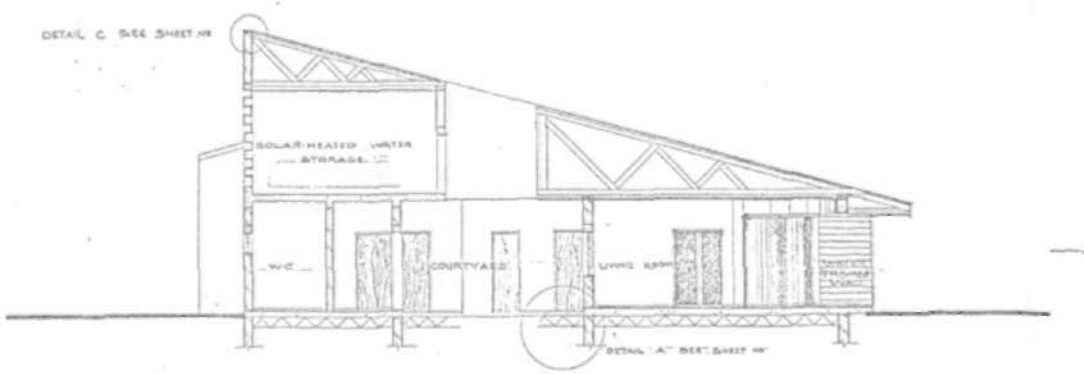
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southern elevation



plan



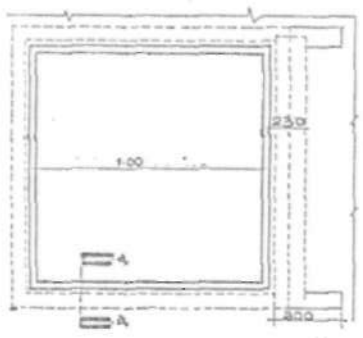
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Plate 5



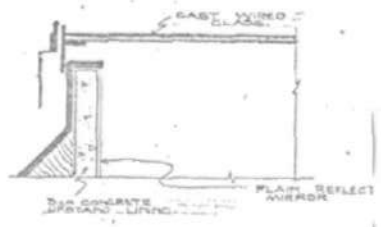
Plate 5

South-Eastern view of the site. Note the vegetation of the site.

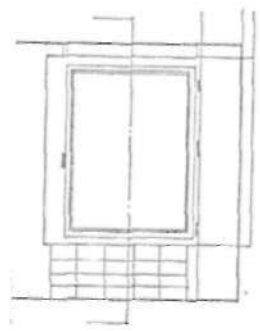


AT ROOF LEVEL SHOWING OPENING 1:8

plan

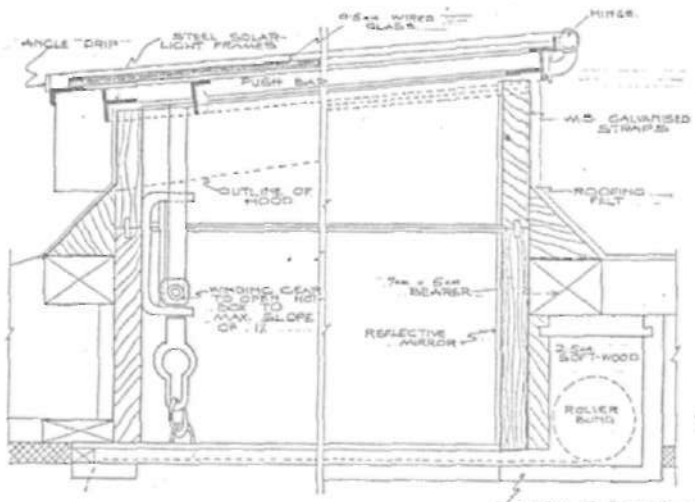


CONCEPTUAL VERTICAL SECTION AT 2



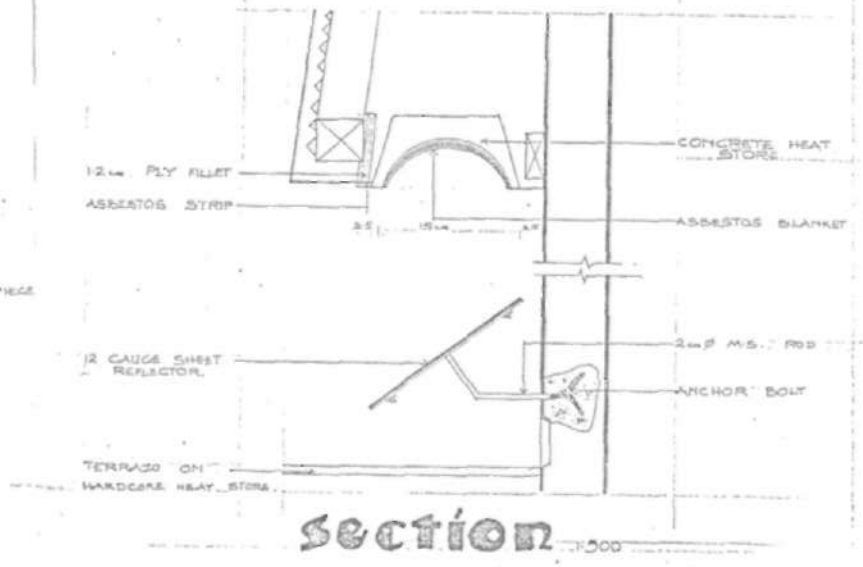
FRONT ELEVATION OF THE SOLAR HOT BOX.

elevation



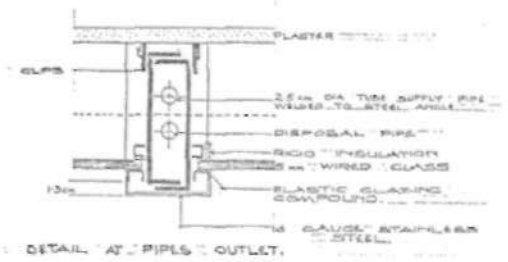
VERTICAL SECTION THROUGH SOLAR LIGHT.

section

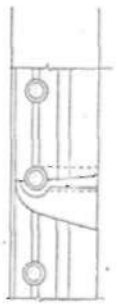


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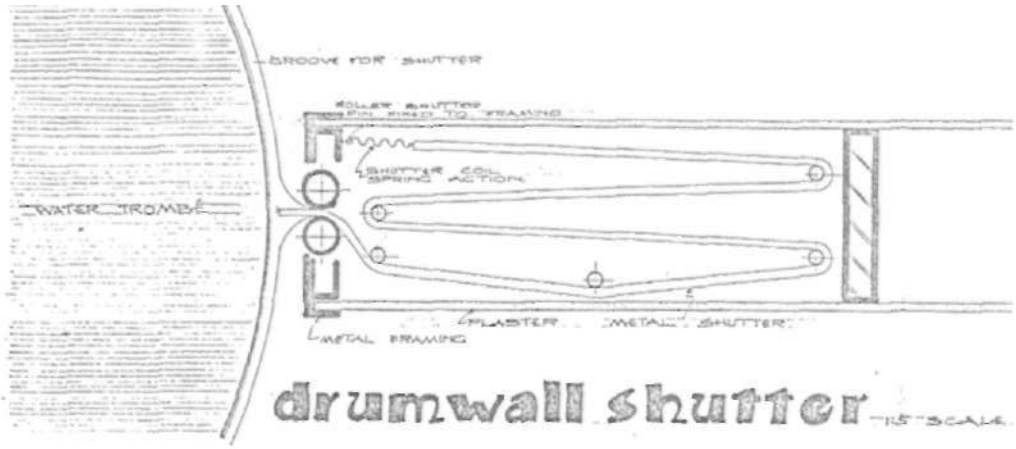
SOLAR HA



DETAIL AT PIPES OUTLET.



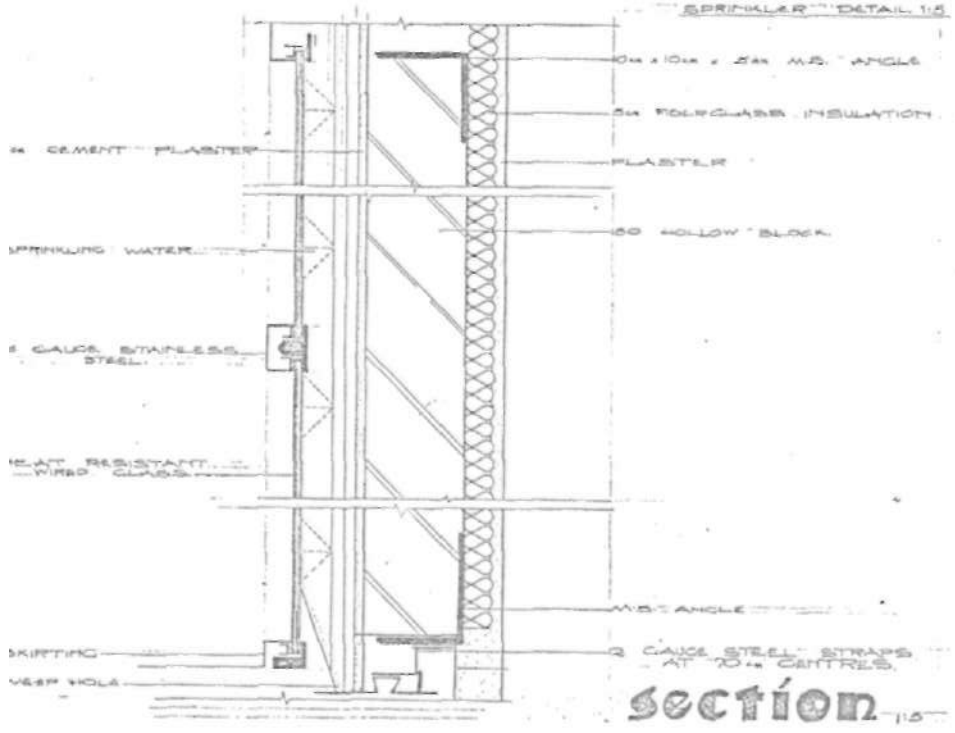
SPRINKLER DETAIL 1:5



drumwall shutter 1:5 SCALE



METAL SHUTTER DETAIL



section 1:5

