SOLAR DOME HOME for NORTHEAST USA

Project For The National Science Foundation's
Workshop On Solar Energy And Energy Engineering

by Kim Briggs

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Advisor: Ali Yousef

ABSTRACT

The purpose of this project is the design of a house in southern Connecticut. The house will be as energy self-sufficient as possible while also maintaining an aesthetically pleasing structure. This will done through the use of soft-technology sources of energy including wind energy, methane gas, and passive solar energy, and also through the use of earth sheltered housing. In the paper, background information is given on the different types of energy and then ways of making use of each one is discussed.

CONTENTS

INTRODUCTION

The purpose of this project is to design a so called dream house in southern Connecticut. The reason for the term "dream house" is that the house will be as energy efficient as possible while at the same time achieving an aesthetically pleasing design. These goals will be accomplished by using alternative sources of energy and hence the house will also be as independent from public utilities as possible.

The main purpose of this is not to isolate oneself so that interaction with the rest of society will be at a bare minimum. Rather, the two basic reasons for wanting to be energy self-sufficient are the cost and the control of existing non-renewable souces of energy.

In New England, where the house is to be designed for, the cost of heating a home with either natural gas or electricity has skyrocketed in the past decade and there are no signs indicating a reversal of this trend. As an example, the cost of natural gas used for a three bedroom house in space heating, domestic hot water, and cooking was $247 for the month of Janurary in 1980 (1).

Also, it is psychologically a good thing to be producing your own power and therefore in greater control of your own life. Besides that, it would be nice not to be dependent on a giant energy conglomerate controlling the distribution of natural resources, which it had come down to in certain parts of the country where people could not get fuel delivered to them.

How all this energy independence will be accomplished is through the use of soft-techology renewable sources of energy including: wind, methane, and passive solar energy and also through the use of earth sheltered housing.

In saying that these sources of energy will be used the idea is not to go into detail designing each system. Instead, the objective of this paper is to introduce a general concept of what an energy self-sufficient house in southern Connecticut might look like and the format it might take to achieve this.

Passive Solar Energy

Passive solar energy systems transport heat by non-mechanical means. A common definition of passive solar heating is that it is a heating system in which the thermal energy flows by natural means such as radiation, conduction, and natural convection—in other words, the building itself is the system(1). If a fan is used in circulating the air than the set-up is called a hybrid passive system.

The idea behind aiding the heating of a house with passive solar energy is a relatively simple one. The heating and cooling of a space are essentially based on the same concept of maintaining a temperature difference between the mass (thermal storage) and the surrounding area (living space) of a house.

This difference in temperature is achieved through two basic elements: south facing glazing for solar collection and massive materials for heat absorption, storage, and distribution. To be affective as a heat storage medium a substance must have a high density and a high thermal conductivity, as well as a high specific heat.

Another important part of any passive system is insulation. These systems can only operate on the energy available in the immediate environment (as opposed to active systems which import energy) and hence, once radiation is collected and reradiated into the space it must be kept there as efficiently as possible to reduce heat lost to the outdoors.

As far as the ways of collecting sunlight are concerned, there are three basic categories in which they may be broken up into. The categories are direct gain, indirect gain, and isolated gain.

Direct gain of solar energy is where the actual living space is directly heated by sunlight entering through the glazing. This method **works** well in cloudy climates with large amounts of diffuse radiation and will work more effectively than an active system in such areas. When using direct gain there is a larger amount of south facing windows and strategically located thermal mass. Storage for direct gain is not recommended where cloudy or foggy weather prevails because of the time needed to reheat a mass after it has radiated its energy, for the same reason minimum thicknesses of mass should also be used.

Indirect gain consists of sunlight striking a thermal mass between the space and the outdoors. The radiation is absorbed by the mass, converted to thermal energy and transferred to the living space. There are basically two types of indirect gain, roof ponds and thermal storage walls. Indirect gain collectors are often integrated as part of a house's decor. Providing storage for indirect gain systems consists of increasing the surface area of a wall (or roof pond) and not its thickness.

Isolated gain involves a system that is separate from the living area. The most common application of isolated gain is a convection loop which uses natural convection to circulate air. The pictures on the following pages show the general concepts behind the different types of passive solar energy gain.

Figures on pgs. 5+6 are from:
(Mazria) The Passive Solar Energy Book

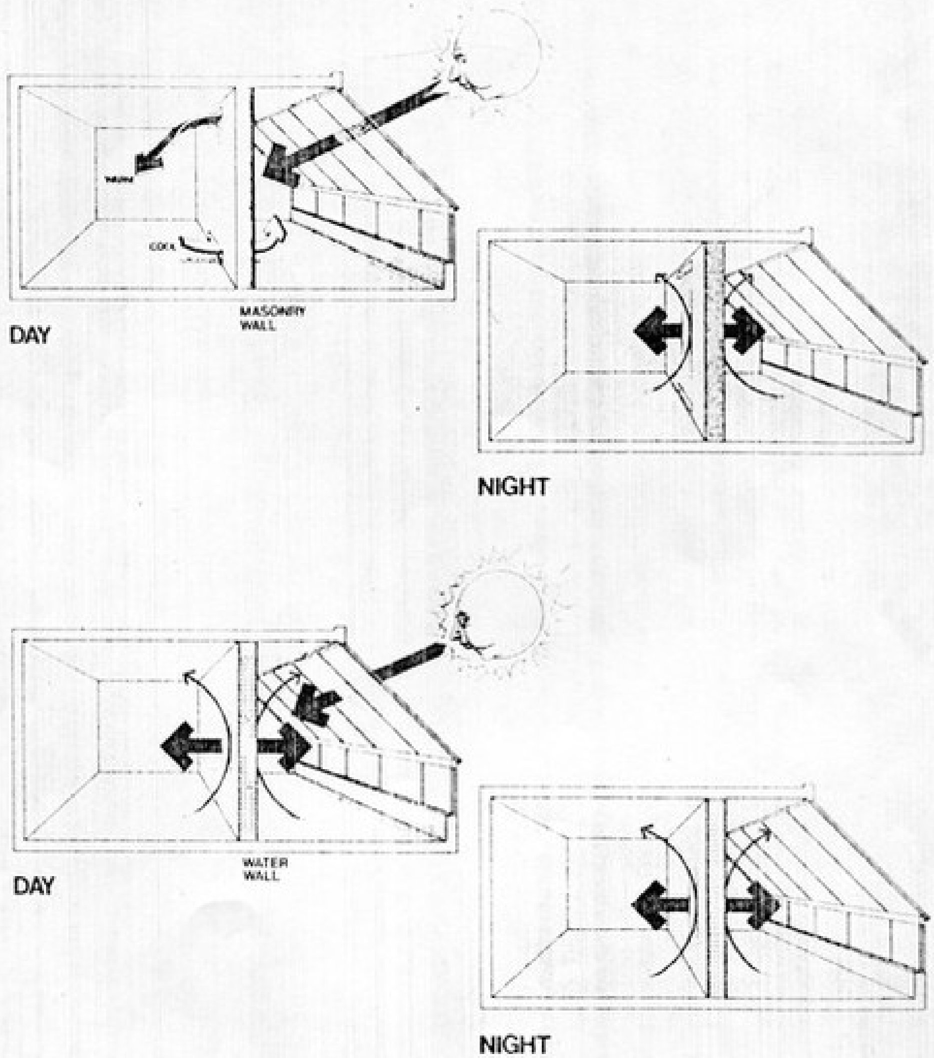


Fig. III–10: Indirect gain—attached greenhouse

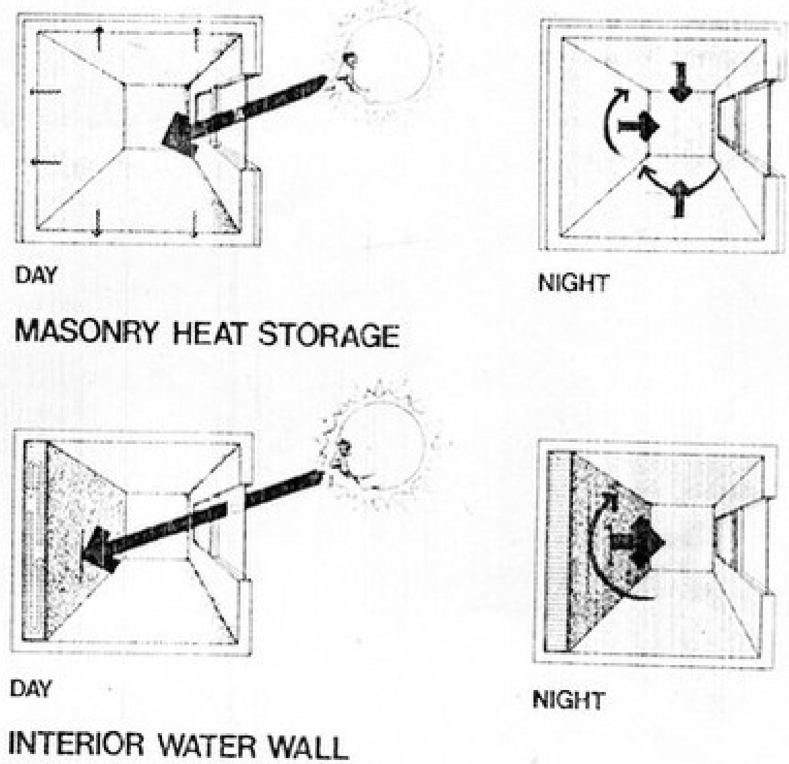


Fig. III–1: Direct gain systems.

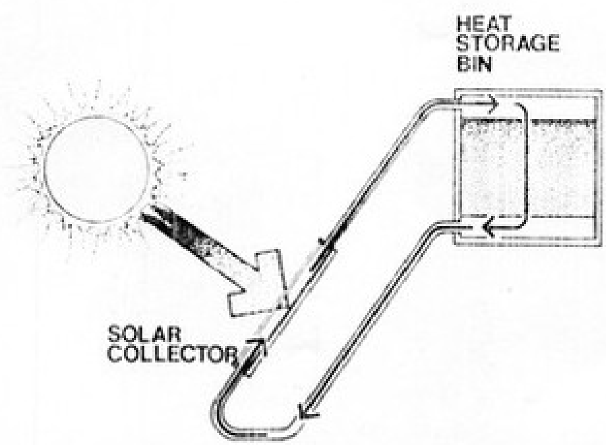


Fig. III–13: Convective loop.

Greenhouses

The advantages of a solar greenhouse include utilizing heat gain during the winter, growing one's own food, and the aesthetic pleasure of having a garden in one's own home. For plant growth the four basic criteria of light, temperature, atmosphere, and ventallation must be considered so as to suit the local climate and the type of plants to be grown. For solar heat gain and storage there are numerous criteria that must be considered.

In orientating the greenhouse it should be south facing and elongated along the east-west axis (but it may be off by as much as 20^{o} without a significant change). By doing this a greenhouse will receive 25% more solar radiation on January 21^{st} than a greenhouse elongated north and south.

Whenever possible it is wise to recess an attached greenhouse into the building so that the east and west walls are common portions of the house. This reduces heat loss and increases the amount of heat transferred to adjacent spaces. Heat loss can also be reduced by avoiding any unecessary construction joints and also by providing earth berms where the sun does not reach.

Further ways of preventing heat loss are to reduce the window area (at a trade-off with wanted radiation), to use multiple layers of glazing (at a trade-off with sunlight intensity—usually two layers is optimum), and also to use movable insulation during the night; using 3" fiberglass nightime insulation over a 14 hour period can cut daily heat losses (through double glazing) by a factor of one half.

When sizing greenhouses in cold climates usually .65-1.5 ft^2

of south facing glazing is used for every 1ft^2 of adjacent building floor area. This amount of glazing collects enough heat during a <u>clear</u> winter day to keep the greenhouse and adj-acent area at an average temperature of 60-70^{o}F.

The angle of the south slope of the greenhouse roof should be figured for a period around January or February when the effect of reduced temperature and radiation are the worst as opposed to December 21st when the sun is the lowest in the sky. This angle is usually somewhere around latitude plus twenty degrees but should be a little less steep if there are a large number of cloudy days during the heating season.

The storage of heat is an important part of any solar green-greenhouse which helps to prevent overheating during the day and underheating during the night. The simplest way to collect and store heat is in massive materials commonly located against the north wall, as the north wall, or at the front of the south facing kneewall.

If the north wall is used as a source of heat storage and transfer then it is best to make it a medium or dark color and and avoid blocking direct sunlight to it. In cool and cold climates small vents or operable windows should be located in the wall to allow heat from the greenhouse directly into the house; but masonry, if used alone, cannot store enough heat, in cold climates extra thermal mass is needed (e.g. water drums). If a water wall is used instead of masonry, the larger the volume of water, the smaller the daily temperature fluctuations. With .65

or more cubic feet of water for every 1ft^2 of glazing area no extra mass is usually needed except in cold climates. However, a water wall is only slightly more efficient than a masonry one.

Methane

Methane gas is produced by the breakdown of organic materials by either aerobic (with oxygen) or anaerobic (without oxygen) decay. Natural anaerobic decay processes can be mimicked and hastened by putting organic waste in in insulated airtight containers called digesters.

There are two different kinds of digesters. The first type, or batch-load digester, is filled all at once with organic wastes, sealed, and emptied when materials stop producing gas; the second is the continuous load digester which is fed a little, regularly, so gas and fertilizers are produced continuously.

Batch load digesters have advantages where availability of raw materials is sporadic or limited to course plant waste which contains undigestable material that can be easily removed. They also require little daily attention. Disadvantages of batch load digesters are that it takes a lot of energy to empty and load them and gas production tends to be sporatic (although this could be corrected by connecting multiple digesters to one tank). With continuous load digesters the puoduction of gas is more or less continuous and reliable; they are also especially efficient if fed a regular supply of easy digestable waste.

Digesters are loaded with a mixture of water and waste materials (such as animal manure, garden debris and food wastes) called slurry, and in the case of continuous loa digesters each daily load flows in one end and displaces the previous days load. Each load progresses down the length of the digester to a point where methane baceria are active and large bubbles form and force their way to the top.

Three other endproducts of this decay process are sludge, supernatant, and scum. Sludge is the spent solids of the original manure (or other wastes) reduced to about forty percent of the volume it occupied in its raw state. Supernatant is the spent liquids of the original slurry. Both sludge and supernatant make excellint fertilizers for crops and pond cultures but should be aged a few weeks before using them in this way. Scum is a mixture of course fibrous material, accumulation and removal of scum is one one of the most serious problems with continuous load digesters.

A balance between organic acid producing bacteria and methane producing bacteria is achieved by feeding enough wastes and maintaining the proper temperature, quality of raw materials, and pH in the digester. The pH requirement of a degester is between 7.5 and8.5. However, when a majority of what is being produced is methane, a buffer is formed.

The greatest efficiency of a digester will be obtained when the temperature is between ninety and ninety-five degrees farenheit, But gas production can proceed in ranges from 85-105^{O}F(3). The most effective way of keeping a digester warm is to circulate heated water, which can be waste hot water from a shower or washer, through pipes or coils placed within the digester. A thermostat in the water heater should be set at 140°F (or slurry will cake on the pipes) and digester thermostat set at 95°F (3). A ratio of one sq. foot of coil area per one hundred cubic feet of digester volume is recommended.

It is also a good idea to insulate the digerter. Porous materials are not recommended because they can trap gas if leaked and methane is combustionable if it makes up nine percent of the surrounding air. Styrofoam sheets used in packing are good insulators (although slightly flamable they will usually melt first).

Raw materials in the form of the elements carbon (in carbohydrates) and nitrogen are the chief foods of anaerobic bacteria; carbon is used up about thirty times faster than nitrogen and therefore a 30 to 1 ratio of carbon to nitrogen optimum for wastes fed to the digester.

Wind Energy

If an area has an average wind speed of over 10mph for two or three days per week than the site is usually considered adequate for wind power. However, it may not always be evident if a site is suitable just by being familiar with it at ground level. For instance, wind speeds thirty feet above the ground are twenty to fifty percent stronger than on its suface.

Conversely from that, the sensation of strong gusts of wind does not necessarily mean good winds for producing electricity. Rough terrains act to create large amounts of turbulance and hence it may seem "windy", But air flowing over rounded hills can act to increase the wind power density and therefore is the more desirable type. For this reason it is highly recommended that the propellers of a wind generator should be close to ten feet above surrounding objects within a 500 ft radius, if possible, to avoid tubulance.

At the present time small wind electrical systems are not economically competetive with electricity from utility companies. However, increasing costs of electricity from utilities, government subsidies for individuals installing wind systems, and/or decreased capital costs of these systems as a result of a large volume of production may greatly increase their economic competetiveness.

Net energy analysis of small wind systems have concluded that the systems are energetically competetive with existing utilities. The maximum efficiency any wind generator can obtain is 60%, but even with a more realistic conversion efficieny of 5% current estimates of the economics of wind power in favorable wind locations put the cost of power at $325 per installed kW, as compared with nuclear power at about $300 per kW and $240 per kW for coal fired fired plants(4).

Wind Energy

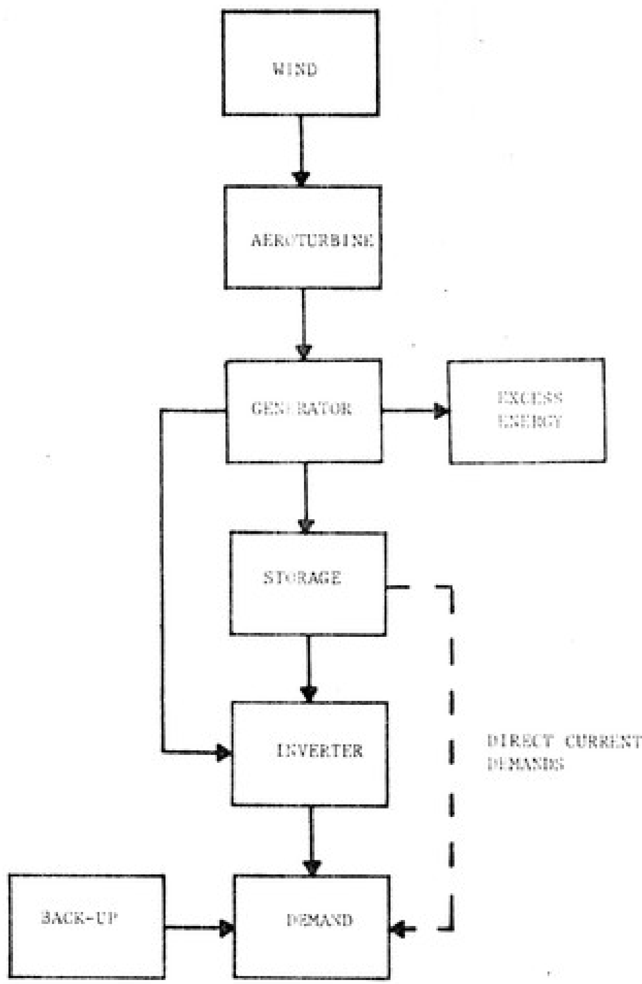
By looking at the figure on the following page, one can get a general idea of the components of a small wind-power system. The wind, acting as a force, turns a propeller connected to an aeroturbine which operates an alternator or a generator to convert mechanical energy into electrical energy which can either be used directly or may be stored; the most common means used now being lead storage batteries. Because most electrical demands are for alternating current an inverter is located between the storage and demand. A back-up system is also included which may be something such as a small fossil fuel generator or an existing electrical grid.

The limitations of small wind generators are that most systems don't provide 230 volts ~~volts~~ for large appliances (e.g. electric ranges, air conditioners, clothes dryers, etc.) and a single generator cannot always meet the average American families needs, which can be up to 300KW per month.

The following are terms useful to know when researching or dealing with wind energy: Rated Power-The maximum electrical output of a generator, Swept Area- The area through which the generator's blades operate (i.e. the blade diameter), Cut-in Speed-The wind speed at which the generator begins to produce electricity, Rated Speed- The wind speed at which the generator produces its rated power, Cut out Speed- The wind speed at which the generator shuts down to avoid damage.

FIGURE 1

BASIC COMPONENTS OF A SMALL WIND ELECTRIC SYSTEM



Underground Construction

When considering the total U. S. energy consumption, residential space heating uses 11% and residential air conditioning 1%; commercial space heating consumes 7% and 2% goes for its air conditioning. As can be seen from these figures, the potential energy saving through more efficient building design is quite large.

According to some estimates, complete earth sheltered housing could provide savings on heating and cooling costs of up to 75%. The house being designed for this project is not completely earth sheltered, but by maximizing earth mass around the building energy consumption may be minimized. Two ways energy conservation factors affect the overall configuration of a dwelling are by imposing a compact plan on the geometry and increasing the amount of earth surrounding the building.

The earth itself is not a good insulator, but it is an excellent temperature moderator. As an insulator, soil is about twenty-five times less efficient than todays best insulation. It is not insulating quality but rather thermal mass that makes the earth so appealing for use in construction.

This large amount of thermal mass surrounding a building greatly reduces temperature variations. Heat gets trapped underground in the summer from warm weather and rains, then in the winter the top of the ground freezes and the heat is released very slowly.

For example, below an 8 in. depth in soil, temperature fluctuations are essentially eliminated even with air temperature ranging from 15-45°F. At a depth of five feet, in a study done in St. Paul, Minnesota (5), soil temperature went to yearly extremes of 35-65°F while air temperatures ranged from -30-100°F.

In typical above grade construction energy is wasted by unwanted heating and cooling of exterior surroundings while in earth sheltered housing the amount of wasted energy is significantly decreased because the temperature difference is so much smaller. Heat losses due to infiltration are also reduced to a great extent or eliminated.

If underground walls are totally insulated the building will be isolated from the soil and will not benefit as much from the soil's mass. It is most important to increase the thermal resistance near the top of the wall and reduce the amount of insulation on the way down. Below seven feet in depth the insulation may be omitted due to insignificant temperature changes.

In general, advantages of earth sheltered housing (some of them only apply to completely sheltered design), include low utility costs, land conservation, low maintenance (the building is protected from the elements and there is no exterior wall maintenance), water pipes will not freeze, there is a safety factor from outside fires, hurricanes, and earthquakes; security is improved, there are lower insurance rates, and the structure has an extremely long life.

Passive Solar Energy

Near the geographical area where the house is to be designed for, a study done at MIT(5) on an active flat plate system found that the cost of collectors and installation was about five times greater than the saving in fuel cost over a ten year period. Since conditions don't seem too favorable for active systems they will not be included in the design although it should be remembered that the possibility may exist.

Generally speaking, the heat required to heat a home is directly proportional to the area of the building and the number of degree days in a heating season. Heat losses from a house may be kept to recommended values by providing adequate insulation and reducing air leakage. A study done in St. Paul, Minnesota(5) showed heat losses of a house as 15% from walls, 13% from the roof, 5%from the floor, 27% from windows and doors, and 40% from exchanges with the outside air.

As can probably be inferred from previous statements, passive solar energy will be utilized to help meet the energy needs of the house by letting the maximum amount of sunlight inside during the heating season and also by insulating heavily against heat loss.

The maximum amount of sun is let in by means of a solar greenhouse (which is discussed separately in the paper), skylights, and a large area of south facing glazing. To aid these windows in direct gain there is also a great deal of mass located where the sun can reach it during the day. Typically (and also in this case), one-half to two-thirds of the total mass of the heated

(continued)

space (including floors and walls) will be constructed of masonry including concrete, concrete block, brick, stone and adobe.

A general rule to provide cloudy-day storage for one to two days is to construct the southern glazing 10-20% over the minimum area needed to heat the space and build interior walls and floors of solid masonary eight inches thick.

Prevention from over-heating and cooling of the house will be accomplished by keeping the sun out, by ventilation, and by the fact that part of the house is underground . One way the sun may be kept out is by horizontal shading above glazing and when possible (if it is desired) these overhangs may also act as reflectors for winter sun.

However, overhangs do not provide adequate shading for east and west facing windows, so properly located deciduous trees will block the low morning and late afternoon summer sun. Aside from exterior shadings another method that can be used is interior blinds and shades, although they are not as efficient.

Insulation to the house will be provided by underground construction and fiberglass insulation in the walls and ceilings to balues of R30 and R40, respectively. Other types of insulation available for use in this design include movable insulation that is stuck on a window frame at night and insulation in the form of blinds and shades.

Another aspect of the design of this house is a protected entrance. An unprotected door can account for up to 10% of the total heat loss from a house. Building an enclosure around the entryway provides a layer of air that acts as insulation and also sets a maximum for the amount of cold or hot air that can be exchanged with the warmer or cooler inside air.

ENERGY SYSTEM-Methane

When considering a methane digester for use on a homestead scale, there are two general questions that should be answered: 1) With the organic wastes and resources at hand, what kind of a digester should be built and how big should it be? and 2) What is the best way of using the gas and sludge produced to satisfy the energy needs of the people involved?

It also must be decided as to whether the energy source is being used exclusively, or the potential of synergy (i.e. many systems working as a whole) will be developed(3). It had been decided from the beginning of this project that the purpose would be the latter case of synergy.

Raw materials that will be available for digestion will be dependent on such things such as climate, the type of agriculture practiced, any animals used and their degree of confinement, etc. The advantage of animal manure is that it is easy to collect with proper design of livestock shelters and it is easy to mix as slurry. Plant wastes are usually more available but they can also be used as compost or animal food.

Plant waste are also bulky and contain more undigestable materials than other forms of waste. Ways to take advantage of plants include pressing plant fluids out and digesting them directly (thus eliminating most of the scum), digesting plants that don't contain ligin (an undigestable fiber) such as seaweed, or culturing algae for digestion.

It seems for the purpose of this project, which is to provide year-round fuel, that a continuous load digester offers the most advantageous characteristics. From personal experience of living in the area in which the house is designed for (southern Connecticut) it can liberally be said that with enough land area + the cimate (see climatological data in appendix) would allow for almost enough garden and yard debris (e.g. grss cuttings) along with food wastes to produce enough organic wastes to sufficiently meet the cooking needs of an average household with possibly some left over to help heat hot water. If some animals are incorporated into the system there should be little trouble meeting both needs.

Now that the kind of digester and the general extent of raw materials are known, the next thing to do is to determine the relative size of the digester. The most inportant factors in sizing a continuous load digester are loading rate and detention time. The loading rate is the amount of raw material (lbs. of volatile solids) fed to the digester per day per cubic foot and detention time is the number of days a given mass of raw material remains in digerser. Dilution of materials decreases detention time but if too much water is added layers may form.

(Pictures on pgs. 21 + 22 where taken
from Producing Your Own Power.)

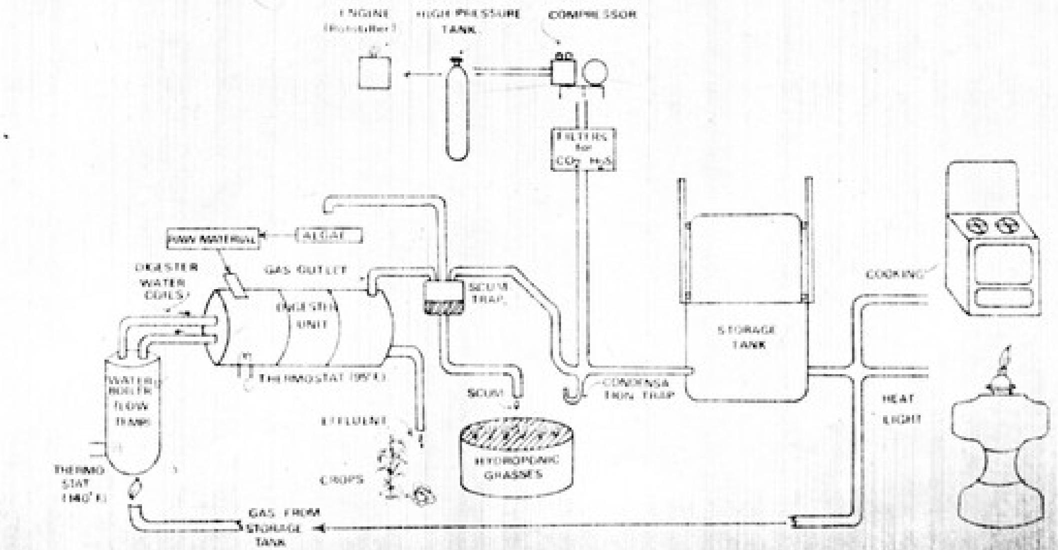


FIGURE 60. Integrated organic digester operation (using 50-gallon drums for digester)

Using Gas

Properties of Methane

Specific Gravity (air = 1.0)	.55
Dry Weight, lb/ft³	.04 (gas)
Liquid Weight, lb/gal	3.5 (liquid)
Fuel Value, Btu/ft³	950–1050
Air for Combustion, ft³/ft³	9.5
Flammability in Air, % Methane	5–14

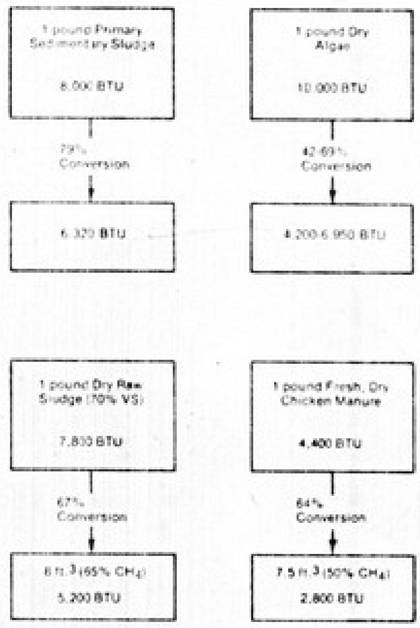


FIGURE 68. Efficiency of methane production from different materials.

TABLE 23. Uses for Methane

USE	FT³	RATE
Lighting	2.5	per mantle per hour
Cooking	8-16	per hour per 2-4 in burner
	12-15	per person per day
Incubator	5-7	ft³ per hour per ft³ incubator
Gas Refrigerator	1.2	ft³ per hour per ft³ refrigerator
Gasoline Engine*		
CH_4	11	per brake horse-power per hour
Bio-Gas	16	per brake horse-power per hour
For Gasoline		
CH_4	135-160	per gallon
Bio-Gas	180-250	per gallon
For Diesel Oil		
CH_4	150-188	per gallon
Bio-Gas	200-278	per gallon

*25% efficiency

Domestic Hot Water ?

ENERGY SYSTEMS-Methane

The last thing to be delt with concerning methane is the best way to make use of the gas and sludge produced. Methane cannot be easily liquified (it requires 5,000 psi) for any portable uses like propane, but it can be used in anything that uses natural gas such as cooking and domestic hot water. In fact, natural gas is between 70 and 95% methane.

The fuel value of the gas produced from organic decay is directly proportional to the amount of methane (CH_4) it contains. The basic chemical reaction for the production of methane is: $2C + 2H_2O \longrightarrow CH_4 + CO_2$ and in general pure methane gas has a heat value of approxiamately 1,000 Btu/ft^3 as opposed to natural gas with a value of $\approx$ 1,500 Btu/ft^3. With the right conditions 50-70% of raw materials are converted to methane while the majority of what is left is sludge.

Something that can be done with sludge is sludge hydroponics (instead of using chemical solutions) and sludge ponds. These ponds can feed fish and be used to produce algae which in turn when dried can produce more methane, hence completing the cycle—— potentially a very rapid and efficient process.

ENERGY SYSTEM-Wind Energy

A small wind electrical system contains the basic components of: 1) a wind-driven power source, 2) a storage system, 3) conversion devices to convert generated or stored power to

ENERGY SYSTEM-Wind Energy

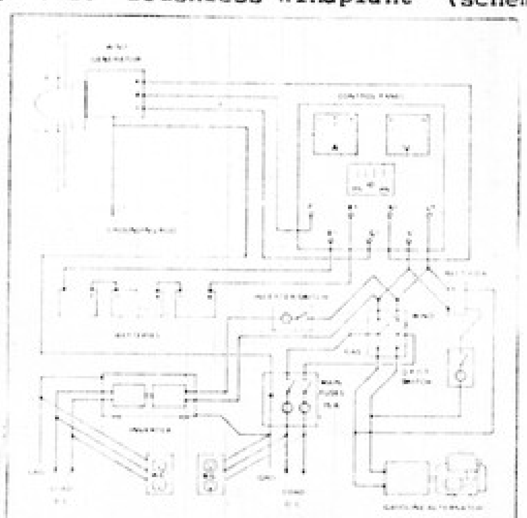
usable forms, and 4) a back-up system such as a gasoline generator.

If there is a relatively high demand for electicity at low wind speeds then a larger propeller should be used as far as the power source is concerned, if this is not so then a smaller propeller will suffice.

At the present time the most practical type of electrical storage is still probably lead storage batteries for small scale use. Special " stationary" or "house lighting" batteries are available,made especially for the purpose of being charged and re-charged, in sizes from 10 ah (ampere hours) to 8,000 ah. The wind power installation design for this house has the recom-minded value of battery storage of a capacity for three days without wind.

Since the purpose of this project is not to design each and every aspect in detail the operation of a wind generator is given from an actual working system in a house in Maine with similar wind data to the design location.

The wind generator of the aforementioned system is a Quirk 2,000 watt 115 volt "Brushless Windplant" (schematic below)

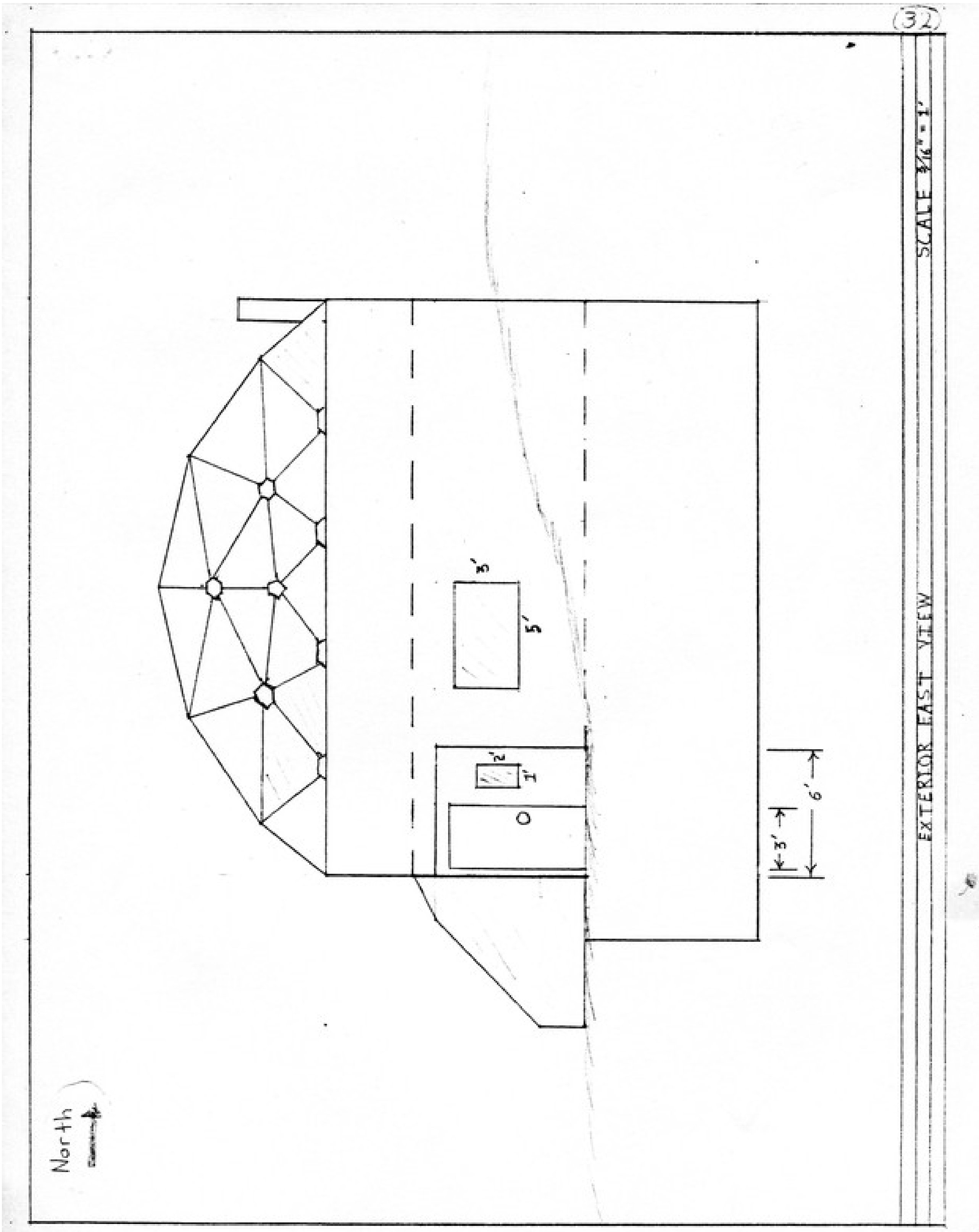


(from Producing Your Own Power)

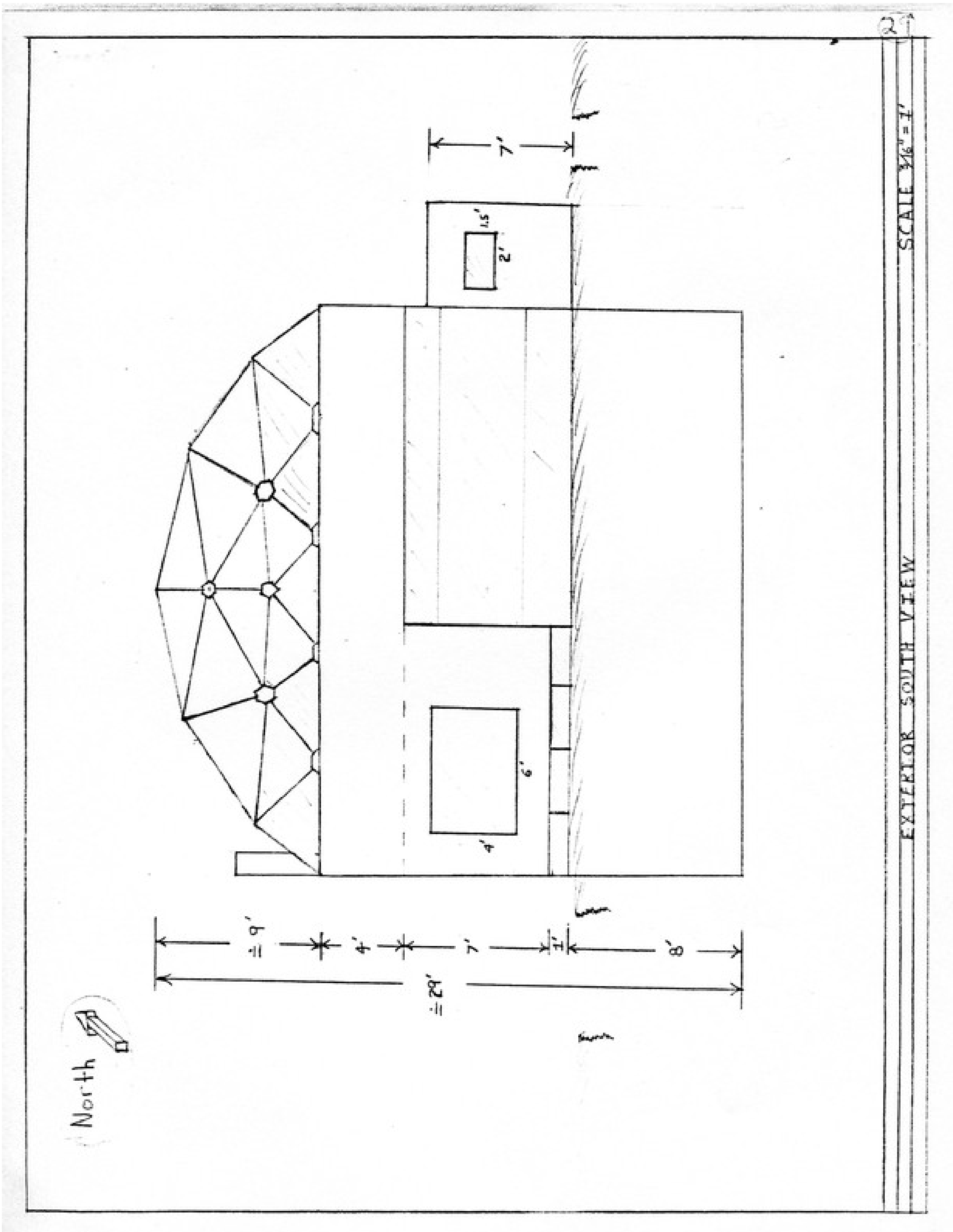
and works so that the when alternating current is produced it is converted to direct current by diodes located right inside the alternator housing which is part of the wind generator in the diagram. This direct current goes to a transistorized control panel which automatically channels current to where it is needed and any extra is automatically stored in the batteries. If all the batteries are charged the control panel turns off the generator output.

An inverter changes DC current to AC current and is essential for powering such things as radios, televisions, and stereos that require an accurate alternating current, usually of 60 cycles per second. Since mechanical inverters are very innefficient at small loads, by matching the size of the inverter to the load, losses may be cut down drastically. The best solution, however, are probably electronic solid state converters which are available at 80% efficiency.

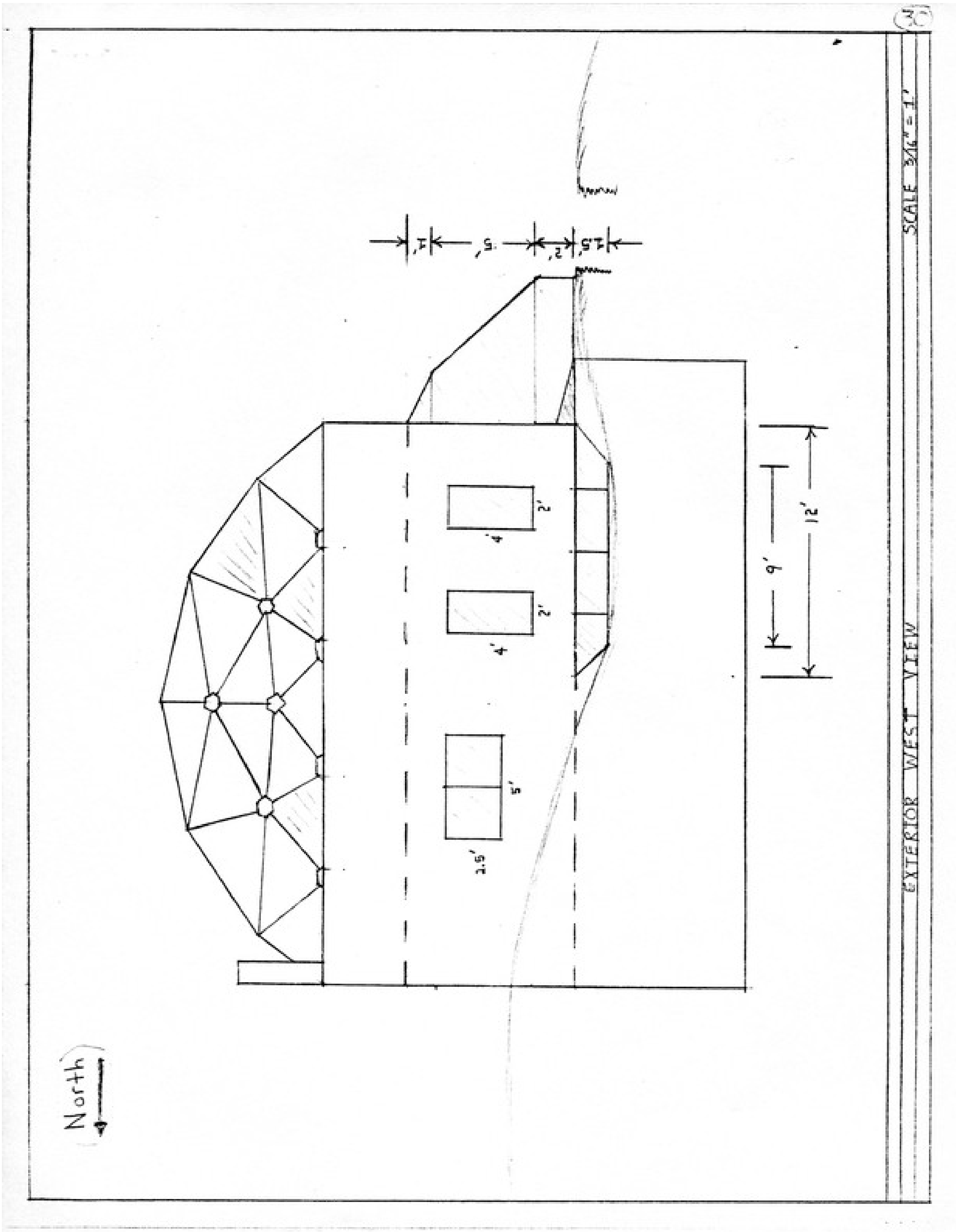
The above system described powers 6-8 75watt light bulbs every evening, a radio, television, stereo, electric typewriter, blender, toaster, vacuum cleaner , skill saw, electric drill and a 1/3 hp deep-well water pump (15amp fuse). It was estimated that the system was getting approxiamately 110KW per month which is about 1/4 average American family consumption. The average American load though, includes such high electricity consumption devices that might not be neededin the "dream house" such as air conditioners, an electric range (methane stove), and a clothes dryer (solar-wind model used).



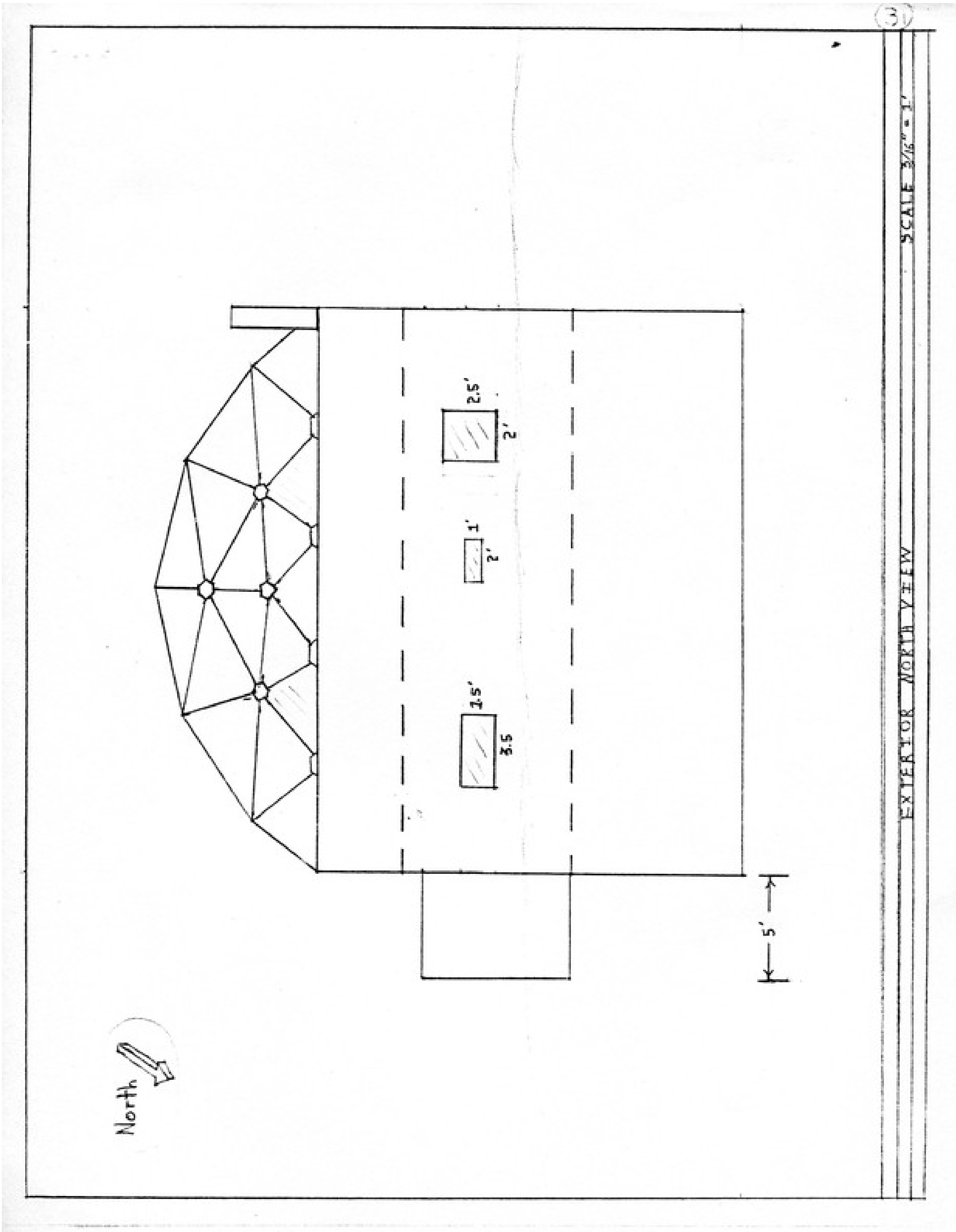
EXTERIOR VIEW: EAST



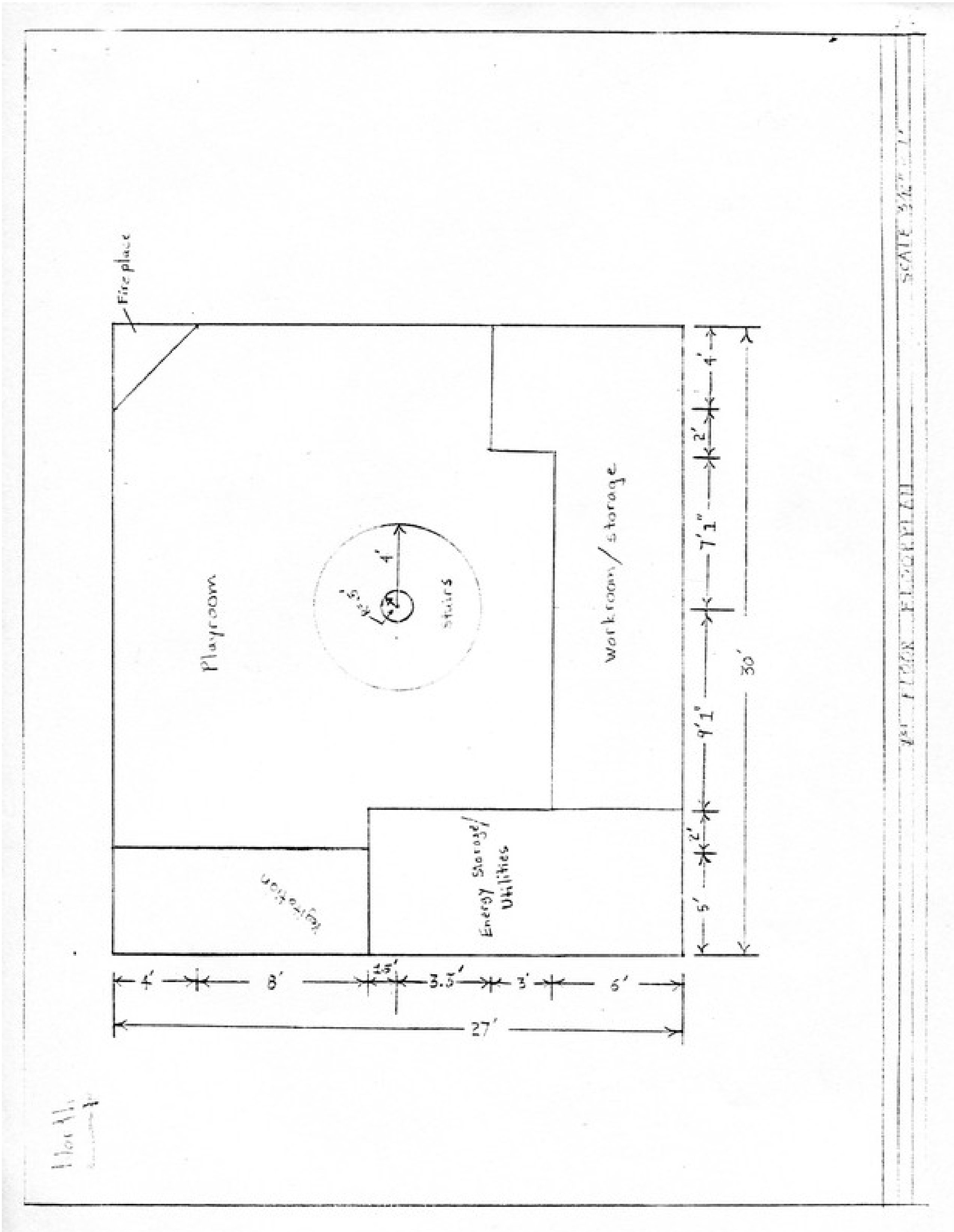
EXTERIOR VIEW: SOUTH



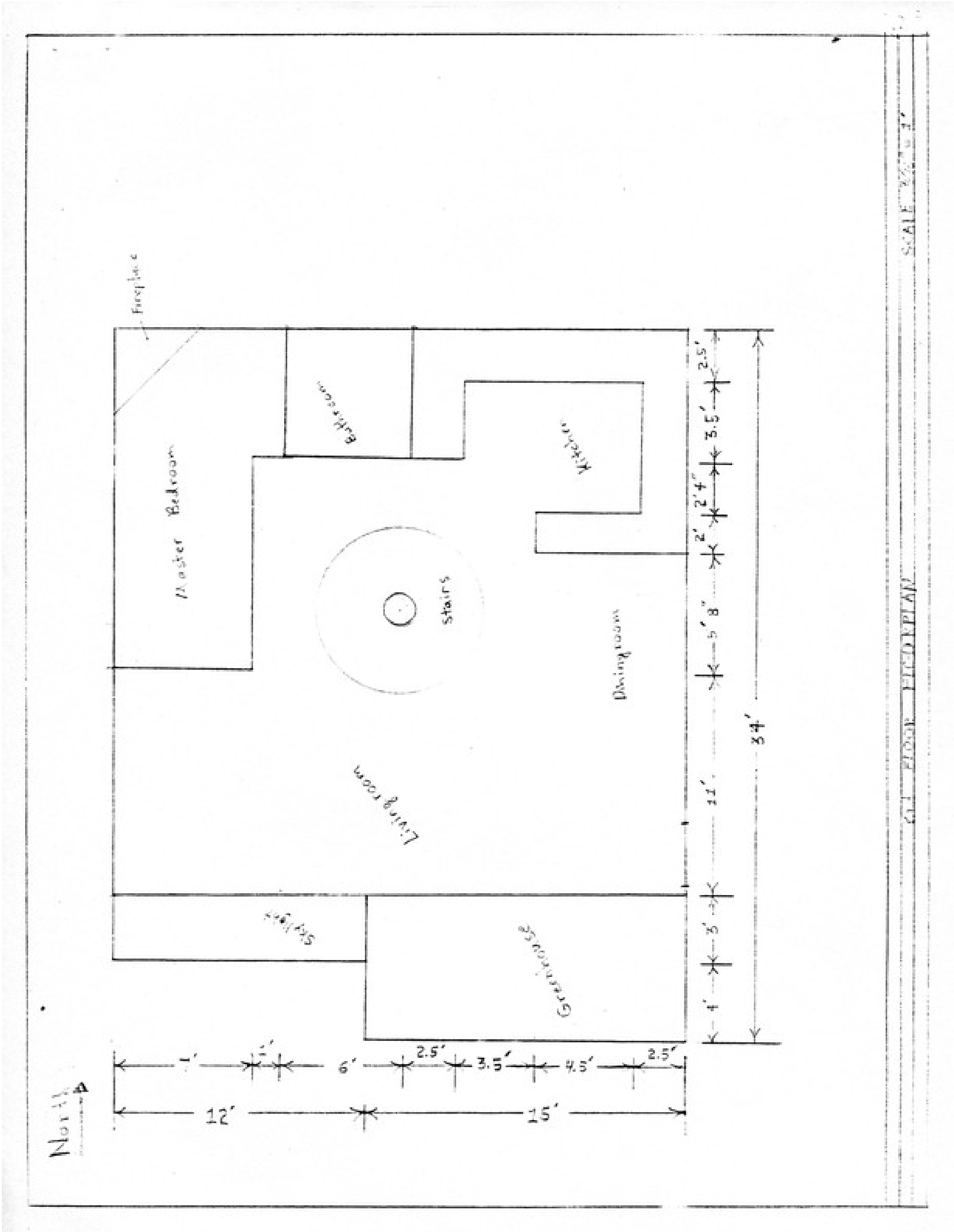
EXTERIOR VIEW: WEST



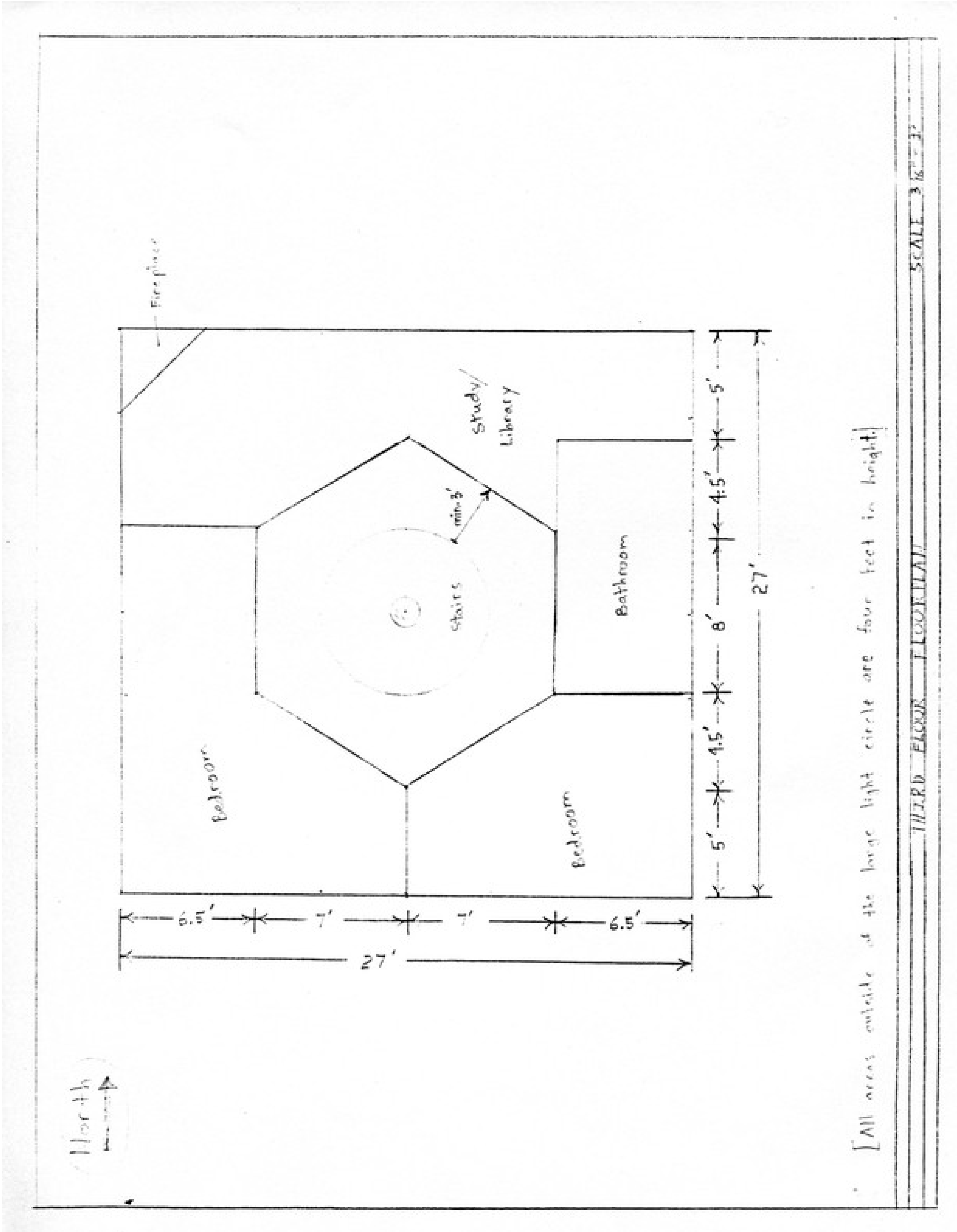
EXTERIOR VIEW: NORTH



FIRST FLOOR: Mostly below grade.



SECOND FLOOR: Entrance level.



THIRD FLOOR: Domed roof.

CLIMATOLOGICAL DATA

U. S. Government Weather Records, 1979 Coastal Division, CT

Month	Average Temperature	Precipitation	# of days with ppt	Average wind speed	comment	Average Langleys	% sun	total possible sun (15th of mo.)	Average # of sun hrs	# of Degree Days
JAN.	31°F	12.8"	13	16mph	mild and very wet	155	40-50%	$9\frac{1}{2}$ hrs	155	1,079
FEB.	23°F	4.2"	10	15mph	very cold, little snow	232	50-60%	$10\frac{2}{3}$ hrs	178	966
MAR.	42°F	4.7"	9	12mph	—	339	50-60%	12 hrs	215	853
APR.	49°F	5.2"	12	13mph	normal & wet	428	50-60%	$13\frac{1}{4}$ hrs	234	510
MAY	62°F	5.4"	12	11mph	warm & very wet	502	60%	$14\frac{1}{3}$ hrs	274	208
JUN.	67°F	2.4"	10	10mph	normal	573	60-70%	15 hrs	291	—
JULY	74°F	1.0"	6	9.5mph	normal	548	60-70%	$14\frac{3}{4}$ hrs	309	—
AUG.	72°F	5.8"	12	11mph	—	475	60-70%	$13\frac{3}{4}$ hrs	284	—
SEPT.	65°F	5.1"	8	12mph	cool	391	60%	$12\frac{1}{3}$ hrs	238	66
OCT	54°F	3.7"	9	12mph	below normal & wet	293	60%	11 hrs	215	307
NOV	48°F	3.4"	11	11.5mph	very mild	182	50%	10 hrs	157	615
DEC.	37°F	2.7"	9	13mph	mild & low snowfall	146	50%	$9\frac{1}{3}$ hrs	154	986

References

1) Figures from reference one are from an actual utility bill from my home.

2) Edward Mazria
The Passive Solar Energy Book

3) Carol Stoner
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4) Barry Hack
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5) Farrington Daniels
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