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The Sun Garden, A Solar Greenhouse Residential Development

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THE SUN GARDEN

A SOLAR GREENHOUSE RESIDENTIAL DEVELOPMENT

PETER C. SUTTON SPRING 1979

A Terminal Project submitted to the faculty of the College of Architecture, Clemson University, in partial fulfillment of the requirements for the degree of

MASTER OF ARCHITECTURE

APPROVED:

[redacted]

Committee Chairman

[redacted]

Head, Department of Architectural Studies

[redacted]

Dean, College of Architecture

DEDICATION

This Terminal Project, for the Degree of Master of Architecture, is dedicated to my parents whose support and encouragement made this possible.

ACKNOWLEDGMENTS

My sincere appreciation goes to the following professors in the College of Architecture for their assistance in making this terminal project a reality: Martin Davis, Robert D. Eflin, Fritz Roth, and Johannes Holschneider.

I would also like to express my appreciation towards Professor John Jacques for his general enthusiasm and inspiration during the formative period of this project; and appreciation is expressed towards Mrs. Carol Hood for typing this manuscript and to Joseph Nuzzacco for his time and effort during the final days before presentation.

My greatest appreciation goes to my loving wife for her support and patience and the many hours sacrificed for the completion of this Terminal Project.

FOREWARD

The following study is motivated by the desire to bring together the basic human needs of shelter, life support (food), and energy production into a living environment conducive to individual, family and community needs. This study shall attempt to apply given data in a fresh and creative manner. No attempt will be made to rewrite or reproduce any data, technical or otherwise, not directly related to the project. Although some data will be needed for basic understandings.

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INTRODUCTION

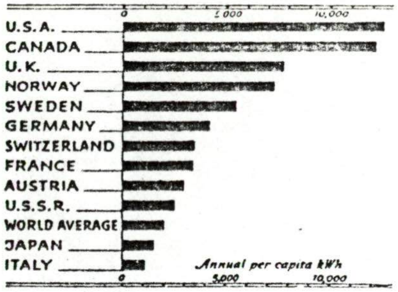


FIG. 7. ORDER OF RANK OF TWELVE COUNTRIES ACCORDING TO THEIR PER CAPITA CONSUMPTION OF ENERGY

SOURCE: ENERY FOR MAN, THIRRING-HANS, HARPER & ROW-1976-NY.

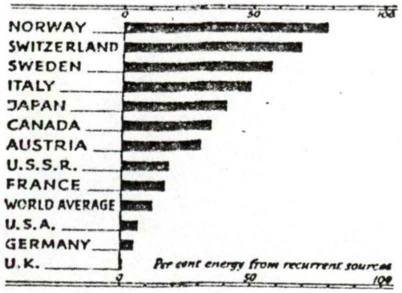
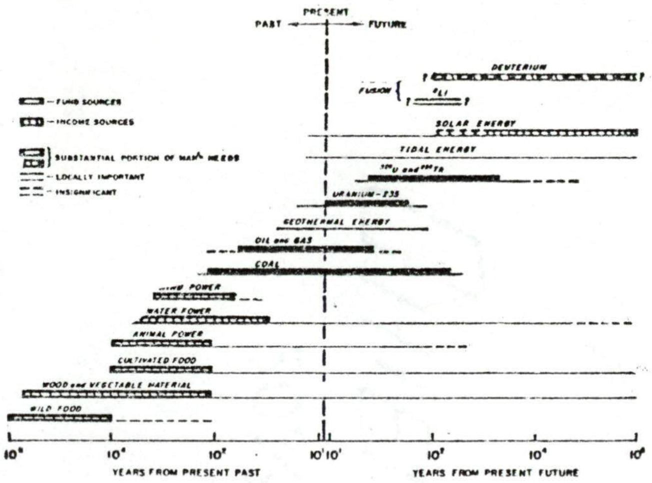


FIG. 8. ORDER OF RANK OF THE SAME COUNTRIES ACCORDING TO THE PERCENTAGE OF ENERGY DRAWN FROM RECURRENT SOURCES

Energy

Americans have always taken plentiful energy for granted. Not until the recent energy crisis (1974-75) have we come to realize that the fossil fuels that currently suupply 95% of the energy in the United States is a finite supply. An energy breakdown would find that coal makes up 20% of our energy consumption, oil 40%, natural gas 30%, and natural liquid gas and hydroelectricity 4%.[1] How long will these energy sources last? At the present rate, natural gas has a life expectancy of 30 years, petroleum 38 years, and coal 2,300 years. If five times the known resources are discovered, the life expectancy of natural gas and petroleum will only rise to 49 years and 50 years, respectively. For coal, the situation changes quite a bit if the other sources are exhausted. Coal's life expectancy will drop to 111 years.[2]

Fossil fuels are characteristically dirty, expensive to locate and mine, and used for a variety of other products in a variety of fields (for example, texiles,



Man's Use of Energy

SOURCE: THIRRING, HANS
ENERGY FOR MAN

agriculture chemicals, and plastics). Fossil fuel energy generation is relatively inefficient as exemplified by the 17.6% energy loss in electricity generation.[3,4] With these established facts why have we not choosen an alternative energy source? One reason is that we are not prepared to handle anything but concentrated energy sources.[5] Our institutions are most interested in forms of energy that lend themselves to centralization and control. This is the primary reason why more effort has been put into nuclear research as opposed to solar energy or other alternatives.[6] Nuclear energy has not yet proven to be successful due to inherent dangerous wastes caused by fission and the relatively new process of fussion which is cleaner and more efficient but will not be ready for use for some future date.[7] Thus, the energy dilemma remains unsolved. A partial solution is residential use of solar energy. Of the toal U.S. energy consumption, 15% is used domestically for home heating, cooling and water heating; if 2/3 of the 15% of housing energy consumption could be transferred to solar, it

THE EARTH'S ANNUAL ENERGY INCOME FROM THE SUN

	Approximate Figures	
	Q	10^{12}kWh
(a) Gross radiation energy striking the earth ...	5140	1,500,000
(b) Part of (a) reaching the surface of the earth ...	3200	940,000
(c) Part of (a) converted into wind	90	26,000
(d) Part of (b) reaching land areas	900	260,000
(e) Part of (b) spent in evaporation of water ...	1000	290,000
(f) Part of (e) spent in lifting water-vapour ...	17	5,000
(g) Part of (f) recovered in the form of rivers ...	0·17	50
(h) Part of (g) used for power plants	—	0·4
(i) Part of (d) photo-synthesizing land vegetation	0·15	45
(j) Part of (b) photo-synthesizing marine vegetation	1·25	375
Present annual energy consumption of mankind ...	0·09	26

(Compiled from data given by Ayres and Scarlott)

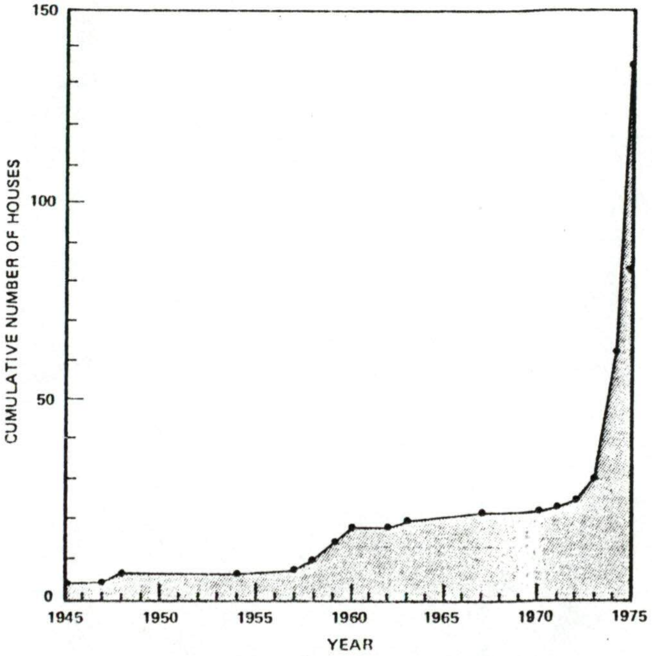
SOURCE: THIRRING, HANS
<u>ENERGY</u> <u>FOR</u> <u>MAN</u>

would reduce national consumption by 10% and world consumption by more than 3%.[8] National and global pollution would drop similarly. Unlike the fossil fuels, solar energy has no wastes, is not open to sabatage or blackmail, and it does not ravage our landscapes. "The energy falling on our globe every 15 minutes is considerably greater than the annual energy consumption of mankind."[9] Solar heating and cooling are feasible today, not at some nebulous future date.

"The solar energy falling on the roof and walls of a home are several times the amount needed to heat it." We can bring this energy into the home and be intelligent about its use.

> Most of the cost of solar devices lies inmundane and necessary processes such as manufacturing and assembling components, installing devices on buildings, connecting plumbing and electrical fixtures pouring footings for subsystems on the ground and digging excavations for storage tanks.[10]

By 1985, combined solar heating and hot water systems should be able to provide supplementary solar heat for residential and commercial buildings at prices

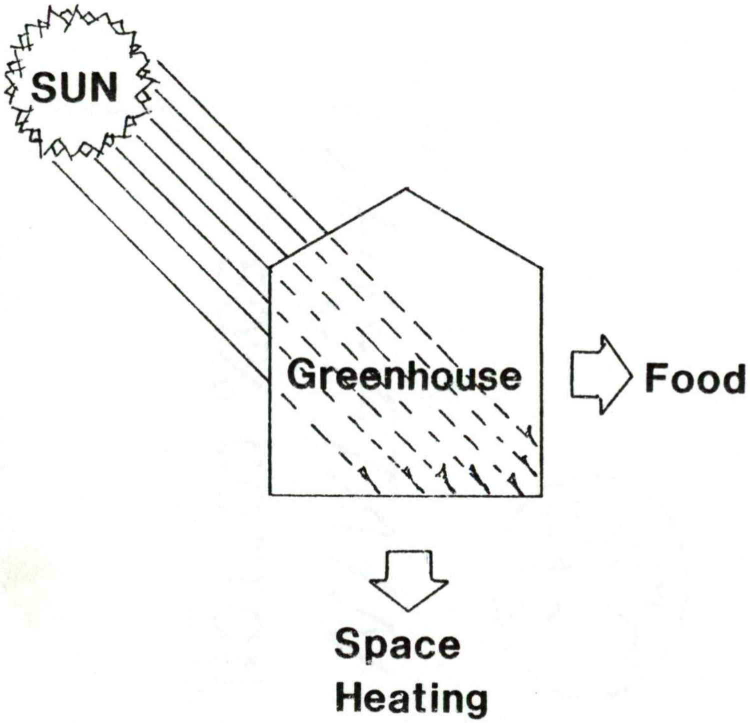


SOURCE: W.A. Shurcliff, *Solar Heated Buildings: A Brief Survey*, 1976.

The growth of solar homes in the United States.

SOURCE: ANDERSON, BRUCE
<u>SOLAR HOME BOOK</u>

competitive with conventional electric heat and heat pumps. A 50% reduction in heating loads and a 70% reduction in cooling loads over typical construction can be achieved through the proper use of configuration and materials in relation to seasonal changes in the sun's path and prevailing wind directions.[11] "The energy that goes into erecting a building is a small fraction of the energy it consumes during its lifetime."[12] Excluding taxes, the various domestic energy and utility systems costs may account for 40% of the first cost of a home over its life cycle and up to 90% of the operating costs. In conclusion, the adaption to solar energy is not likely to occur until fossil fuel production costs rise above solar costs. Solar energy will probably be put into use more readily abroad because of higher energy prices. Extensive world wide development of solar energy systems are needed to relieve the strain of competition for oil resources and will create num erous job openings. Extensive land use will be needed to facilitate collection,



but this requirement is far less devastating than those created by coal strip mining and oil derricks and spills.

Greenhouse Food Production: An Alternative

Residential use of greenhouses can be justified for not only their solar heating ability, but for their food production capability. It has already been established that energy costs can be substantially reduced through solar heating; additional energy savings can also be created by reducing food production energy costs through residential greenhouse growing.[13]

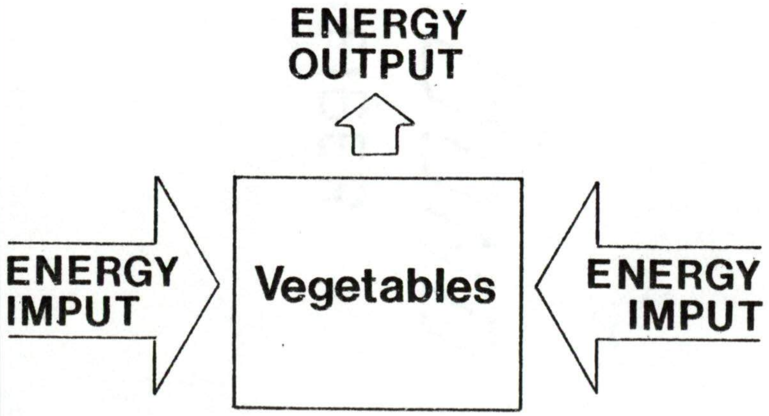
Greenhouses have the ability to produce off season crops or plants more efficiently than field grown crops. Today there are 7,800 acres of greenhouses in the United States, producing a variety of crops and there probably exists five times as many residential greenhouses. With up to 60% of today's family income spent on food and fuel, residential greenhouse food production looks attractive. Why have we not capitalized on greenhouse growing especially with today's food costs? The reasons

Percent Reduction in Fuel Use When Greenhouse Temperatures Are Lowered

	Present Greenhouse Temperature						
	65°F.			60°F.		55°F.	
	New Greenhouse Temperature						
y Average . (°F.)	60°F.	55°F.	50°F.	55°F.	50°F.	50°F.	45°F.
	Percent Reduction in Fuel Use						
20	11	22	33	12	24	14	28
24	12	24	36	14	28	16	32
28	13	26	39	16	32	19	38
32	15	30	45	18	36	22	44
36	17	34	51	21	42	26	52

Harrison and Roberts. *Florist Notes.* Cook College, Rutgers University, December 1973.

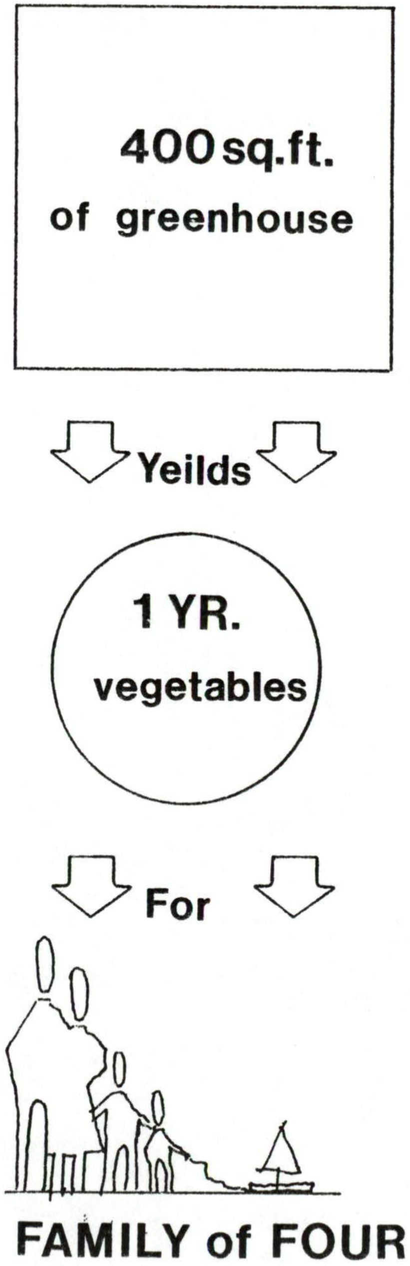
SOURCE: McCULLACH, JAMES C.
<u>THE SOLAR GREENHOUSE BOOK</u>



are economic. "Labor and energy demands have forced greenhouses either out of business or to a more profitable crop such as flowers."[14] Present requirements for greenhouses are 5,000 x 10^6 BTU.[15] Total fuel load is 5.6 million barrels of fuel oil. Without proper insulation or heat storage and the fact that 80% of heat gained during the day is lost at night, there is a need for oil heat to maintain proper temperatures.[16]

Present greenhouse grown crops are only competitive during the off season. If reliance on oil were reduced significantly by insulating and storing heat gain during the day, greenhouse production could be competitive all year round.[17]

Our food production relies heavily on energy. For instance, one 16 ounce can of corn contains about 375 kilo calories of food, but requires 3,010 kilo calories for planting, cultivating, harvesting, canning and transporting.[18] Residentially grown greenhouse vegetables and fruits can eliminate many of these production processes thus reducing cost. Comparative water use

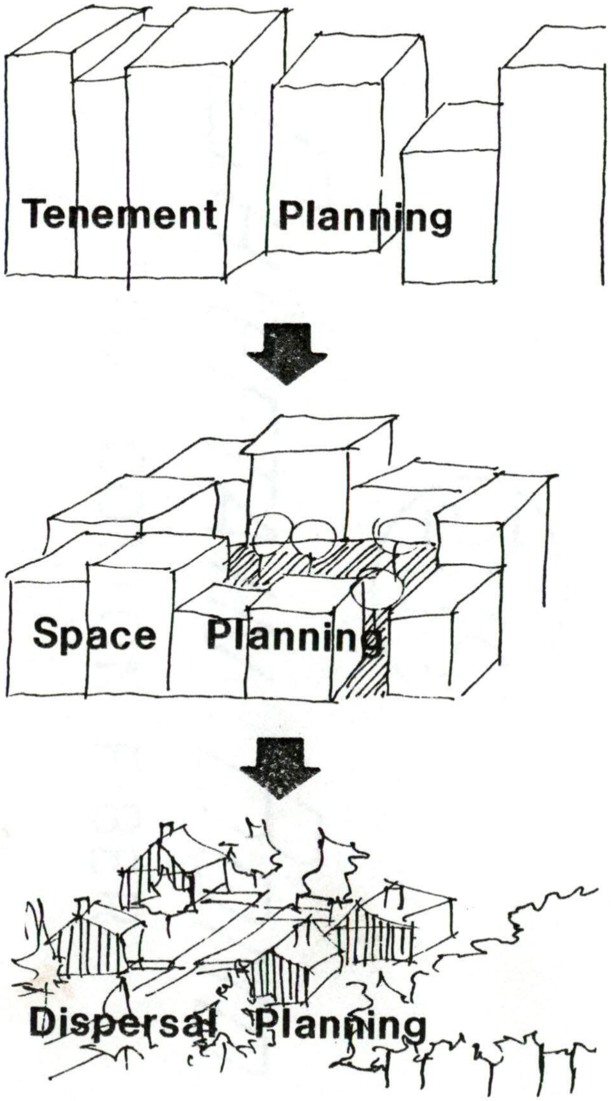


efficiency is exemplified by the fact that one ton of greenhouse tomatoes require 11,700 gallons of water; and for one ton of field tomatoes, 162,500 gallons of water is required.[19] Greenhouses can be very efficient because of their closed controlled environments, but have remained an energy burden to the present.

The Energy Research and Development Agency in Washington, D. C. and other agencies are developing more economical ways for heating and maintaining a greenhouse. One new study into methods of supporting plants has reduced labor 66%. Residentially applied greenhouse maintenance costs can be negated.

Assuming year round production, about 500 - 800 sq. ft. of greenhouse area would be required to meet the average family of our requirement of 40,000 BTU of food per day. Maintenance for this size greenhouse is estimated at three or four hours per week.[20]

Two thirds of the world's population is hungry, and food demands are rising steadily. Solar greenhouses have the capability to significantly supplement our insufficient food supply. By exploiting all natural sources we can save manual labor, promote food production, and raise the general standard of living.[21]



Historical Insight

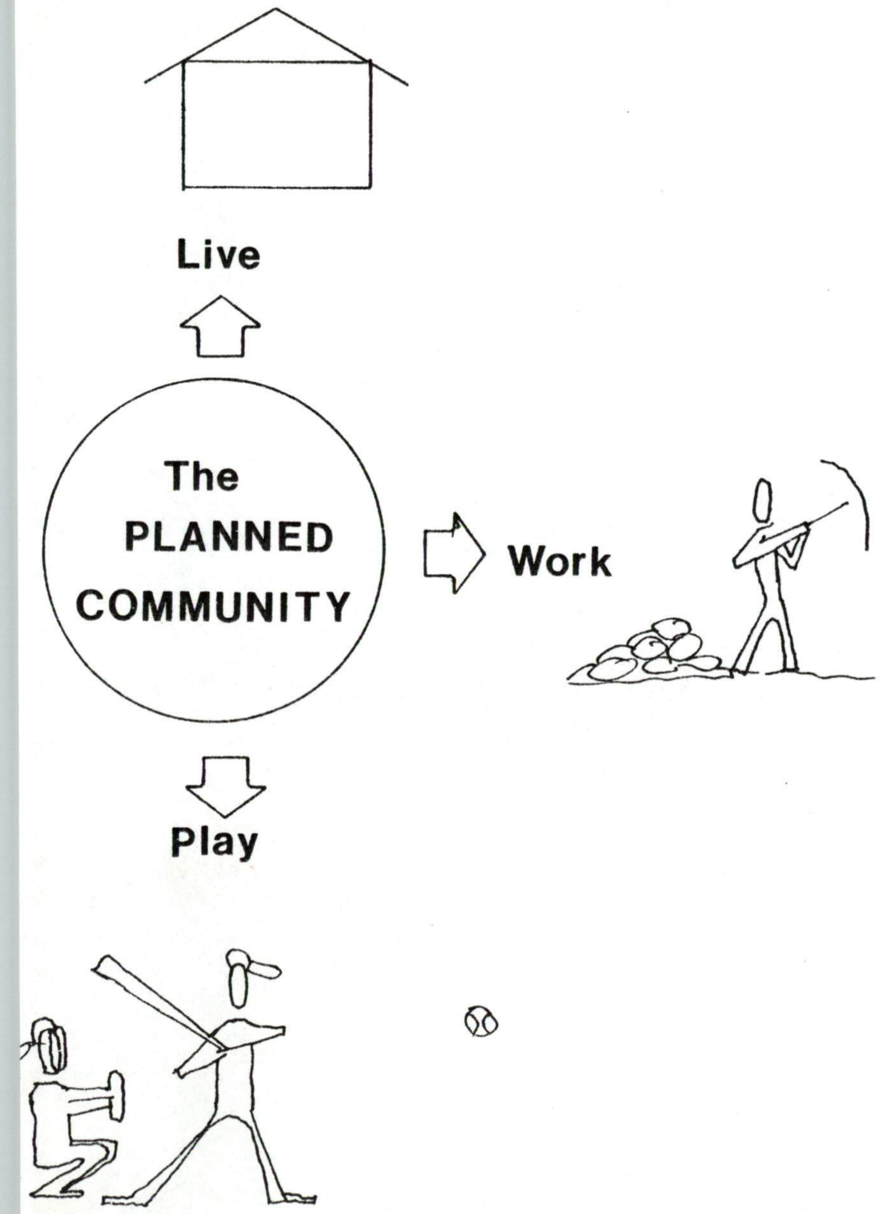
The second half of the 19th Century experienced rapid population growth and increased urban migration producing over crowded conditions in both Europe and the United States. Products of this phenomenon were the Building Code and Public Health reform movements which were organized attempts to deal with problems of density and urban environment. Initial solutions encompassed three different housing approaches:

1. constricted tenement planning (1879)and back to back row housing which created deplorable living conditions,

2. housing models which would provide higher standards of space, access, light, ventilation, heat and sanitation,

3. "and the final reaction advocating the planned dispersal of urban congestion through proposed disurbanization of both rich and poor to rural locations. The third reaction pointed to the garden city as a panacea for our social and economic ills."[22]

The garden city concept was based on the theory that totally self-sufficient planned communities could exist outside of the city in reduced densities. People could



live, work, play and associate culturally and politically within the confines of the planned community. As this concept was developed and translated architectually in projects like Radburn, New Jersey (1928-1933) and Chatham Village, Pittsburg (1929-1932). The original vision was redefined due to the rapid progress and acceptance of the automobile. The increased mobility provided by the automobile created a new commuter society which essentially eliminated the need for localized places of work.

After World War II, demands for decent housing greatly increased without sufficient effort generated to fill the gap already existing between supply and demand. Even with the slight reversal of migration trends of the post war period from suburban to urban, new developments were on the drawing boards and by the mid-fifties and early sixties an urban exodux began which produced a suburban housing boon.[23] With nearly 70% of all dwellings in the U.S. being single units and 20% mobile homes, the extent of suburban development has become apparent. Quantity not quality is prevalent because

Humanistic

Planning

of the use of cheap building materials, creating high energy usage per square foot and causing a rapid rate of deterioration and a high regeneration rate. Mass production of homes has never really been successful due to specific problems of location, codes, unions, climates and culture.[24] All of this is contained within a culturally deficient'' dormitory like suburban sprawl.'' The original garden city concepts were diluted creating the climate for suburban planning as we now know it. This type of planning based on economic and efficiently engineered grid systems of roads and highways and utilities and the mechanical subdivision of real estate into neat little squares and rectangles. The fallacy of this kind of planning, or lack of it, is the total disregard for the human considerations of diversity, variety, and choice of the living experience. The act of living is very personal; to mechanically solve the problems of habitation is unrealistic.

> The dramatic contrast between the successful effort to put a man on the moon and the failure to provide decent houses for all citizens

> made it clear that the most serious problems of housing are social and economical not technical.

Despite deficiencies, the suburb with its single family dwelling units has a strong sense of security, territorial definition and easy surveillance but today are out of reach economically.[25] A new goal for housing may be to maintain the features and amenities of the single family house while aggregating many more units on a single site for economics sake. Economically induced sacrifices may be

> a reduction of private outdoor space to give more community space; a loss of identity for individual units to allow repetition of structure and economy of production; a reduction in ease of access to increase security and reduction in view and exposure of dwelling to increase privacy and numbers of units.[26]

PERSONAL PHILOSOPHY

Energy, Food Production and Housing

Careful investigation and research has been undertaken in each of the areas mentioned: energy, food production, and housing. The data gathered is readily available and generally scientifically based.

When designing the human living environment all three of these areas must be addressed in order to properly access and subsequently solve the problems encountered in human settlements or housing projects. The architect or planner cannot be expected to be the authority in each of these areas but can use the data already provided by researchers in the past. Too often housing projects are over simplified into terms of pure economics or aesthetics with no concern for either the social psychological aspects of energy conservation and food production.

SUMMARY

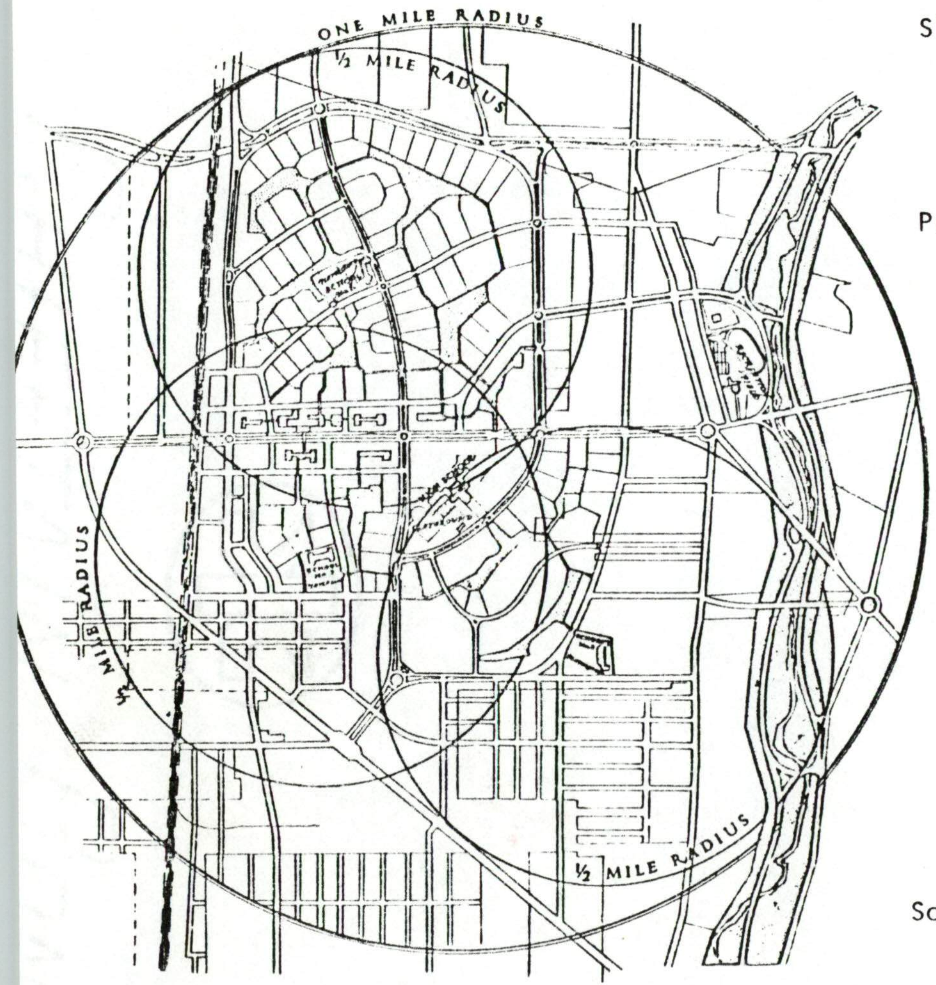
In view of the increasing energy restrictions, inefficient land use and rising food costs, this study has been undertaken with a veiw toward providing housing

designs of an energy efficient nature capable of year round food production organized upon a community scheme emphasizing clustering of living units to create usable open space.

Case Studies

HOUSING CASE STUDIES

Case Study I



Project: Radburn Housing Development

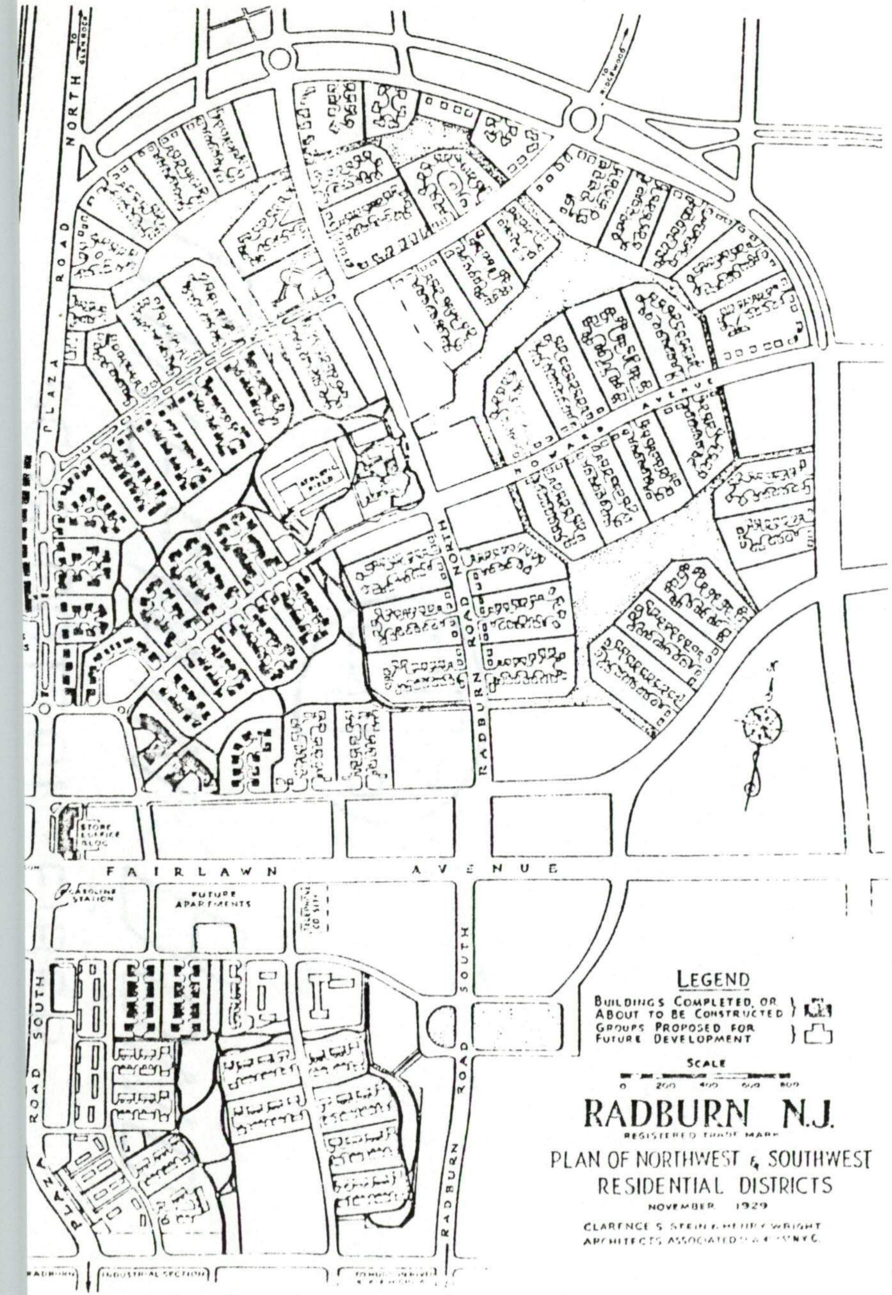
Architects: Clarence S. Stein and Henry Wright

Site: Fairlawn, New Jersey

- a large track of unfertile farm land 16 miles from New York City.

Program:
detached housing
row housing
apartments
superblocks instead of traditional small rectangular blocks
parks
schools (elementary)
localized shopping facilities
including post office
church

Source: Clarence S. Stein, <u>Toward New Towns for America</u> (New York, New York: Rheinhold Publishing Corp., 1957), pp. 36-73.



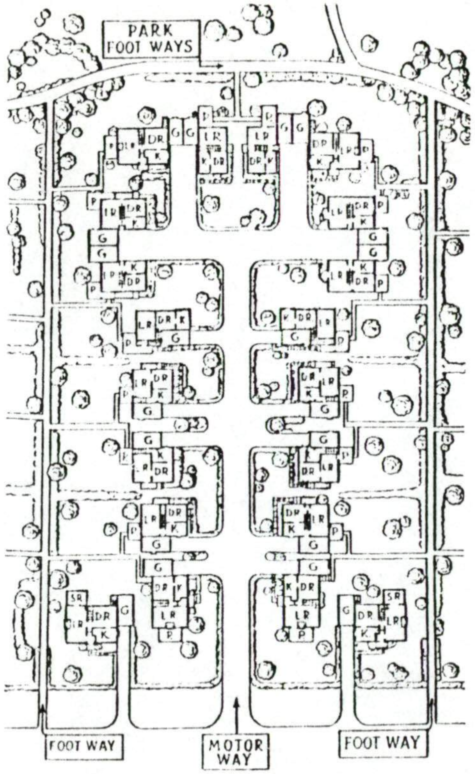
SOURCE: STEIN, CLARENCE S. TOWARD NEW TOWNS.

Background:

With the close of World War II, a new enthusiasm emerged towards improving our environment. Inspiration motivated Clarence Stein and others to form the Regional Planning Association to discuss regional development and new communities. Clarence Stein was appointed chairman of the Commission of Housing and Regional Planning and proceded to travel to England to study the "New Towns" in attempt to gain a more constructive approach to housing. Stein studied the Garden Cities of Ebenezer Howard and Raymond Unwin and returned a disciple of them. A short time later, Stein met developer Alexander Bing and the garden city concept was reborn and realized first, with Sunnyside (an urban housing project) which was a trial run, and secondly, Radburn, conceived as the first Amercan Garden City.

Concept:

To design a Garden City for the use of the automobile that would be safe and pleasant community.



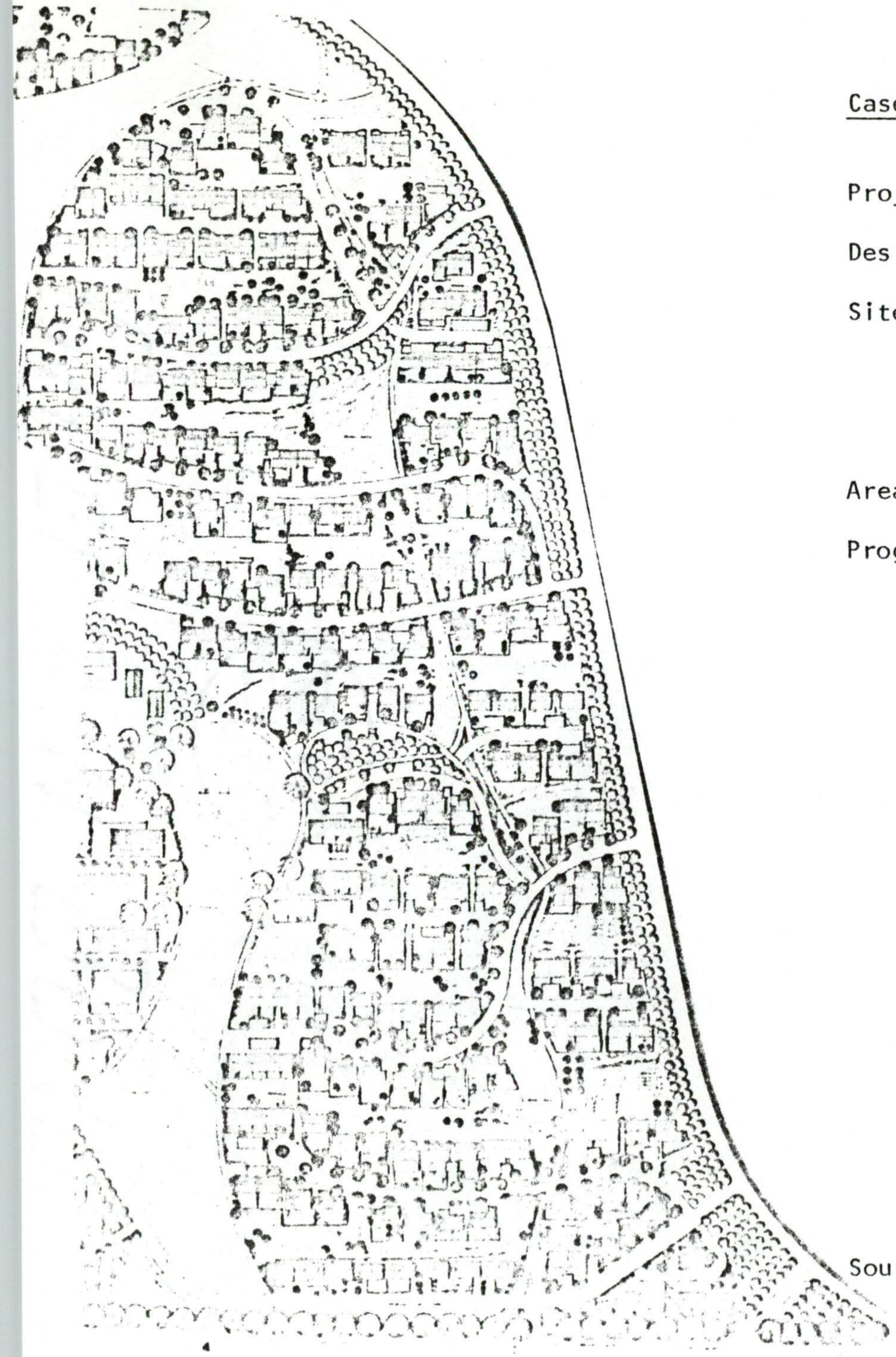
SOURCE: STEIN, CLARENCE S
TOWARD NEW TOWNS ...

Building Design/Response:

Translating concept to architectural reality, Stein created large blocks called "superblocs" containing large expanses of open spaces or parks with all houses oriented on the park or a pedestrian street with the vehicular traffic on the opposite side, thus segregating pedestrian and vehicular traffic. Automobiles circulated freely around the superblocks but not through them. Deadend roads with cul de sacs served the housing units but only penetrated partially into the blocks, thus discouraging non-local traffic. The architecture was simple but attractive.

Evaluation:

Although Radburn was never completed due to the depression and did not become a true Garden City, the project is still considered a success. In relation to the existing housing situation, it can be concluded that Radburn is safer, more orderly and convenient, more spacious and peaceful. The integration of the green spaces bring people closer to nature. The project's total cost is less than other developments with an equivalent amount of open space. Organized association of some type is needed to enrich community activity and maintain community spaces. The organization of units around cul-de sacs with pedestrian streets creates two public sides to the houses. This is extremely successful in the clean pleasant environment that is created. There are no formal back yards to clutter up or neglect. The home owner is inspired to maintain both sides of his property because they both come in to public view. In reality, it is the land planning more than anything that makes Radburn work. Typical suburban developments encourage people to neglect property; whereas, Radburn is an inspiration. It motivates people and makes them community minded.



Case Study II

Project:	Village Homes
Designer:	Michael Corbet
Site:	Originally the University of California farm, but now is Davis, California. Soil is very productive.
Area:	70 acres
Program:	single homes duplexes apartments carports community center (future) co-operative store (future addition) small hotel (future) day care center (future) community workshop (future) office space for small business (future) greenbelts common open spaces

Source: Robert L. Thayer, "Designing an Experimental Community." Landscape Architect (May 1977), pp. 223-228.

Background:

In 1970, Corbet developed the idea for a semi-drop out community which would be self-supporting and based on interaction, cooperation, and conservation. The project was to be completed in five years.

Concept:

Low energy community design incorporating solar technologies and agriculture production.

Building Design/Response:

Using a simple western ranch and early solar venacular of stucco, stained wood, and tile roofs to reinforce the village, Corbet set up a housing organization based on long, narrow streets with cul de sacs with internal common spaces opening up into large greenbelt areas to be utilized as agricultural production plots cooperatively maintained. For a sense of unity, the living units were planned in clusters of eight with a southern orientation for maximum solar gain. Corbet confronted rainfall deficiencies by contouring the site plan to collect and store rain run-off in small holding ponds.

Evaluation:

The present state of Village Homes is uncompleted and because of local codes, city council restrictions, and financing, certain concessions have diluted the original master plan. Corbet had to reduce agricultural land and add some non-solar houses. He was also required to lengthen setbacks and use concrete parking bays instead of gravel. The project is undergoing growing pains and remains in an experimental stage, but the following observations have been made: the inhabitants tend to be environmentalists, young marrieds, some traditional families and low energy missionaries with individual units looking more like laboratories. Despite cooperative efforts, people have spent more time on private areas than public common ones. Cooperation and association have met with more success on cultural and recreation levels (singing clubs, arts, crafts and sports). Complaints have surfaced regarding strict aesthetic standards and fences, house colors, facades, and other features.

Positive indications are: steady growth, growing participation on all levels, lower energy costs, traffic control and increasing visibility of bicycles and pedestrians.

Case Study I

Project: Sprinbrook Lake House, 1975

Architect: Lee Porter Butler

Site: Jackson, Tennessee

suburban, wooded, relatively flat
location; 35° N Latitude

Program:

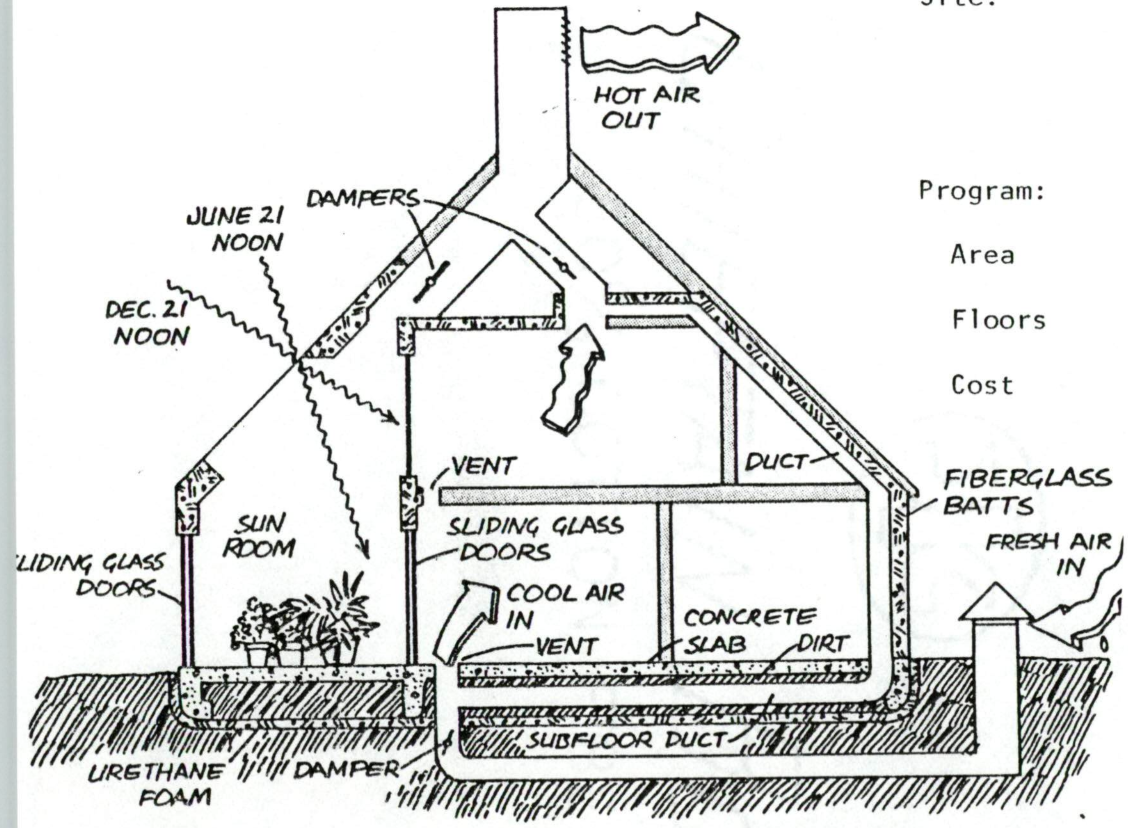
Area 1,440 sq. ft.

Floors Two

Cost $38,000 plus lot

sun room
living room
dining room
master bedroom
bedroom 1
bedroom 2
carport and storage

kitchen
bath 1
bath 2
utility
foyer
playroom



OURCE : ANDERSON p.111

Source: Bruce Anderson, The Solar Home Book, (Harrisville, N.H.: Cheshire Books, 1976), pp. 109-111.

Energy Conscious Features:

1. Passive solar system using thermal storage in concrete flooring and earth,
2. Sun room as buffer zone and thermal modulator,
3. Natural gravity convection for heating and cooling,
4. Shade trees on south side,
5. No windows except opening to sun room.

Building Design/Response:

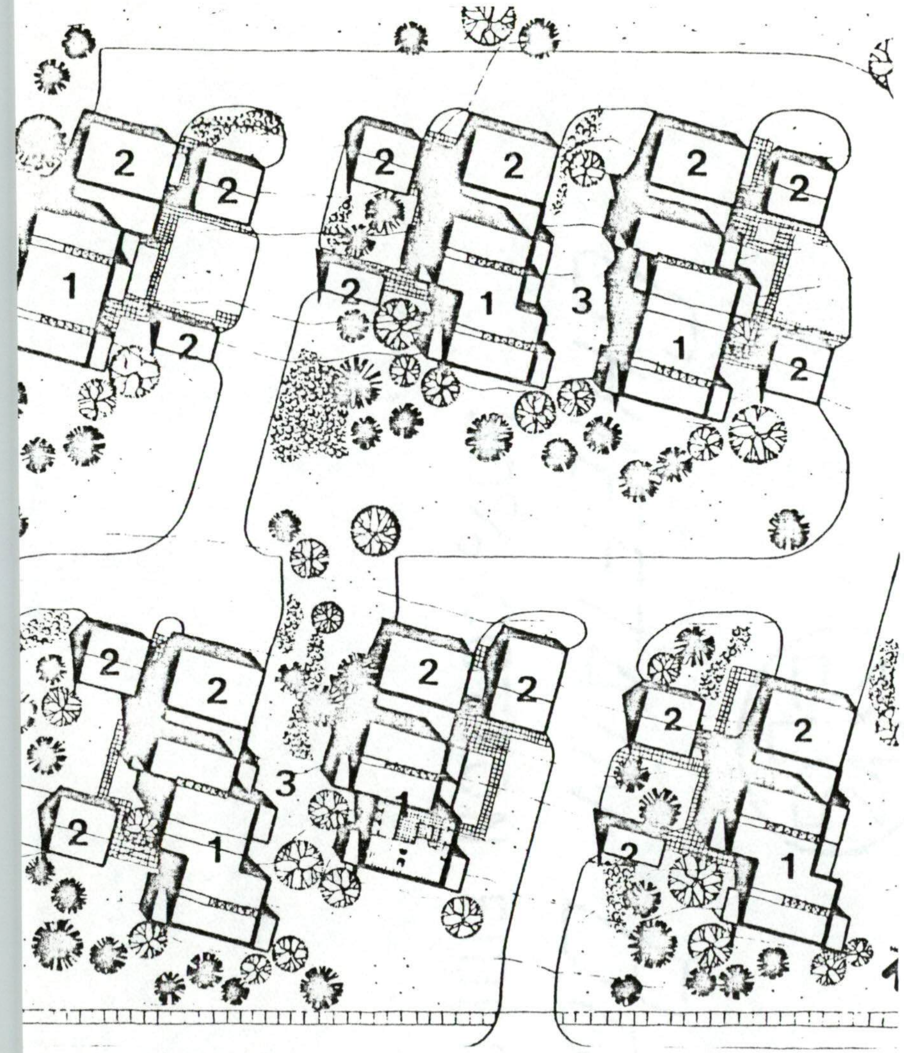
Butler employed standard building materials and window units to provide an attractive yet economically feasible home. The 360 sq. ft. of glass collected more than 500,000 BTU's per day. Located amid deciduous trees, little clearing was necessary and plenty of natural shading and cooling was already provided.

Evaluation:

Wind, sun, site, natural air currents, gravity air convection are taken advantage of producing a virtually energy self-sufficient home. The sun room acts as solar collector and buffer to air infiltration from outside. There is no mechanical system, and heat collected from the sun room is circulated by natural convection. Cool air is drawn from below ground by natural convection as well during warmer months. Interior design temperature is 68^{o} with an extreme summer high of 78^{o}.

Negatively, the single glass used would cause a large amount of heat loss and the temperature difference between the two levels would be considerable especially during periods of extreme heat or cold.

Economically, the house is quite successful and ecologically sound.



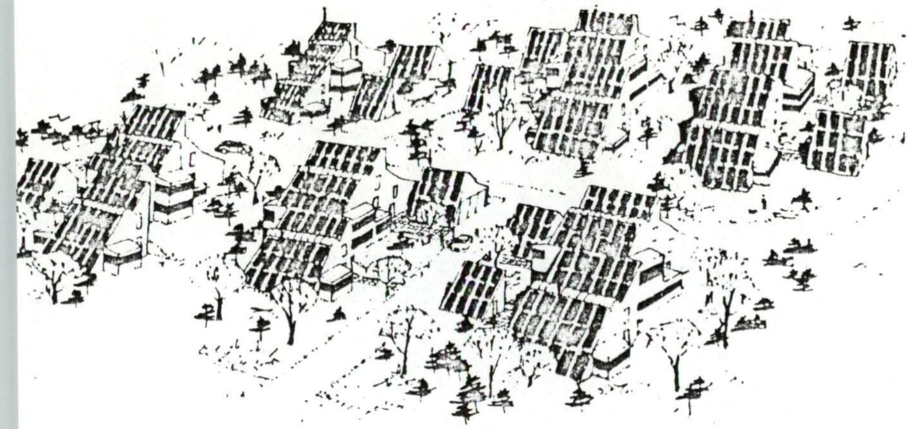
SITE PLAN

1. LIVING UNITS
2. GARAGE PARKING
3. COMMUNITY SPACE
3. BUILDING SERVICES (

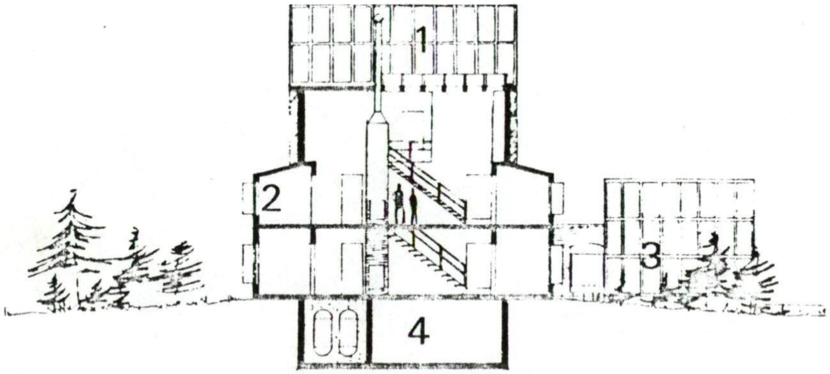
Case Study II

Project:	A Proposed Cluster Design for a Temperature Climate
Architect:	Giffels Associates, Inc.
Site:	Boston, Massachusetts rural suburban, flat, wooded; 40° N latitude
Program:	24 living units grouped in six clusters of four
Area	1,200 sq. ft.
Floors	Two
Cost	Not Available
Basic Unit	two bedrooms utility space two baths kitchen entry vestibule (air lock) living room

Source: Dr. Kaiman Lee, Encylopedia of Energy Efficient Buildings, Vol. 1, (Boston, Mass.: Environmental Design and Research Center, 1977), pp. 255-262.



PRIMARY ORIENTATION: SOLAR, WIND
SECONDARY ORIENTATION: PRECIPITATION



E-W SECTION

1. FLAT PLATE COLLECTORS
2. PORCH WITH ADJUSTABLE WINDOWS
3. GARAGE
4. BASEMENT (STORAGE, LAUNDRY, ETC.)

Energy Conscious Features:

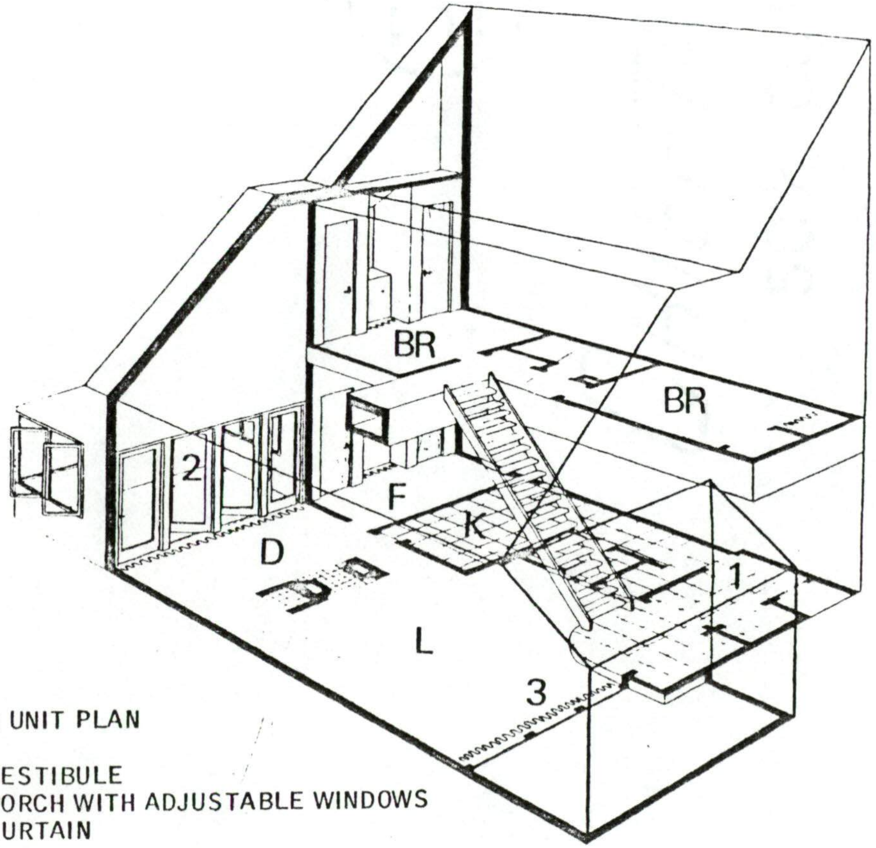
1. Roof mounted solar collectors facing southwest,
2. Aluminum flat plat collectors,
3. Transport medium 50% water, 50% ethylene glytol (similar to antifreeze),
4. Dual insulated tank storage: 1 hot water, 1 hot water heat,
5. Hot water aid duck work integral with fireplace.

Building/Design Response:

The clusters are all oriented in same direction with variety of space created by adjacent garages which define individual private spaces. The individual floor plans are quite open allowing for natural circulation of air and maximum flexibility of use. The solar system is integrated with the fireplace a single verticle element.

Evaluation:

From a heating standpoint, the system is quite feasible, but the open plan makes for difficulty in regulating a balanced temperature on both levels of the house. The clustering arrangement works quite well when analyzed as a single cluster or a small group of clusters; but in a large development, this repeated arrangement is potentially monotonous. Some orientation variation and introduction of different cluster types could improve the situation in a large scale development.

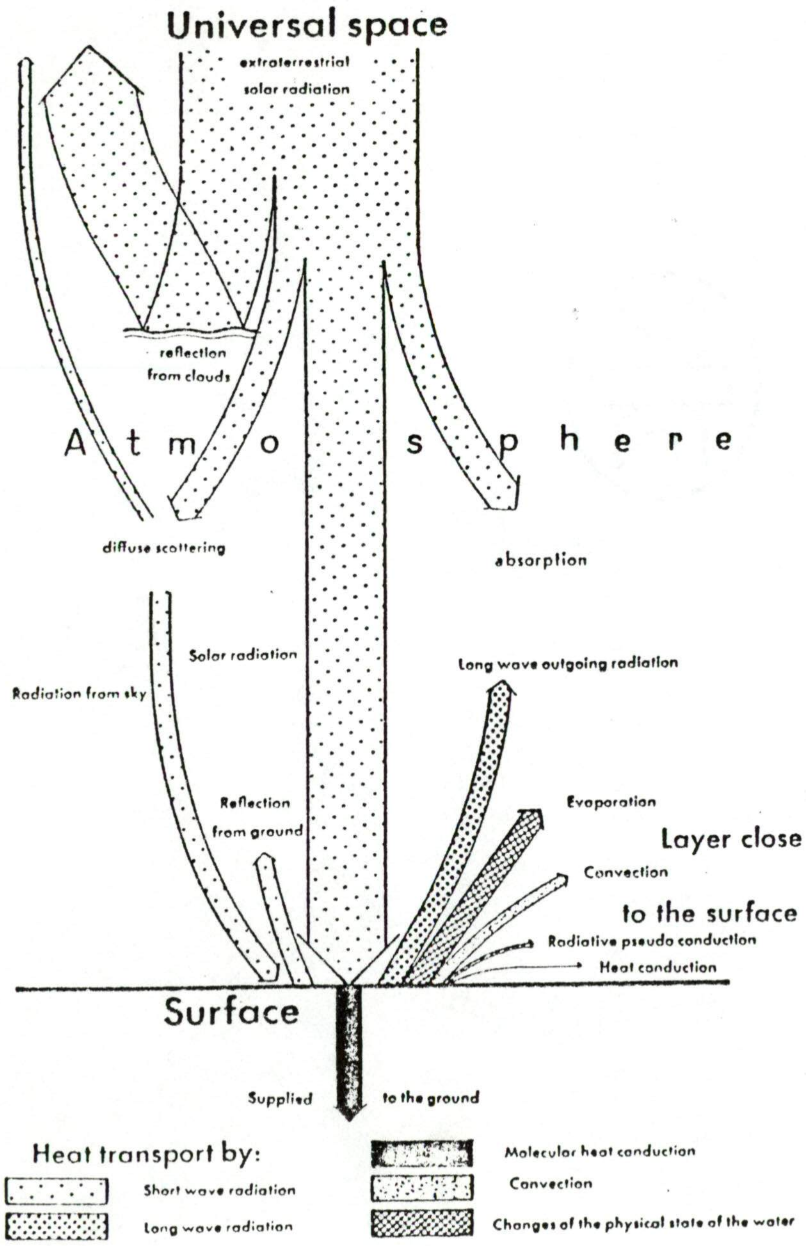


LIVING UNIT PLAN

1. VESTIBULE
2. PORCH WITH ADJUSTABLE WINDOWS
3. CURTAIN

Energy System

ENERGY SYSTEM



To facilitate a practical means for accomplishing energy and food production goals already established, a passive solar hybrid system has been selected for space heating and an active flat plate water system has been chosen for year round domestic hot water production.

To obtain a general understanding of the principles of solar energy the following is a brief examination of some of the fundamentals. The energy that we receive from the sun is primarily in the form of light, a short wave radiation which only a part of is visible to the human eye.

When the radiation comes in contact with a liquid or solid, it is absorbed and transformed into another energy known as heat. The material may then transfer this heat to other solid, liquid or gas materials of lower temperature through conduction or radiation in the form of long wave radiation. There are two types of sun rays that reach the earth:

1. direct parallel rays and

SOURCE: THIRRING, HANS - ENERGY FOR MAN.

2. diffuse (non parallel) rays or sky radiation reflected from clouds or atmospheric dust.

Solar energy that reaches buildings is not only diffuse and direct rays, but radiation reflected from adjacent ground building surfaces, snow, etc., known as incident radiation.[27]

For a building to avoid today's reliance on high technology heating and cooling systems it must meet three basic requirements. First, the building must be a solar collector - let the sun in for warmth and hot air out for cooling. Second, the building must be a solar store house - it must store heat for when it is cold and keep cool for hot times. Third, the building must be a good heat trap - reduce the heat loss of the building through insulation and reduction of air infiltration.[28]

Passive Solar Energy Systems (Or Low Impact Technology Solutions

When designing a solar heating system for a particlar building, a sensible solution would be one that did not require a high level of sophisticated materials, components, systems, subsystems, and moving parts; this is a low impact technology solution. Examples of low impact solutions are insulating shutters for windows, shading devices, thermal inertia in buildings, thermosiphening solar collectors and greenhouses. "Thermosiphening solar panels circulate air or water naturally without an auxiliary source of power, such as fan or pump." As the air or water is heated by the sun, it expands and rises through the collector. This draws cool air or water from the solar heat storage or from the building. This passive collector needs no insulation between absorber and outside air to minimize heat loss or heat gain depending on whether you are cooling or heating. Thermal inertia refers to the heat capacity of materials. Greater density and mass increase heat storage capacity thus increasing thermal inertia. Greenhouses also circulate air naturally; so as the air is heated in the greenhouse, it can be drawn directly into adjacent spaces or pumped to distant locations. This passive collector would need insulation and shading from heat losses and gains in order to provide a proper environment for the plant material inside the greenhouse.[29]

Active Solar Energy System

The difference between an active and passive system is characterized by the use of fans, pumps, anything requiring a second energy source to operate. "Several characteristic properties apply to all solar heating/cooling and domestic hot water systems, whether they are simple or relatively complex." Any solar system consists of three components: collector, storage and distribution; and may include three additional subcomponents: transport, auxiliary energy system, and controls.[30]

Solar Collectors

"The collector converts incident solar radiation (also called insulation) to usable thermal energy by absorption on a suitable surface." There are two types of collectors focusing and nonfocusing. Transparent cover sheets, like glass or plastic are used to facilitate the greenhouse effect - letting in of short wave radiation and trapping of long wave heat radiation. Optimum angle of incidence is 90° - anything less than 30° will create a loss greater than the gain. Absorbing surfaces should absorb a high degree of radiation but should reradiate very litte. Dark surfaces are most effective absorbers (i.e., black, dark green, dark brown).[31]

"A present, collectors which are factory produced and shipped to the building site are relatively high in cost due in part to the small volume manufactured."[32] Custom built collectors are generally less expensive but not as efficient thermally.

Open Water Collector: are fabricated on the site using corrugated metal roofing panels painted black and covered with a transparent cover sheet. This sytem is not very efficient in cold climates.

Air Cooled Collector: employs air (or gas) as the transport medium between collector and storage.

Advantages to this system are low maintenance and relative freedom from freezing problems. Also, air can be passed directly into rooms for use, thus eliminating inefficient transfer of heat encountered in liquid systems.

Liquid Cooled Collector (most widely used): The liquid medium is passed through the absorber plate of the collector and then is pumped to the storage tank, transferring heat to the storage medium. Freezing, corrosion, and leaks have been the major problems that have plagued liquid cooled systems. These are efficient collectors.[33]

Storage

"The storage component of a solar system is a reservoir capable of storing thermal energy." Storage is necessary for handling thermal needs when it is cloudy or in the evening. The storage unit may be as simpleas a masonry wall (sensible heat storage) or as complex as a chemical phase change storage unit (latent heat storage).

> The type, cost, operation, and required size of the solar storage component will be determined by the method of solar collection, the dwellings heating and cooling requirement, and the heat transfer efficiency to and from the storage unit."

Sensible heat storage is the simplest, least expensive type of storage - it is the heat energy absorbed and reradiated by roofs, walls, or "greenhousing" of windows that directly heat spaces (rooms).

Other types of heat storage are: water storage, rock storage, latent heat storage, salt hydrates (phase change), and parafin.[34]

Distribution

"The distribution component receives energy from the collector or storage component and dispenses it at points of consumption - spaces within the dwelling." Domestic water heating is a part of the distribution system, generally consisting of a heat exchanger, backup heater, piping and controls. There are three main types of distribution: gas flow, liquid flow, and radiation. Each one of these types can be accomplished several ways; some are mechanical (fans, pumps) others are natural (radiation, convection). The type of distribution is usually determined by the collection and storage system.

Gas Flow Distribution - Natural Convection: uses the properties of hot (less dense) and cool air for circulation. The advantage to this system is the lack of mechanical devices.

Forced Air: "a forced air system relies on mechanical equipment and electrical energy for the distribution of thermal energy. Larger than normal air vents are needed for this system because of the relatively low temperature of the air circulated. The system works by mechanically blowing air through a collector or a storage bed into the rooms of the building.

Liquid Flow Distribution - Forced Radiation: relies on the transfer of heat to air by radiation and convection from circulating hot water through tubes. For cooling, a refrigeration unit is used which passes chilled water through a fan coil unit located at point of distribution.

Natural Radiation: "is the transfer of heat by electro-magnetic waves without the assistance of mechanical devices. This system is dependent on differential air temperatures for distribution.[35]

System Employed: space heating

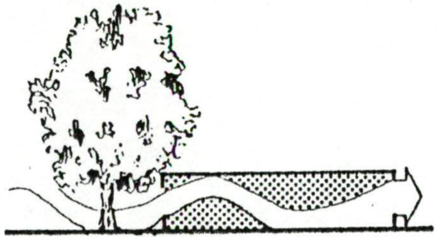
- Hybrid Passive System
- Collector: Two Greenhouses (air cooled)
- Storage: 2" dia. Railroad Rock
- Distribution: Gas Flow (air)

  Natural Convection and Forced Air (one fan system)

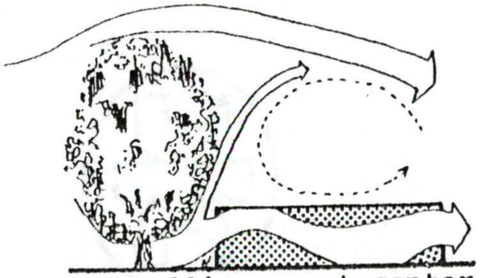
Domestic Hot Water: active system

- Collector: Flat Plate (metal)
- Storage: Water (tank)
- Distribution: Liquid Flow (water)

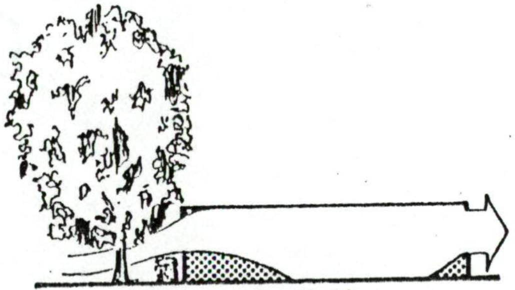
  Forced Radiation (heat transfer).



tree 5' away at center



tree 10' away at center



hedge at building
tree 5' away

Solar Angles - Shading - Site Considerations

When designing with the sun there are several exterior factors to be concerned with. One must have an understanding of solar angles (azimuth angle-angle of incidence-altitude angle) to properly orient your building and/or solar collectors to maximize the efficiency of your solar system. Shading devices can only be effective when solar angles are understood. Environmental (site) considerations such as: adjacent trees or buildings may shade your building from collecting the sun's rays but if used properly, they can block unwanted winds which reduce thermal inertia of buildings and may shade hot sun rays in the summer. (Deciduous trees are most effective sun shade since their leaves in summer, shade, and in winter, after they have fallen, allow warming sunlight to pass through them to adjacent structures.)

Project Identification

PROJECT IDENTIFICATION

Problem Statement

To develop a small planned community of moderate density (4.5 units/acre) emphasizing energy conservation and passive solar technologies. The project will consist of 162 multi-family living units, recreation and community facilities and a community park. The project will be located on a 36 acre site in the north suburban region of Greenville, South Carolina.

The project solution will concentrate on establishing solar housing design criteria for the overall master plan, a typical housing cluster and a typical living unit within that cluster.

Site Selection

Greenville, South Carolina is experiencing rapid residential and commercial growth. After investigating three urban sites and two rural sites, one of the rural sites was chosen on the basis of its ability to satisfy the established goals and objectives, and its appropriateness for the evolving concept.

Justification:

- central between three cities: Greer, Travelers Rest, and Greenville
- rural, allows for moderate density and generous open space
- zoned, residential
- soil conditions conducive to gardening
- area experiencing rapid residential growth
- located between two major highway arteries.

Activity Distance From Site

A. Medical

1. dentist, 10 minutes away, Wade Hampton
2. Greenville General Hospital, 15 minutes
3. Greenville County Health Department, 15 minutes
4. Ambassador Clinic, 10 minutes, Wade Hampton
5. Wade Hampton Veterinarian, 8 minutes
6. Wade Hampton Chiropractic Clinic, 8 minutes.

B. Churches

1. Pentecostal Holiness Church, 5 minutes
2. Pebble Creek Baptist Church, 1 minute
3. Pleasant View Baptist Church, 2 minutes
4. The Lutheran Church of Our Savior, Wade Hampton, 9 minutes.

C. Schools

1. Greenville Tech., 20 minutes
2. North Greenville College, 20 minutes
3. Bob Jones University, 20 minutes
4. Furman University, 25 minutes
5. Wade Hampton High, 15 minutes
6. Proposed Elementary School, 1 minute
7. Brush Creek Elementary School, 8 minutes

D. Cultural Activities, Recreation, Entertainment

1. Greenville County Museum of Art, 15 minutes
2. Greenville County Library, 15 minutes
3. Greenville Memorial Auditorium, 15 minutes
4. Cleveland Park, 17 minutes
5. Paris Mountain State Park, 10 minutes

6. Hillandale Golf Course, 15 mintues
7. YMCA, Cleveland Street, 20 minutes
8. Bijou Theater, 10 minutes
9. Mountain Boggin, 8 minutes

E. Shopping

1. Downtown Greenville, 15 minutes
2. McAlister Square, 15 minutes
3. Edwards Forest Plaza, 4 minutes
4. Wade Hampton Mall, 10 minutes

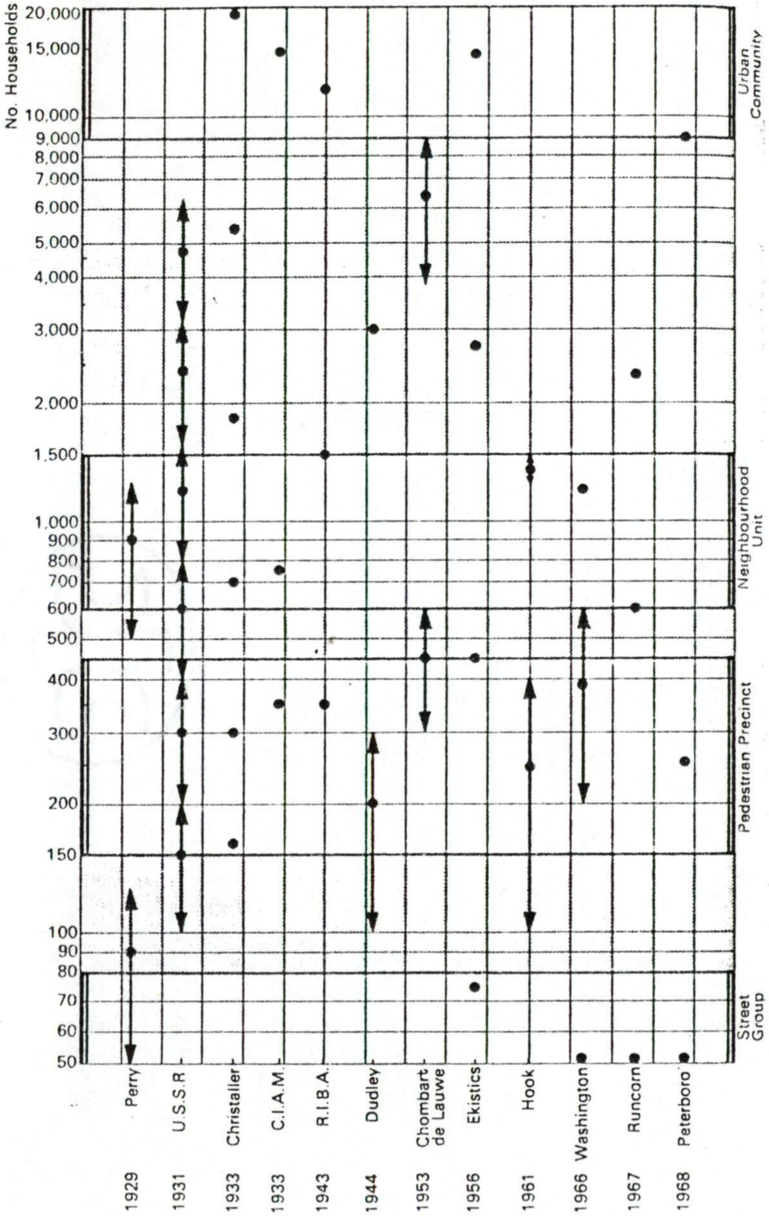
F. Other

1. Green, 10 minutes
2. Travelers Rest, 25 minutes
3. Greenville-Spartanburg Jetport, 18 minutes
4. Post Office Wade Hampton Branch, 8 minutes
5. Fire Department, Wade Hampton Branch, 5 minutes.

(Note: All times are driving times.)

User Description

The typical inhabitant of this community would possess interests in ownership, child safety, energy



SOURCE: BELL, GWEN - HUMAN IDENTITY IN URBAN ENVIRONMENT.

conservation, and community affairs. His hobbies could range from a variety of recreational activities to horticulture and gardening.

Project Scope

When beginning a housing project, the actual number of housing units and the range of ancilliary facilities used is an important issue to deal with. Often the solution is determined by zoning (allowed densities), client whim, economic capability or simply designer perogative. These are all some what arbitrary and incomplete, but most importantly none deal with the actual function of living. How do people live? How can certain social units be accommodated and what psychological stimuli do we wish to expose to the inhabitants?

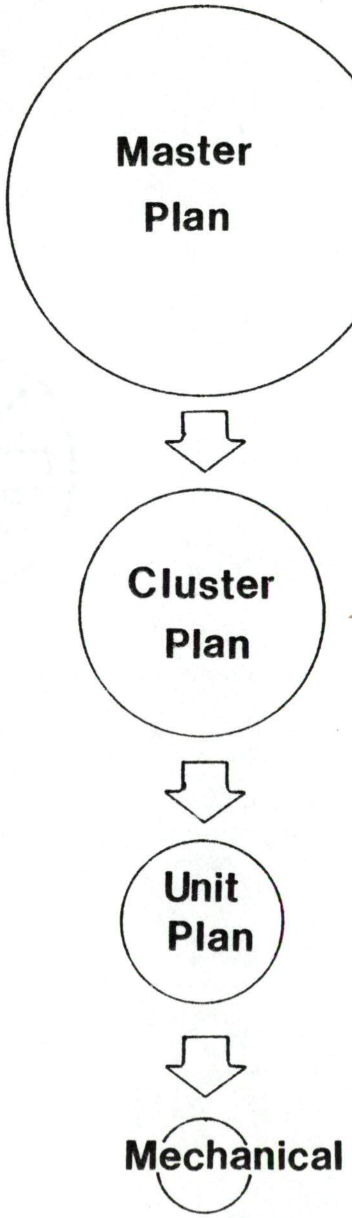
Between 1929 and 1968 many theories about the optimum scale of human settlements have been developed. The actual breakdowns were in the form of social groups based on a number of households within that group. Gwen Bell in her study, "Human Identity in the Urban

Environment," formulates her own social breakdown by putting these theories through a matrix to identify certain similarities. The results were the following social groups with their accompanying characteristics:

1. The Street Group: 50-80 households - pedestrian scale, common frontage upon a street, sharing of a common hallway of an apartment block, on nodding terms;
2. Pedestrian Precinct: 150-450 households or 500 to 1,500 people, typical small town and village size, easy walking distances, can support at this size, food shops, nursery or daycare, and community clubs; this is the group that this project falls within.
3. Neighborhood Unit: 600-1,500 households or 5,000 people, has primary school, local shopping center. Recently this group has been updated to around 2,000 to 3,000 households, but is still considered too small for the choice and variety that is needed for this many people and too large for personal human interaction.
4. Urban Community: 9,000 to 20,000 households, 40,000 people. A complete city with a complete variety of facilities and activities.[36]

Project Approach

The project situation will be approached from a broad standpoint and then progress to greater detail.



First, an overall master plan will be developed to illustrate the overall concept or big idea. Next we shall examine a typical housing cluster, its planning constraints and mass-void relationships. Then a typical living unit shall be developed to illustrate interior-exterior relationships as well as the typical constructions and architectural vernacular employed. Finally, we shall examine closely the solar energy system employed and make comparisons as to its justification.

Program

PROGRAMMATIC REQUIREMENTS

Description of Activities

I. Recreation

  A. Active: sports, gardening, bicycling, walking, jogging, picnics, home maintenance

  B. Passive: sunning, community class, just hanging out

II. Education

  A. Day Care

  B. Community Center Affairs (lectures etc.)

Living Unit Types

I. Passive Hybrid Solar (2 & 3 bedrooms)

II. Passive Hybrid Solar (2 & 3 bedrooms)

Living Unit Space Breakdown

I. Passive Hybrid Solar

Two Bedroom	Subspace	Sq. Ft.
	Greenhouse	324
	Living Room	234
	Dining Room	96
	Kitchen	100

	1/2 Bath	18
	Full Bath	84
	Bedroom 1	100
	Master Bedroom	132
	Storage	150
	Mech./Misc.	86
	Circulation	160
	Total	1,484
Three Bedroom		
	Total	2,000

II. Passive Hybrid Solar

Two Bedroom	Subspace	Sq. Ft.
	Greenhouse	252
	Living Room	260
	Dining Room	96
	Kitchen	72
	1/2 Bath	24
	Full Bath	64
	Bedroom 1	108

	Master Bedroom	156
	Storage	122
	Mech./Misc.	188
	Circulation	142
	Total	1,484
Three Bedroom		
	Total	1,820

Space Relationships

Living Area

Activity:	eating, sleeping, watching T.V., listening to music, reading, entertaining, study (paper work)
Furnishing:	sofa, two or three chairs, coffee table, fireplace, two end tables, book shelves, and plant stands
Design Considerations:	preferably an out of usual circulation, plenty of natural light, views to outside, able to open to greenhouse

Kitchen

Activity:	meal preparation, casual dining, storage, housekeeping

Furnishings: range oven, dishwasher, sink, refrigerator-freezer, counter Preparation space, pantry space

Design Considerations: able to view outside of front and back of house, open to living room, good lighting - natural and artificial light, out of heavily traffic areas, near entrance

Bedroom

Activity: sleep, study,storage, various personal activities

Furnishing: bed, desk, closets, chest of drawers

Design Considerations: privacy important, quiet, intimate, easy access to bathroom, allow for flexible room arrangements

Bathroom

Activity: hygiene

Furnishing: bathtub with shower, water closet, lavatory

Design Considerations: easy access from all parts of close relationship to work and sleep areas, use natural light if possible.

Ancilliary Facilities

Community Assembly Room (function as day care room during day, large assembly at night and weekends)	1,100 sq.ft.
Meeting Room (for small groups)	400 sq.ft.
Rest Rooms (with outdoor access)	200 sq.ft.
Swimming Pool	25 yds.
Tennis Courts	1,000 sq.ft.
Playground	200 sq.ft.
Equipment Storage	100 sq.ft.
Bike trails, jogging, walking paths Open area for touch football, volleyball, etc.	50 spaces

Goals

GOALS AND OBJECTIVES

Goals

1. Energy Independence:

   - to provide the capability to produce energy thus reducing dependence upon outside sources.

2. Food Sufficiency:

   - to provide the capability of producing food thus reducing the dependence upon outside sources.

3. Responsiveness to Context:

   - acknowledgment of existing scale, light, views, circulation, transportation, climate, topography, and vegetation.

4. A Living Community Organism:

   - to create a place possessing those qualities necessary for life's functions and activities.

5. Pedestrian Planning:

   - eliminate pedestrian-vehicular circulation conflicts; design for people.

Objectives

1. Lower Energy Bills:

   - increase winter heat gain, reduce summer heat gain, and reduce winter heat losses through increased insulation and strategically placed glass areas and attached greenhouses.

2. Lower Food Bills:

   - greenhouse and garden food production can significantly offset food costs.

3. Sensitivity to Local Vernacular:

   - acknowledgment of existing architectural vocabulary.

4. Livibility (basic human needs):

   - provisions for exercise, sunshine and fresh air.

   - provisions for the need to get out and so somewhere (additional facilities within the site plan).

   - provisions for household chores outside the residence.

   - existance of a sense of identity and territoriality.

   - provision for individual privacy.

   - existance of private exterior.

   - flexibility of design.

5. Security:

   - define public and private outdoor spaces.

   - avoid unseen or inactive areas or access.

   - existance of social controls (visual and physical presence).

- child supervision (is there a strong relationship between dwelling and play areas).

6. Sense of Community:

   - the organization of units and open spaces to promote loitering and association of inhabitants.

   - the formulation of a range of public and private spaces.

   - does the housing organization permit the family to operate and exist as a social unit cluster dwellings to encourage neighborhood.

Concept Base

THE SUN GARDEN

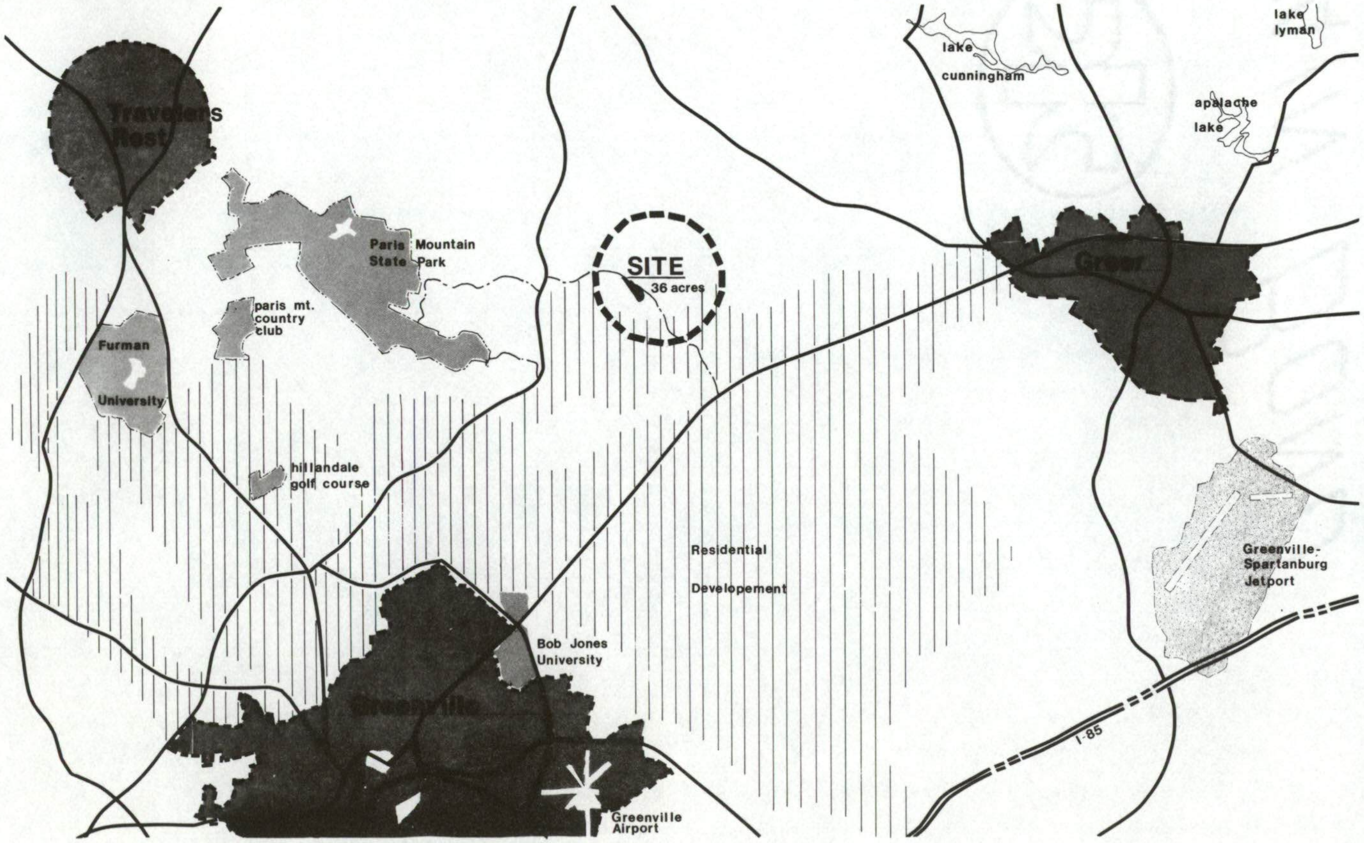
A Solar Greenhouse Residential Developement

A terminal project submitted to the faculty of the College of Architecture, Clemson University in partial fulfillment of the requirements for the degree of Master of Architecture

PETER C. SUTTON

SPRING 1979

ADVISORS: DAVIS, EFLIN, HOLTSCHNEIDER & ROTH



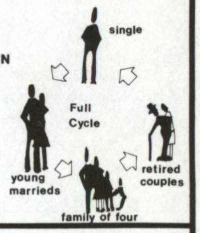
Problem Statement

TO DEVELOPE A SMALL PLANNED COMMUNITY OF MODERATE DENSITY [4.5 UNITS/ACRE] EMPHASIZING ENERGY CONSERVATION AND PASSIVE SOLAR TECHNOLOGIES. THE PROJECT WILL CONSIST OF 162 MULTI-FAMILY LIVING UNITS, RECREATION AND COMMUNITY FACILITIES AND A COMMUNITY PARK. THE PROJECT WILL BE LOCATED ON A 36 ACRE SITE IN THE NORTH SUBURBAN REGION OF GREENVILLE, SOUTH CAROLINA.

User Description

INTERESTS:

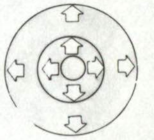
- ENERGY CONSERVATION
- HORTICULTURE
- RECREATION
- CHILD SAFETY
- COMMUNITY ACTIVITY
- OWNERSHIP



Project Scope

SOCIOLOGICAL UNIT:

Pedestrian Precinct



REQUIREMENTS:

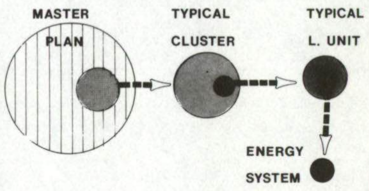
162 living units [4.5 units/acre]

local food shop

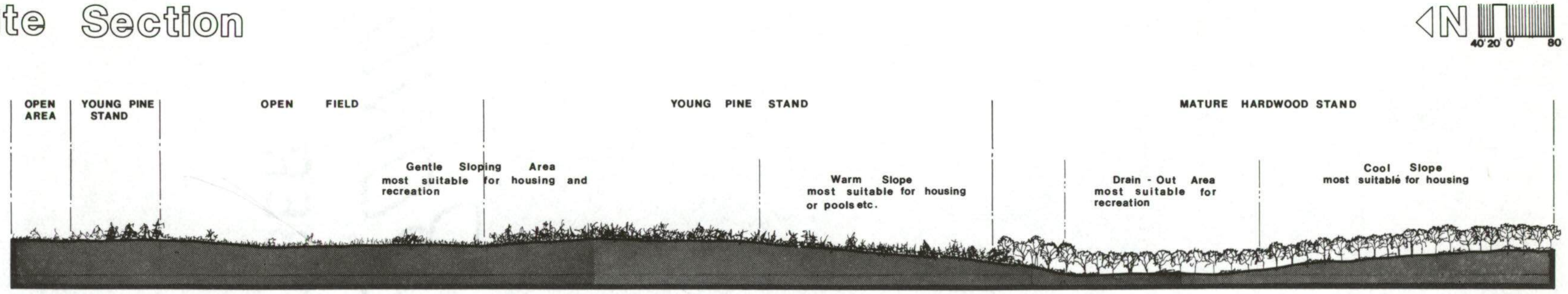
day care

community clubs

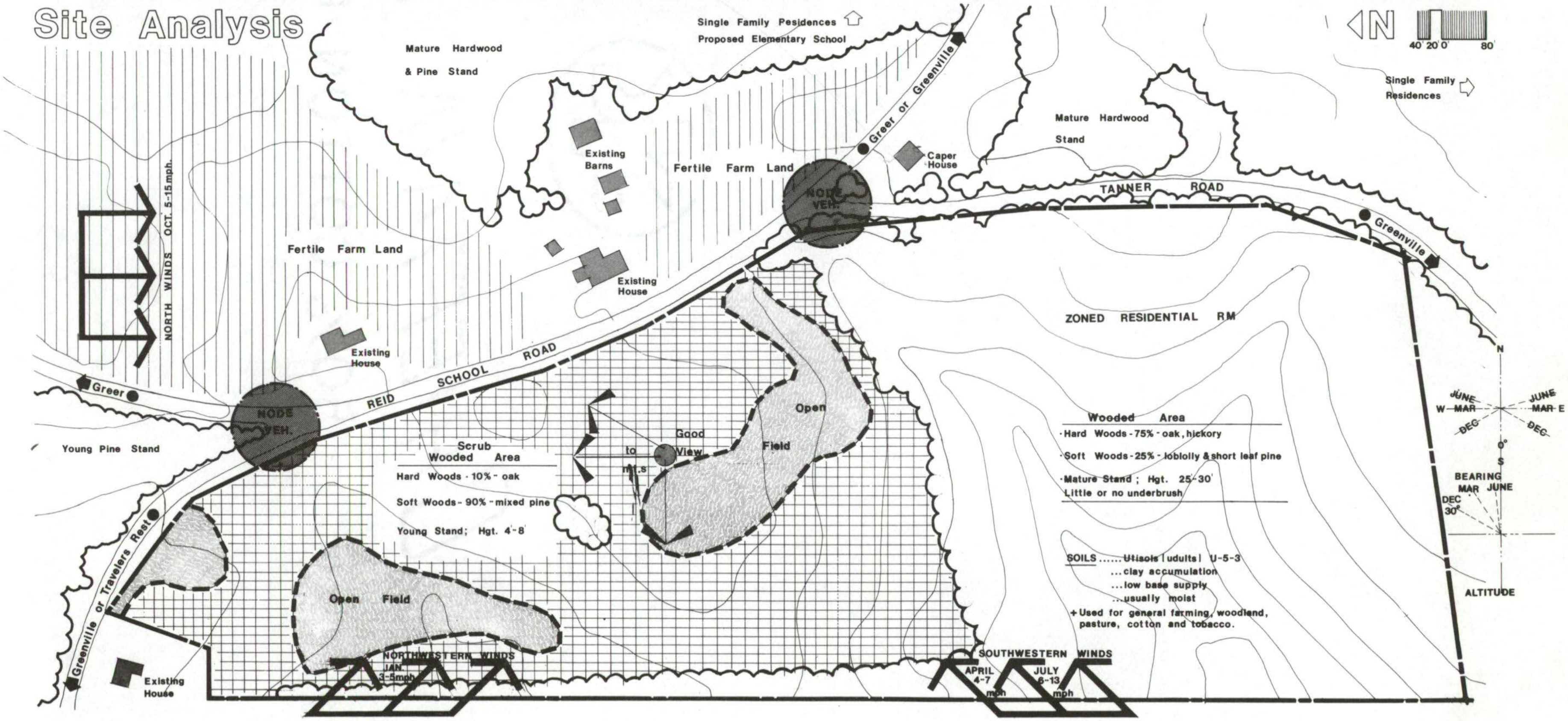
Project Approach



Site Section



Site Analysis



Local Climate

Description:

- very temperate with long spring and fall
- summers hot 80° - 90° F
- cool winter 30° - 45° F
- comfortable days are possible all year round
- wind greater than 5 mph all year (good cooling in summer, but cold in winter)
- lower humidity than coastal areas

"Sunshine is sufficiently available throughout the year to use passive solar heating when it's too cool for comfort."[37]

- need shading to prevent overheating
- day to night temperature swing can be used for cooling
- through most of summer, temperatures fluctuate 30° from day to night

"Homes which are built with massive or heavy materials can provide time lag heating and cooling by storing daytime heat and can maintain nighttime coolness throughout the following day."[38]

- tight massive construction
- wide shaded porches

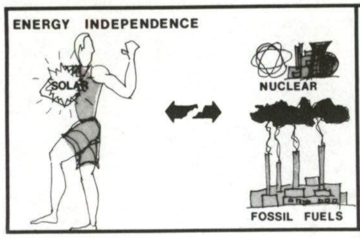
- high attic spaces (ventilation)
- south orientations
- well placed windows for passive solar heating

½ year requires heating; 2 months require cooling.

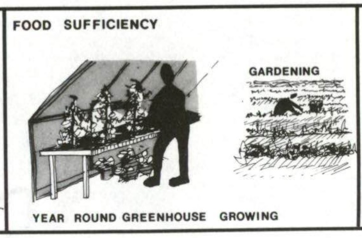
Project Solution

Goals

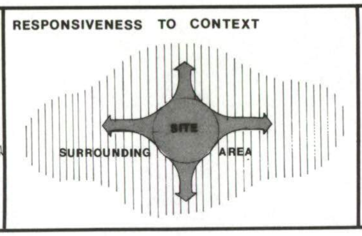
ENERGY INDEPENDENCE



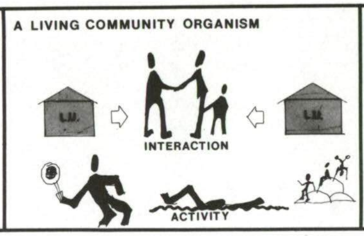
FOOD SUFFICIENCY



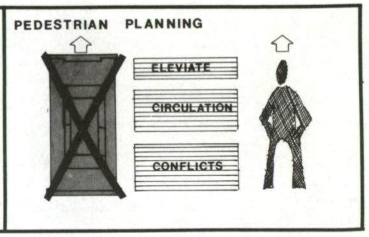
RESPONSIVENESS TO CONTEXT



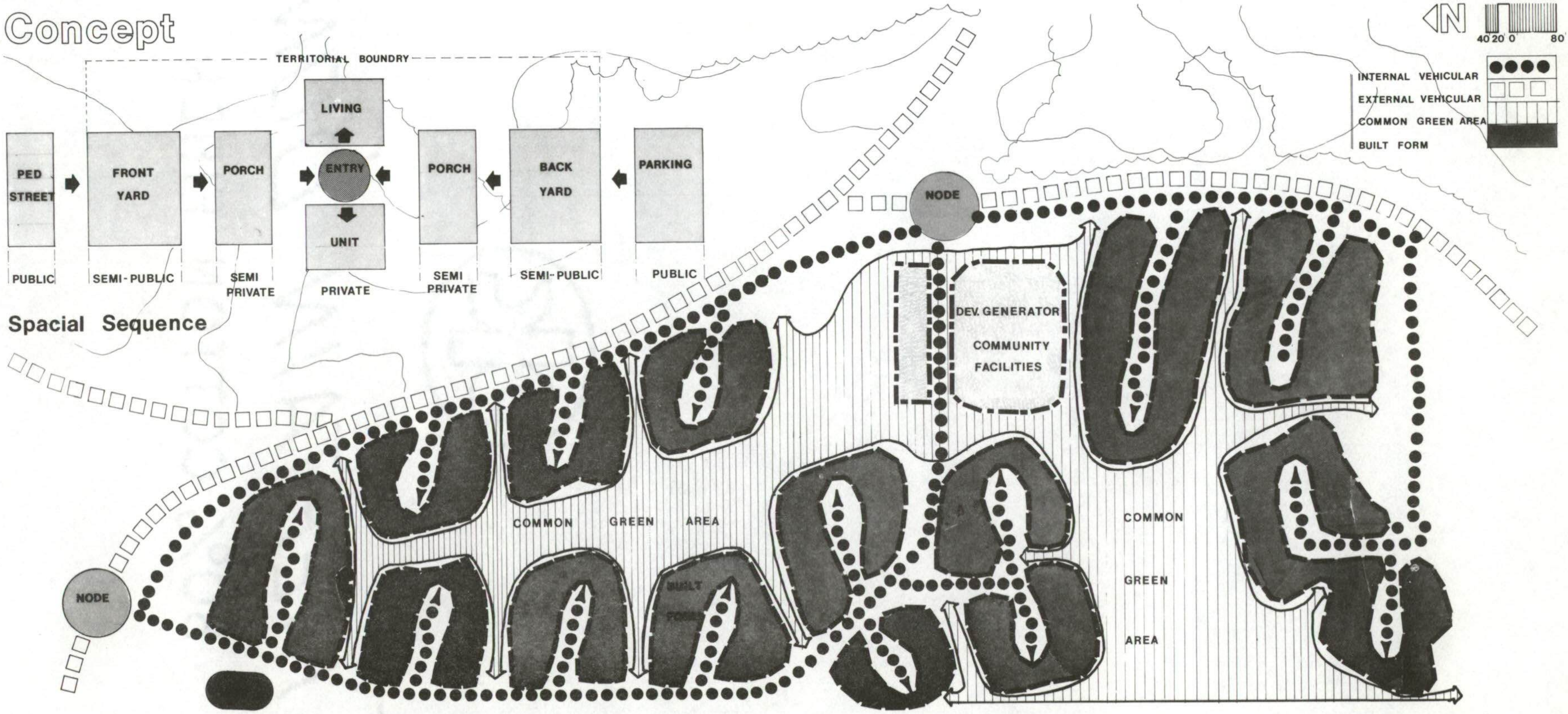
A LIVING COMMUNITY ORGANISM



PEDESTRIAN PLANNING

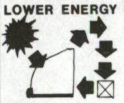


Concept

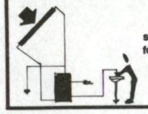


Objectives

LOWER ENERGY BILLS



passive hybrid solar space heating



solar domestic for hot water

LOWER FOOD BILLS

make greenhouse pay for itself in food prod. & energy generation

vegetables produced

money saved

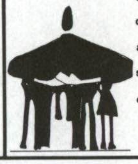
Energy

LIVABILITY

b

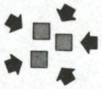
- exercise, sunshine & fresh air
- additional facilities
- outside maintenance
- identity & territoriality
- individual privacy
- private exterior spaces

SECURITY



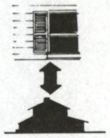
- control size & location of play areas
- define outdoor spaces
- avoid hidden areas
- social controls
- child supervision

SENSE OF COMMUNITY



- cluster dwellings to encourage neighborhood
- family as a social unit
- a range of public and private spaces
- informal groups
- promote loitering and association

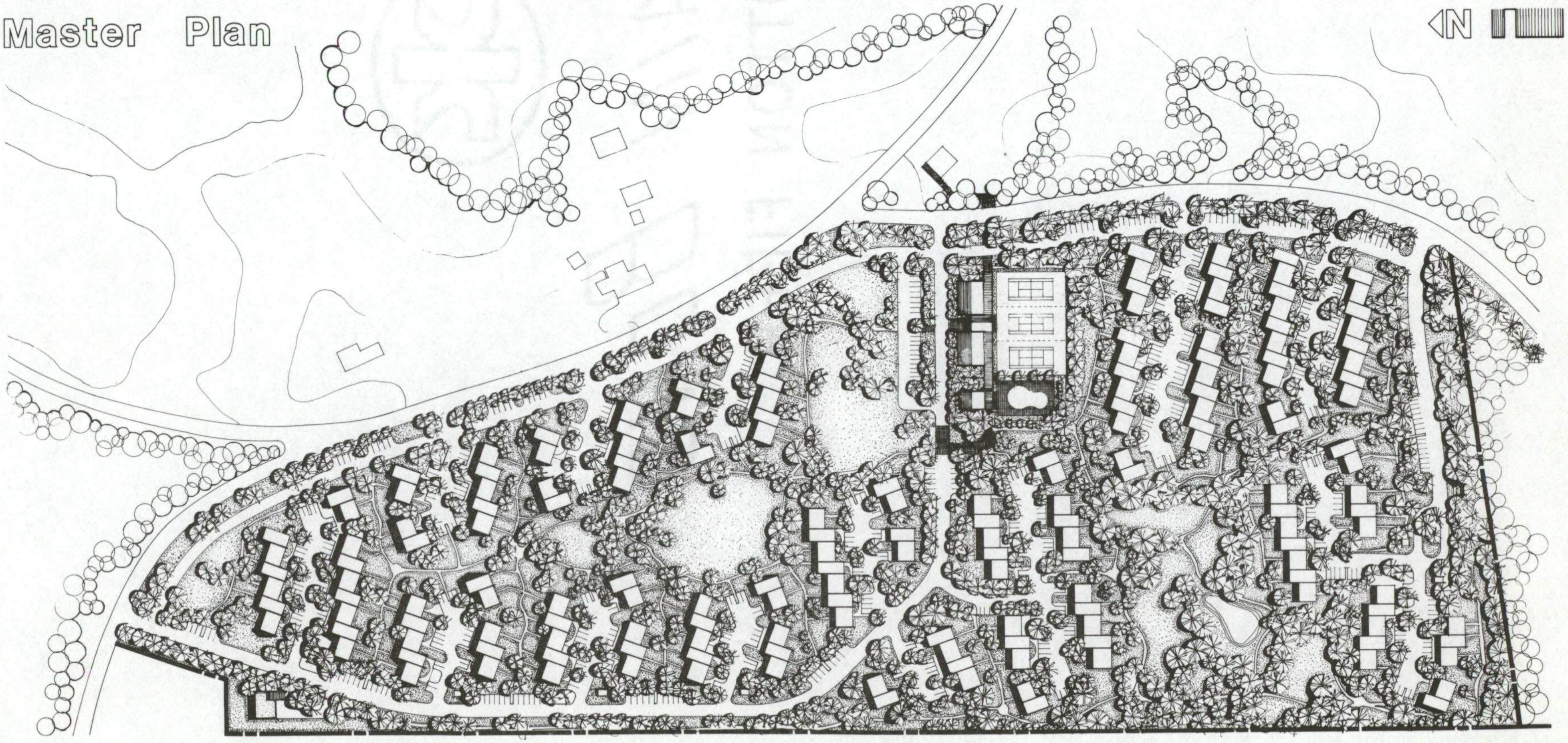
SENSITIVITY TO LOCAL VENACULAR



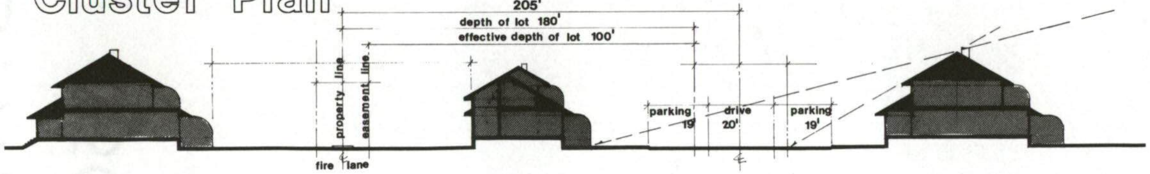
acknowledgement of existing scale and architectural vocabulary

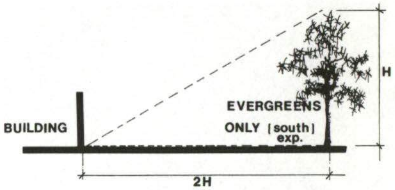
Housing

Master Plan

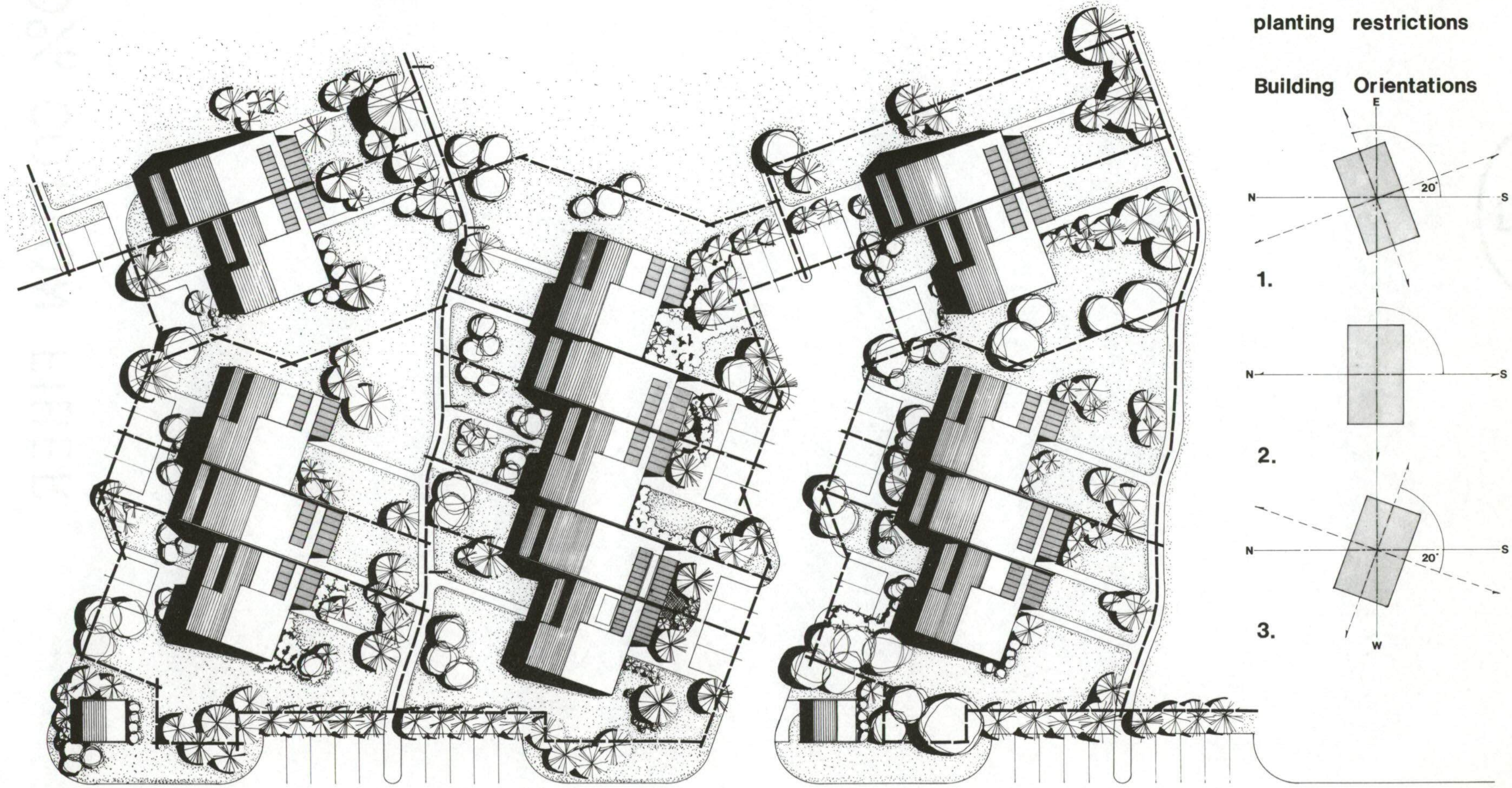


Cluster Plan

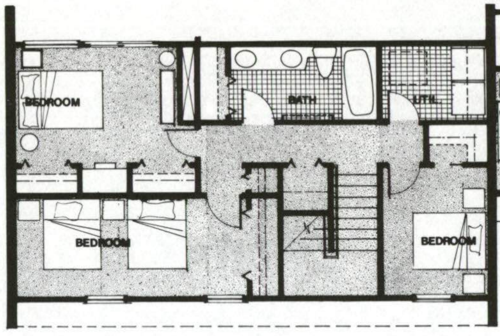




planting restrictions



Unit Plans



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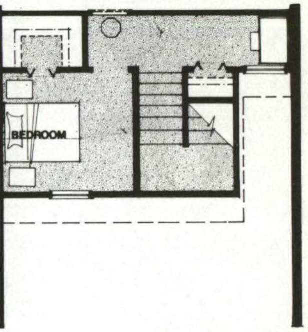

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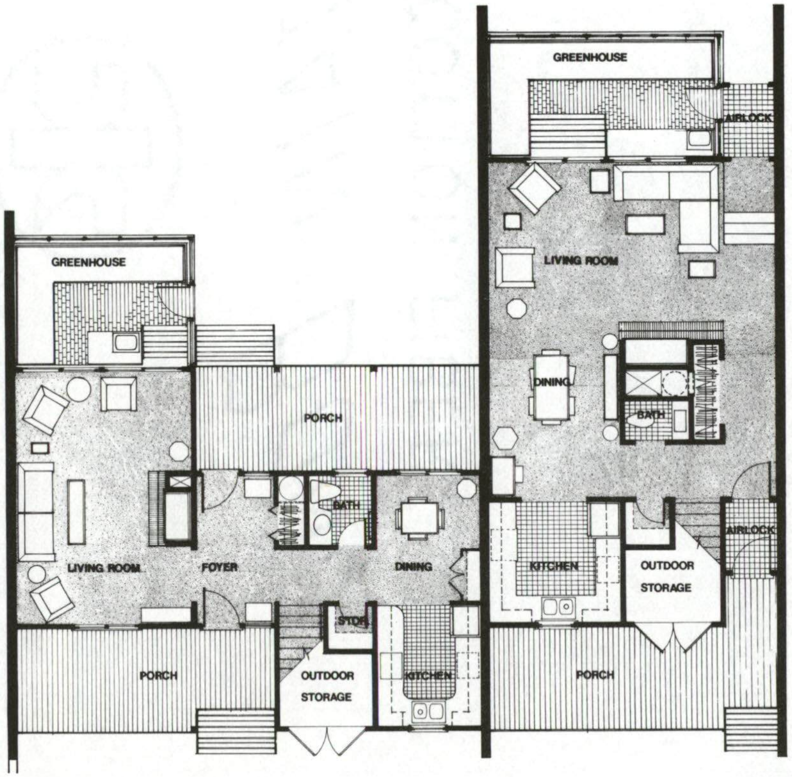

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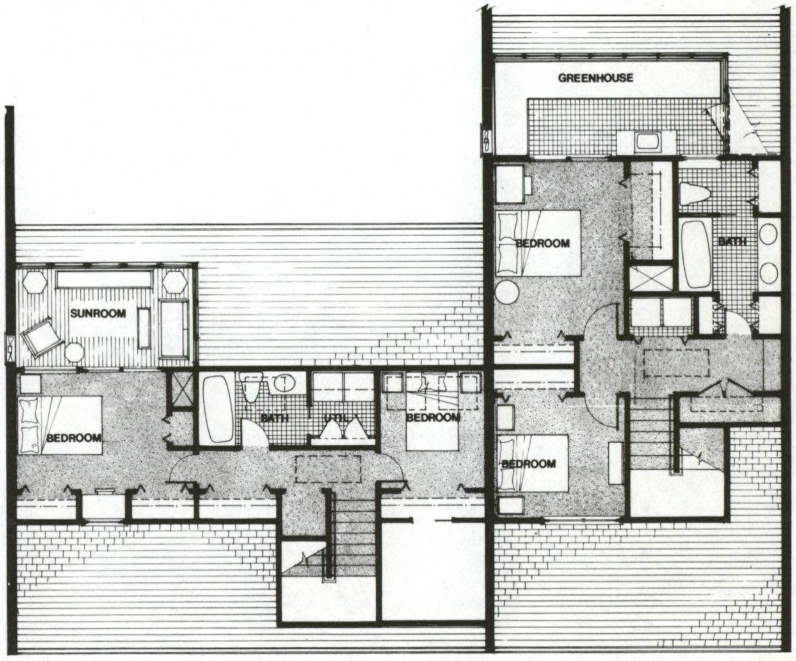

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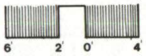
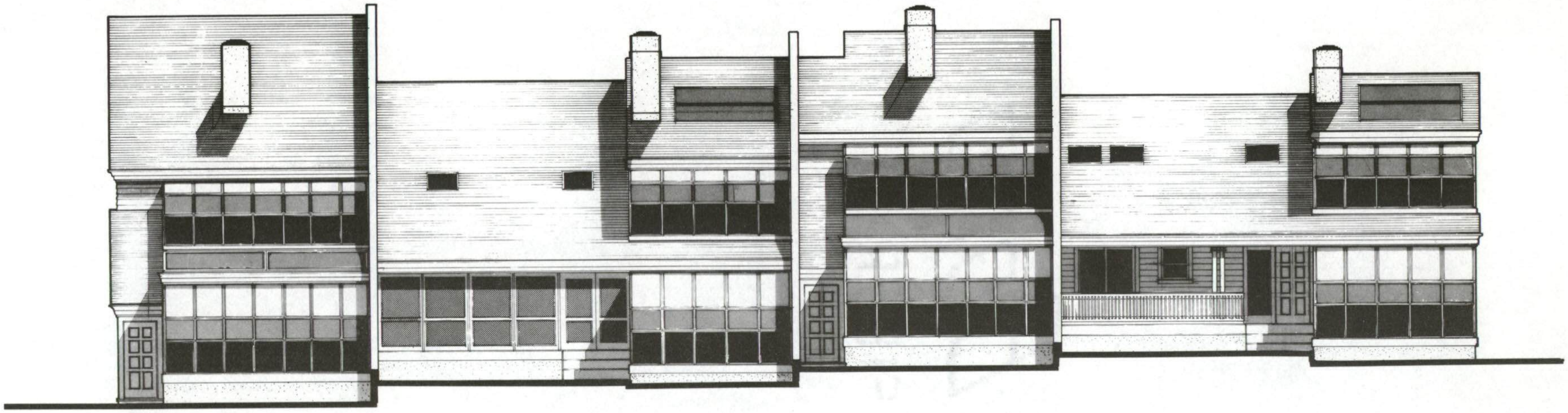
Elevations

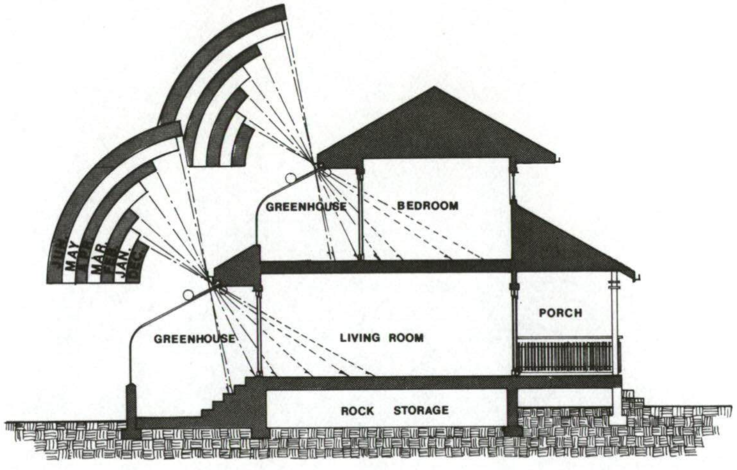




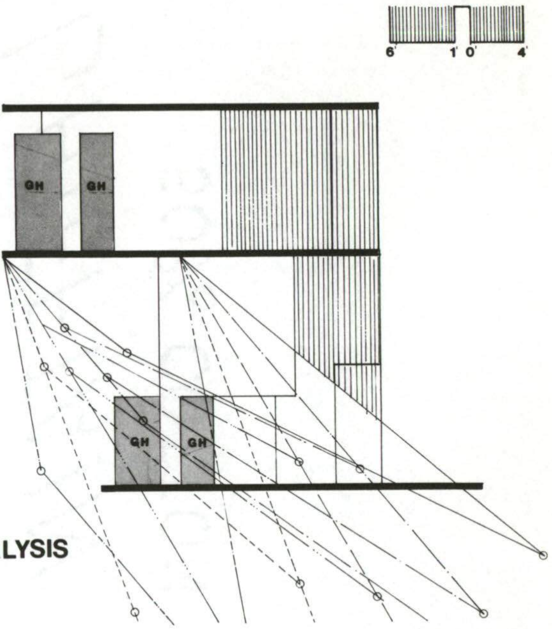
SOUTH ELEVATION

NORTH ELEVATION

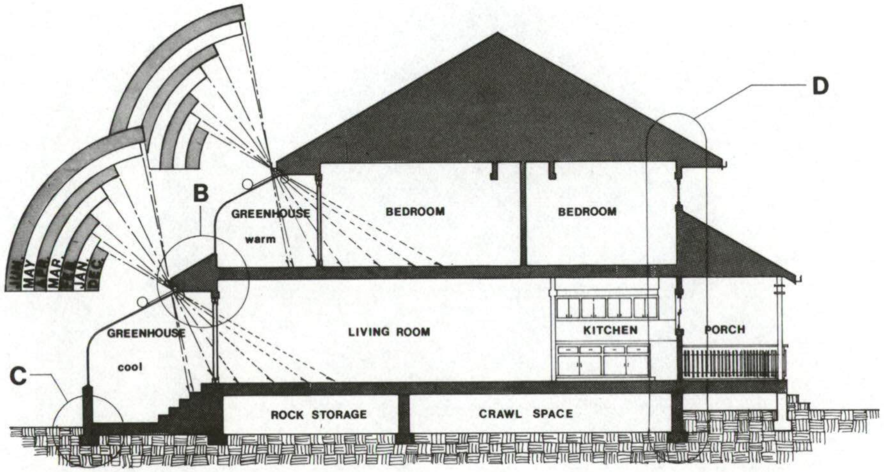
Sections



SECTION B-B



SHADING ANALYSIS



SECTION A-A

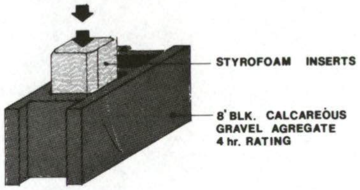
Sun Exposure Time

-BASED ON TRUE SOUTH ORIENTATION-

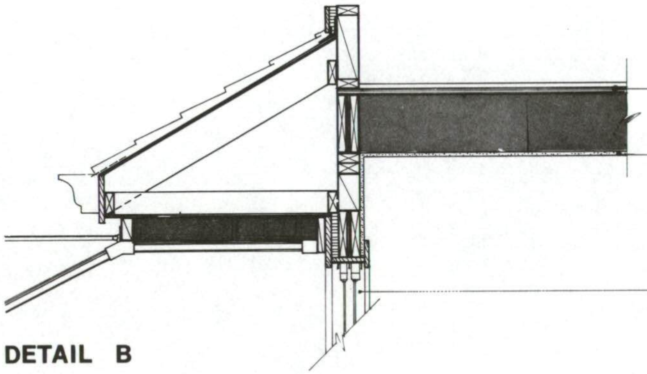
	POSSIBLE	ACTUAL	HOURS SHADED	
MONTHS	SUNSHINE / DAY	SUNSHINE / DAY	PARTIAL	FULL
Nov.	9hrs. 45min.	8hrs. 20min.	1hr. 16min.	—- 10min.
Dec.	9hrs. 5min.	8hrs. 10min.	— 55min.	— —
Jan.	9hrs. 45min.	8hrs. 20min.	1hr. 15min.	— 10min.
Feb.	10hrs. 50min.	8hrs. 35min.	1hr. 20min.	1hr. —
Mar.	12hrs. —	8hrs. 30min.	1hr. 45min.	1hr. 45min.
Total	42hrs. 40min.	34hrs. 35min.	5hrs. 15min.	2hrs. 50min.
%	100 %	81%	12 %	7 %

SHADING CHART

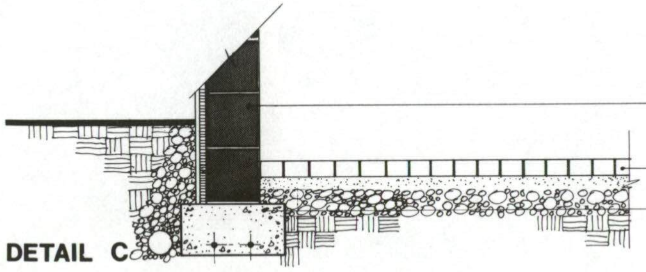
Structural Details



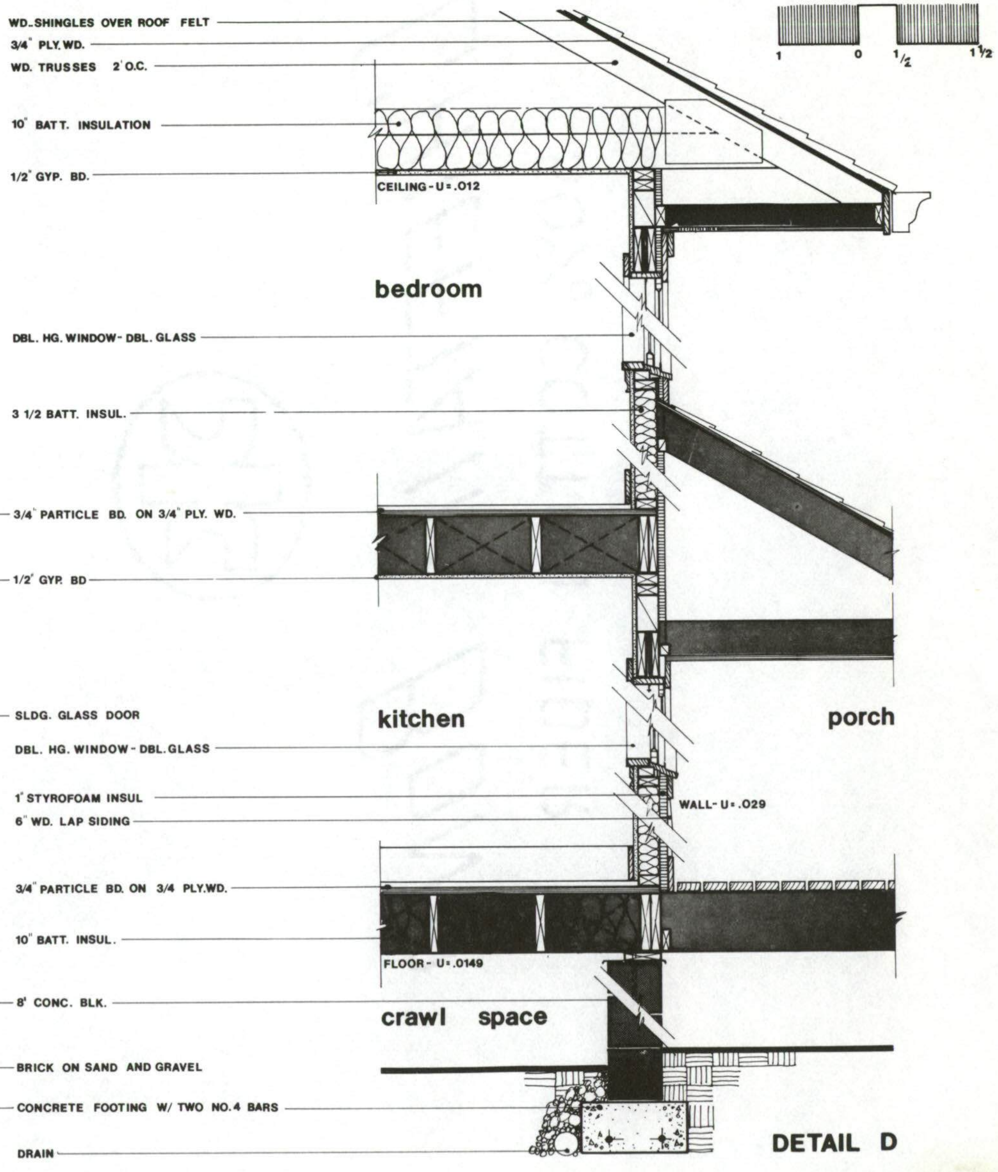
DETAIL A



DETAIL B

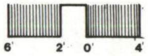


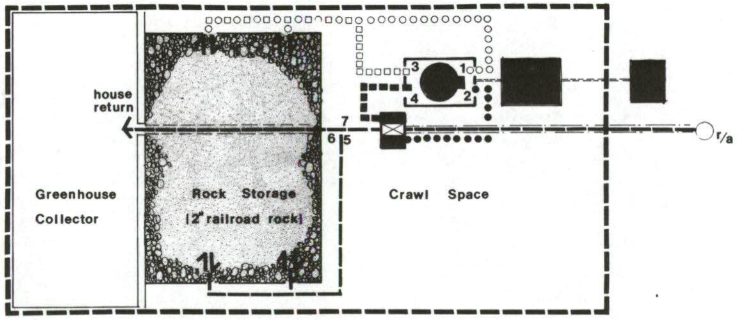
DETAIL C



DETAIL D

Mechanical - Solar

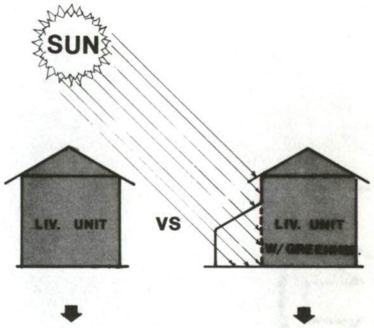




PLAN DIAGRAM / HVAC - passive hybrid

Damper Number [o = open, s = shut]	1	2	3	4	5	6	7	Fan	Back up
Normal Position	S	O	S	O	S	O	S	off	off
Solar Heating Storage	S	O	O	S	S	S	S	on	off
Solar Heating House	O	S	O	S	S	O	S	on	off
Storage Heating House	O	S	S	O	S	O	O	on	off
Back Up Heating House	O	S	S	O	S	O	O	on	on
Fresh Air Cooling Storage	O	S	S	O	O	S	O	on	off
Storage Cooling House	O	S	S	O	O	S	O	on	off

SYSTEMS CHART



WINTER

14,903 BTUS ... HEAT LOSS ... 17,036 BTUS

SUMMER

16,985 BTUS ... HEAT GAIN ... 25,117 BTUS
11,669btu·gh.Ø 20%

WINTER

14,301 BTUS ... HEAT GAIN ... 55,940 BTUS

DAILY BTU

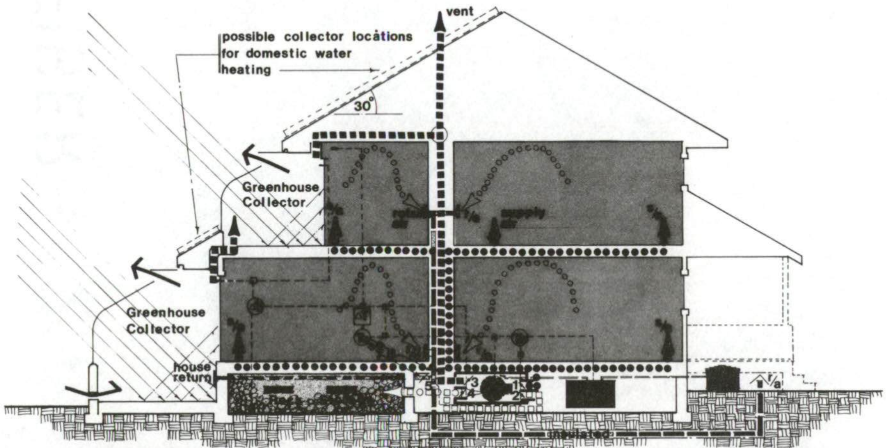
357,672 BTUS ... REQUIREMENT ... 408,864 BTUS

32% DAILY BTU 110%

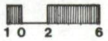
114,408BTUS ... SUPPLIED ... 447,520 BTUS

ROCK STORAGE

2" RD., 30% VOID, CAP.-3 DAYS, VOL. REQ.-1764 cu.ft



SECTION A-A_H / H.V.AC.



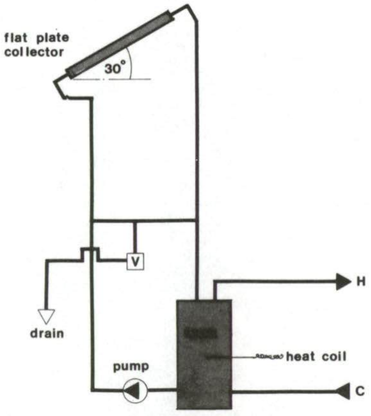
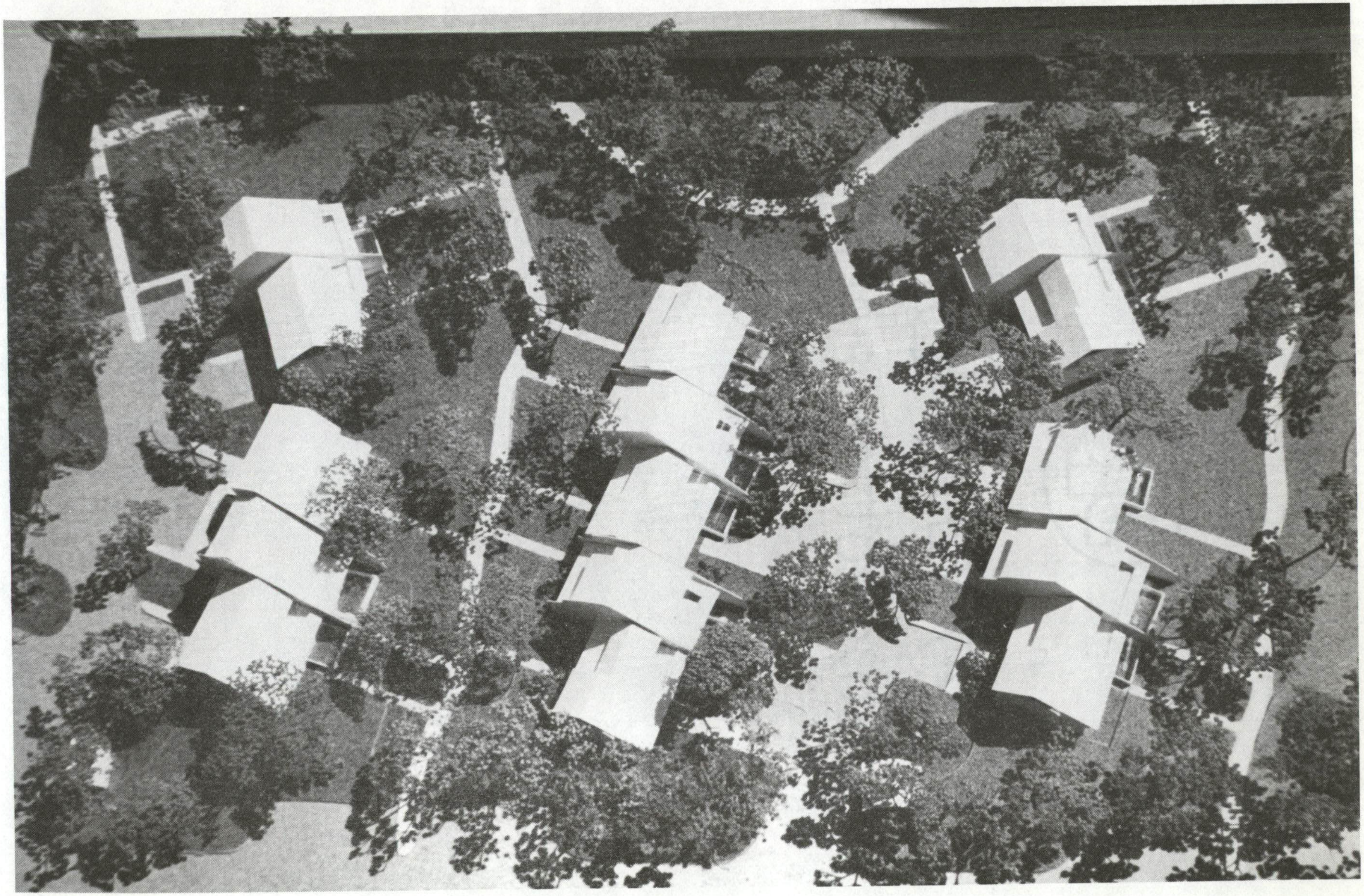


DIAGRAM - domestic hot water

TECHNICAL DATA
a comparative analysis



Conclusion

CONCLUSIONS

Energy

As a result of the initial heat loss - heat gain analysis, several design decisions have shown their importance. The clustering of the living units and implementation of a party wall make a significant energy impact and require certain planning considerations. The sharing of the party wall reduces exterior exposure thus significantly reducing heat losses. The clustering of the units allows for self-sheltering from cold winter winds; the planting of coniferous evergreens on northern exposures will additionally shelter, resulting in an overall reduction in convection heat losses and air infiltration. The strategic use of deciduous plant materials on the south side will provide summer shading and allow for winter heat gain. Solar air rights of all living units must be respected. A community landscape and building zoning ordinance would be necessary to assure maximum efficiency of the passive solar system.

The shading analysis of the cluster assures approximately 80% or better exposure to the sun throughout the critical heating months. The heating of each individual unit would require the greenhouse for solar collection and the back-up system for periods of minimum insolation. The initial calculations indicate that the passive hybrid system is capable of approximately 110% of the daily requirement, but this is during periods of maximum insulation.

The roof slope, 30°, has been designed for maximum, year round domestic hot water production. Additional space for added collectors has been provided for future expansion of hot water collection capabilities. Expansion of space heating capabilities are somewhat limited, but flat plate collectors may be added but would not work at maximum efficiency with present roof slope. Maximum efficiency can be obtained by compromising the aesthetics to a certain degree.

Life Support

The greenhouse area provided in each of the two unit types are capable of providing 63% to 81% of a family of four's yearly vegetable needs. Outdoor gardening can significantly supplement these figures during the growing season between April and October.

What can be grown? Assuming satisfactory conditions of light (south), humidity (moderate), and temperature (60°-90°), one can grow almost anything: flowers, houseplants, ornamentals, herbs, spices and vegetables.

A certain amount of horticultural and greenhouse know-how will be necessary to successfully maintain a productive situation. One should have basic understanding of plant pests and diseases, proper growing conditions - temperature, humidity, light, plant feeding, propagation, greenhouse operation and maintenance. The extent of the expertise needed will depend on the greenhouse function - some may want only a sun room with house plants while others require full food production. Community groups can help inform and educate as well as provide a source for co-operative endeavors in a variety of community and private areas of need (i.e., maintenance, food co-ops, etc.).

Ample sources are available to provide needed information (i.e., books and publications, university extension services, local nurserymen, etc.) about maintaining a greenhouse and growing herbs, vegetables and other plant materials.

Housing

A strong sense of community has already been established with solar energy and food production being the common ground for community interaction. This is further enhanced by the clustering of housing and development of common open spaces for spontaneous recreation and the community facilities for formal activities. Community involvement will be a necessity to maintain the community facilities, common open spaces and the planning necessary to maintain solar air rights and pedestrian priority.

Ownership responsibilities will have to be clearly delineated as to individual ownership, cluster ownership, and community ownership. This will eliminate any confusion of responsibility.

Planting Chart for Greenhouse Vegetables

Vegetables	Best pH	Depth to plant seed (inches)	No. of seeds to sow per gallon container	Distance between plants (inches)	No. of days to germination	Weeks needed to grow to transplant size	Days to maturity	Temperature range for germination (degrees Fahrenheit)
Beans: bush snap	6.8	1½–2	6–8	2–3	6–14	NT	45–65	70–80
pole snap	6.8	1½–2	4–6	4–6	6–14	NT	60–70	70–80
bush lima	6.0	1½–2	5–8	3–6	7–12	NT	60–80	70–80
pole lima	6.0	1½–2	4–5	6–10	7–12	NT	85–90	70–80
Windsor bean	6.2	2½	5–8	3–4	7–14	NT	80–90	70–80
Beets	6.5	½–1	10–15	2	7–10	NT	55–65	65–75
Broccoli, sprouting	6.5	½	10–15	14–18	3–10	5–7	60–80T	60–75
Brussels sprouts	6.2	½	10–15	12–18	3–10	4–6	80–90T	65–80
Cabbage	6.5	½	8–10	12–20	4–10	5–7	65–95T	65–80
Cabbage, Chinese	6.2	½	8–16	10–12	4–10	4–6	80–90	65–75
Carrot	6.0	¼	15–20	1–2	10–17	NT	60–80	60–80
Cauliflower	6.5	½	8–10	18	4–10	5–7	55–65T	65–80
Chard, Swiss	6.5	1	6–10	4–8	7–10	NT	55–65	65–75
Chives	6.0	½	8–10	8	8–12	NT	80–90	60–70
Collards	6.5	¼	10–12	10–15	4–10	4–6	65–85T	70–80
Cress, garden	6.0	¼	10–12	2–3	4–10	NT	25–45	60–70
Cucumber	7.0	1	3–5	12	6–10	4	55–65	70–90
Eggplant	5.5	¼–½	8–12	18	7–14	6–9	75–95T	70–90
Fennel, Florence	6.2	½	8–12	6	6–17	NT	120	60–75
Kale	6.5	½	8–12	8–12	3–10	4–6	55–80	60–75
Kohlrabi	6.5	½	8–12	3–4	3–10	4–6	60–70	65–75
Lettuce: head	7.0	¼–½	4–8	12–14	4–10	3–5	55–80	60–75
leaf	7.0	¼–½	8–12	4–6	4–10	3–5	45–60	60–75
Muskmelon	6.0	1	3–6	12	4–8	3–4	75–100	75–95
Onions: sets	6.0	1–2	DA	2–3	DA	DA	95–120	DA
plants	6.0	2–3	DA	2–3	DA	DA	95–120T	DA
seed	6.0	½	75	½	7–12	8	100–165	60–75
Parsley	6.0	¼–½	10–15	3–6	14–28	8	85–90	55–75
Peas	7.0	2	6–7	2–3	6–15	NT	65–85	50–70
Peppers	6.5	¼	6–8	18–24	10–20	6–8	60–80T	70–85
Radish	7.0	½	14–16	1–2	3–10	NT	20–50	60–80
Spinach	6.5	½	10–12	2–4	6–14	NT	40–65	60–80
Malabar	ND	½	4–6	12	10	NT	70	60–80
New Zealand	ND	1½	4–6	18	5–10	NT	70–80	60–80
tampala	ND	¼–½	6–10	4–6	ND	NT	21–42	60–80
Tomato	6.0	½	6	18–36	6–14	5–7	55–90T	65–80

T Number of days from setting out transplants
NT Not normally transplanted
ND No data
DA Does not apply

Technical Data (Heat Gain - Loss)

Typical Construction:		"R" Values
Roof:	3/4" plywood	0.94
	wood shingles	0.44
	air film (inside)	0.76
	air film (outside)	0.84 (su)

$R = 3$

$1/R = U_r = .335$

Ceiling:	1/2" gyp. bd.	0.45
	10" batt. insulation	62.5

$R = 62.95$

$1/R = U_c = .016$

Combined:

$$U = \frac{UrUc}{Ur + Uc}$$

$$= \frac{.335\ (.016)}{.335 + .016}$$

$$= \frac{.00536}{.431}$$

$U = .012$

Typical Construction		"R" Values
Floor:	3/4" plywood	0.94
	3/4" part. bd.	0.94
	10" batt. insulation	62.5
	air film (inside)	.84
	air film (outside)	.76

R = 65.98

1/R = U = .015

Exterior Wall:	wd. lapped siding	0.592
	1" styrofoam insul.	7.00
	4" batt. insulation	25.5
	½" gyp. bd.	0.45
	air film (vert. inside)	0.68
	air film (vert. outside)	0.25

R = 33.97

1/R = U = .029

Party Wall: (Exterior Exposed)	Stucco (Ext. fin.)	0.94
	1" styrofoam insul.	7.00
	8" concrete block (w/insul.)	5.00
	3/4" air space	1.01
	1/2" gyp. bd.	0.45
	air film (inside)	0.68
	air film (outside)	0.25

R = 15.33

1/R = U = .063

Heat Gain - Summer

1. Opaque Walls

H_6 = AU (ETD)

= 1130 (.029)29

= 950.33 BTUS

2. Roof

H_6 = AU (ETD)

= 672 (.012)29

= 233.85 BTUS

3. Floor

H_c = AU (ETD)

= 672 (.015)29

= 224 BTUS

4. Glass Conduction (without greenhouse)

H_c = AU (te - t)

= 332 (.61)25

=5063 BTUS

Glass Convection (with greenhouse)

H_c = AU (te - t)

= 584 (.61)25

= 8906 BTUS

5. Glass Convection (without greenhouse)

H_c = ASy (SC)

= 332 (.2)85

= 5644

Glass Convection (with greenhouse)

H_c = ASy (SC)

= 584 (.2)85

= 9928 BTUS

6. Mechanical

H_m = 3.4 w

= 3.4 (1,300)

= 4420 BTUS

7. People (4)

H_p = 450 BTUS

Total (without greenhouse)

HG = 16,985 BTUS

Total (with greenhouse)

HG = 25,117 BTUS

Winter Heat Loss

1. Exterior Wall

   H_c = AU (t - te)

   = 1130 (.029)55

   = 1802.4 BTUS

2. Roof

   H_r = AU (t - te)

   = 672 (.012)55

   = 444 BTUS

3. Floor

   H_f = AU (t - te)

   = 672 (.015)55

   = 554 BTUS

4. Glass (without greenhouse)

   H_g = AU (t - te)

   = 584 (.47)55

   = 15,096 BTUS

   Glass (with greenhouse)

   H_g = AU (t - te)

   = 584 (.47)55

   = 15,096 BTUS

5. Infiltration

$H_1 = .018\ g(t - te)$

$= .018\ (975)55$

= 965 BTUS (without greenhouse)

1800 BTUS (with greenhouse)

Total Heat Loss

Without greenhouse = 14,903 BTUS/hr

With greenhouse = 17,036 BTUS/hr

Conclusion

Due to greater glass area, the unit with the greenhouse logically experiences greater heat loss.

Daily BTU Requirement Without Greenhouse
(based on January)

= 357,672 BTUS

With Greenhouse

= 408,864 BTUS

Daily BTUS Supplied Without Greenhouse

=

With Greenhouse

= 561,928 BTUS

Storage Size

2" dia. railroad rock (30% void)

Max. storage temperature = 80^{o}

25^{o}

Temp. usable heat = 65^{o}

Storage coefficient (wgt/cu. ft.) temp. A
.21 (170#) 25 = 892.5 BTUS/cu. ft.

Total Volume Required for 3 day storage

= 1764 cu. ft.

Note: All calculations are approximate. Refer to M. David Egan's "Concepts in Thermal Comfort" for detailed explanation of analysis.

FOOTNOTES

[1] Davis and Schubert. Alternative Natural Energy Sources. (New York, N. Y.: Van Nostrand Rheinhold Co., 1974), p. 10.

[2] *Ibid.*

[3] *Ibid.*

[4] *Ibid.*, p. 16.

[5] *Ibid.*, p. 9.

[6] *Ibid.*, p. 8.

[7] Bruce Anderson, The Solar Home Book (Harrisville, N. H.: Chesire Books, 1976), p. 8.

[8] Chahroudi and Miller, "Buildings as Organisms," Architecture Design (March 1975), p. 158.

[9] Hans Thirring, Energy For Man (New York, N. Y.: Harper & Row Publishers, 1976), p. 261.

[10] Congressional Office, "Applications of Solar Technology at Todays Energy Needs." AIA Journal (October 1977), p. 24.

[11] Chahroudi and Miller, p. 158.

[12] *Ibid.*, p. 157.

[13] Martin Davis, "Solar Greenhouse Residence Project," Journal of Architecture Education (Vol. XXX, 1977), pp. 21-22.

[14] James C. McCullagh, The Solar Greenhouse Book (Emmaus, Pa.: Rodale Press, 1978), p. 4.

[15] Davis, p. 22.

[16] *Ibid.*

[17] McCullagh, p. 4.

[18] *Ibid.*, Introduction.

[19] *Ibid.*, p. 4.

[20] *Ibid.*, p. 158

[21] Thirring, p. 15.

[22] Urban Development Corporation, *Another Chance for Housing* (New York, N. Y., 1973), p. 6.

[23] *Ibid.*, Introduction.

[24] Davis and Schubert, p. 13.

[25] Sam Davis, *The Form of Housing* (New York, N. Y.: Van Nostrand Rheinhold Company, 1977), Introduction.

[26] Davis, Schubert, pp. 1-3.

[27] Bruce Anderson, *Solar Energy* (New York, N. Y.: McGraw Hill, 1976), pp. (not available).

[28] Drake. AIA Research Corporation, *Solar Dwelling Design Concepts* (Washington, D. C.: The U. S. Dept. of Housing and Urban Development Corporation, 1976), pp. 18-31.

[29] *Ibid.*

[30] *Ibid.*

[31] Anderson, *Solar Energy*.

[32] *Ibid.*

[33] Drake, pp. 30-31.

[34] *Ibid.*

[35] *Ibid.*

[36] Gwen Bell, *Human Identity in the Urban Environment* (Baltimore, Maryland: Penguin Books, 1972), pp. 256-185.

BIBLIOGRAPHY

AIA Research Corporation. Solar Dwelling Design Concepts. The U. S. Dept. of Housing and Urban Development. 1976.

"Applications of Solar Technology to Todays Energy Needs." AIA Journal. October 1977.

Anderson, Bruce. Solar Energy. New York: McGraw-Hill, 1976.

Anderson, Bruce. The Solar Home Book. Harrisville: Cheshire Books, 1976.

"Buildings as Organisms." Architecture Design. March 1975.

Bell, Gwen. Human Identity in the Urban Environment. Maryland: Penguin Books, 1972.

Davis, Sam. The Form of Housing. New York: Van Nostrand Rheinhold Company, 1974.

Egan, M. David. Concepts in Thermal Comfort. New York, N. Y., 1977.

"Solar Greenhouse Residence Project." Journal of Architecture Education. 1975-77, vol. XXX.

McCullagh, James C. The Solar Greenhouse Book. Pennsylvania: Rodale Press, 1978.

Stein, Clarence S. Toward New Towns for America. New York: Rheinhold Publishing Company, 1957.

Thirring, Hans. Energy for Man. New York: Harper & Row Publishers, 1976.

Urban Development Corporation. Another Chance for Housing. New York: Modern Art Publications Division, 1973.