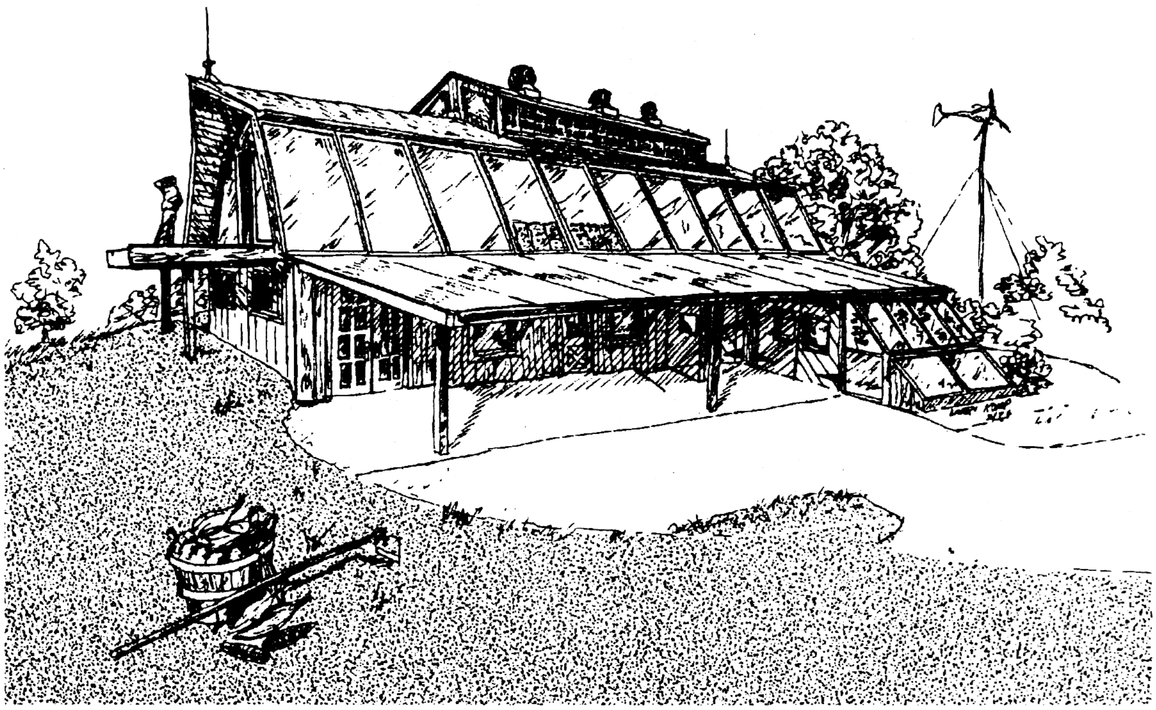
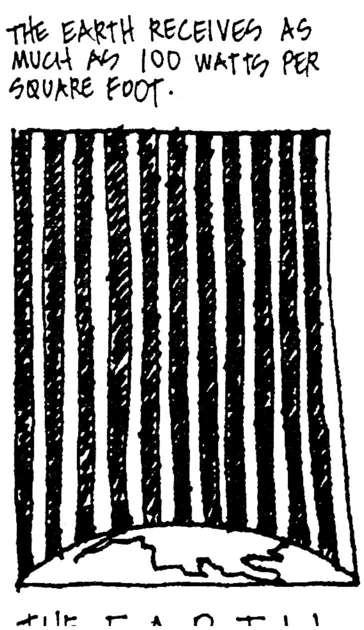
The Maine Solar Primer

2nd Edition





A compilation of
practical information and diagrams
from past issues of
THE MAINE SUN
Produced by
The Maine Solar Energy Association

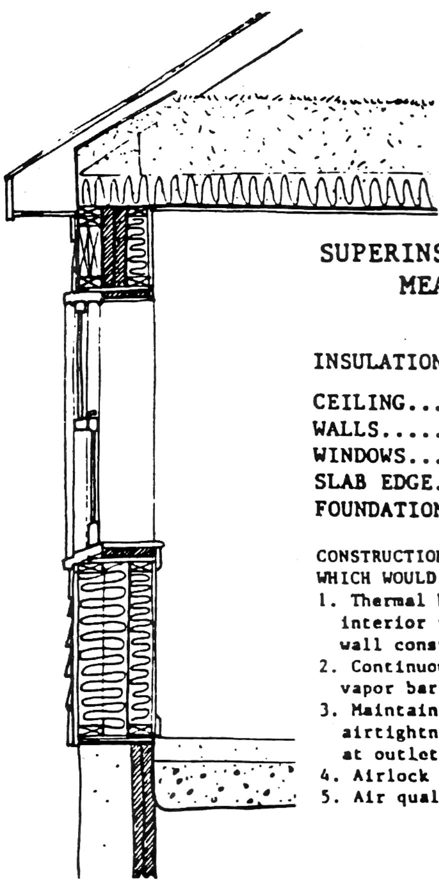
Edited by Richard Komp
Illustrated by
Sarah Holland
Caleb Crawford
Larry Komp
John Burke
Jim Coder

INTRODUCTION

Yes you can use solar energy in Maine. The Maine Solar Energy Association has been preaching this message since the 1970's and over the years our newsletter, **The Maine Sun** has included a number of very practical, do-it-yourself articles showing just how to use the sun's energy to heat your water, dry and cook your food, make your own electricity, and even how to heat yourself and your home. This **Maine Solar Primer** is a compilation of a number of these articles and is intended to encourage all of us to try out some of these ideas. All the plans have been tried out and developed at the various workshops MESEA has organized around the state. We plan to continue offering these workshops, where people come to spend a saturday or a weekend building one of these solar devices as well as finding out how to install and use it. We also have a **Solar Ecological Building Seminar** about once a year where architects and other experts get together to argue amongst each other and teach the rest of us how to design and build our homes. At the back of this book is a membership application for you to join the Maine Solar Energy Association. Please do so and take part in our year-round activities.

SUPERINSULATION

The first step is conservation. This always true whenever you wish to start using solar energy, but particularly so when you are planning to use passive solar energy to keep warm in our long, cold Maine winters. The following is from what used to be the **Farmers Home Administration**, now called the **Rural Housing and Community Development Service** (courtesy of James Sawyer), and appeared in the January 1988 Maine Sun.



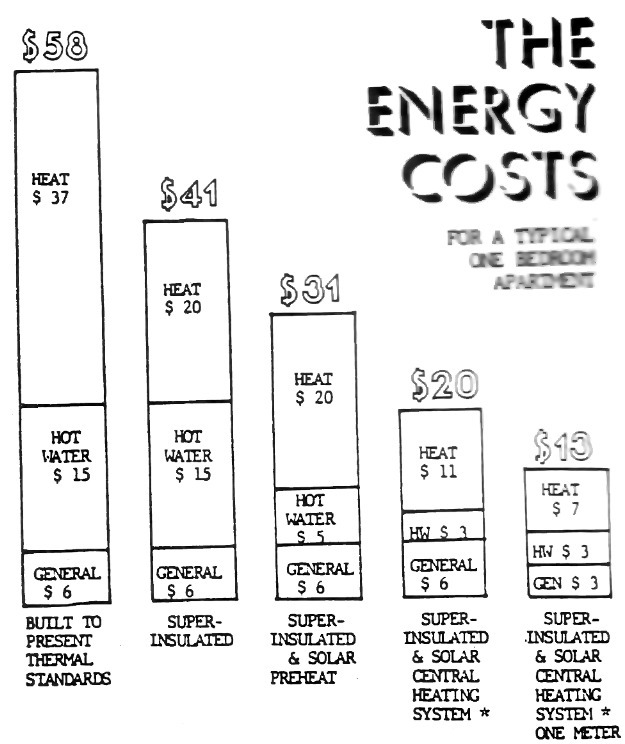
SUPERINSULATION MEANS:

INSULATION LEVELS OF:

CEILING.......R-50 +
WALLS.........R-33 +
WINDOWS.......R-3 +
SLAB EDGE.....R-16 +
FOUNDATION....R-16 +

CONSTRUCTION DETAILS WHICH WOULD INCLUDE:

1. Thermal break from interior to exterior wall construction
2. Continuous, durable vapor barrier detail
3. Maintain thermal & airtightness integrity at outlets, windows etc.
4. Airlock vestibules
5. Air quality system

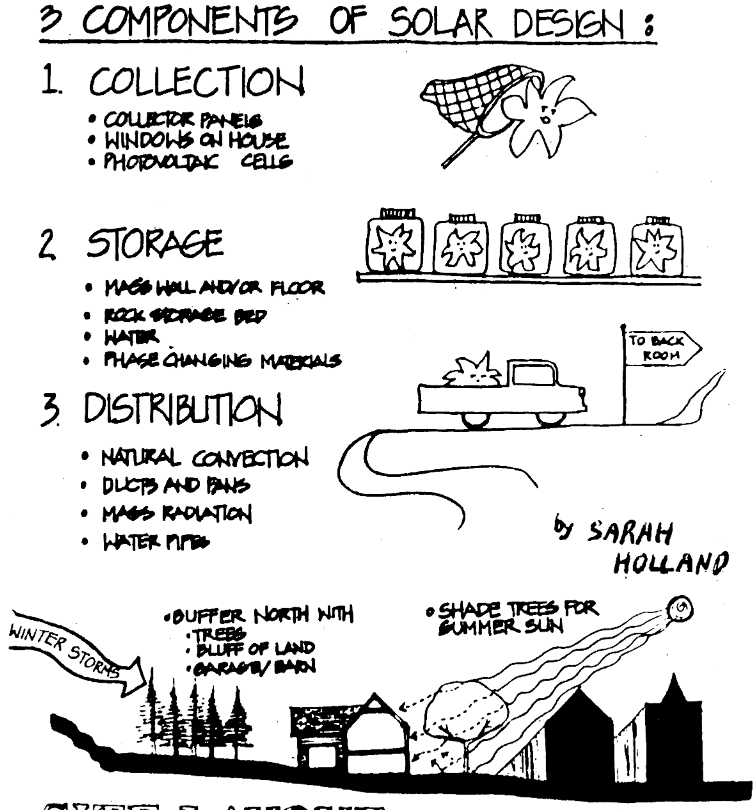


PASSIVE SOLAR ARCHITECTURE

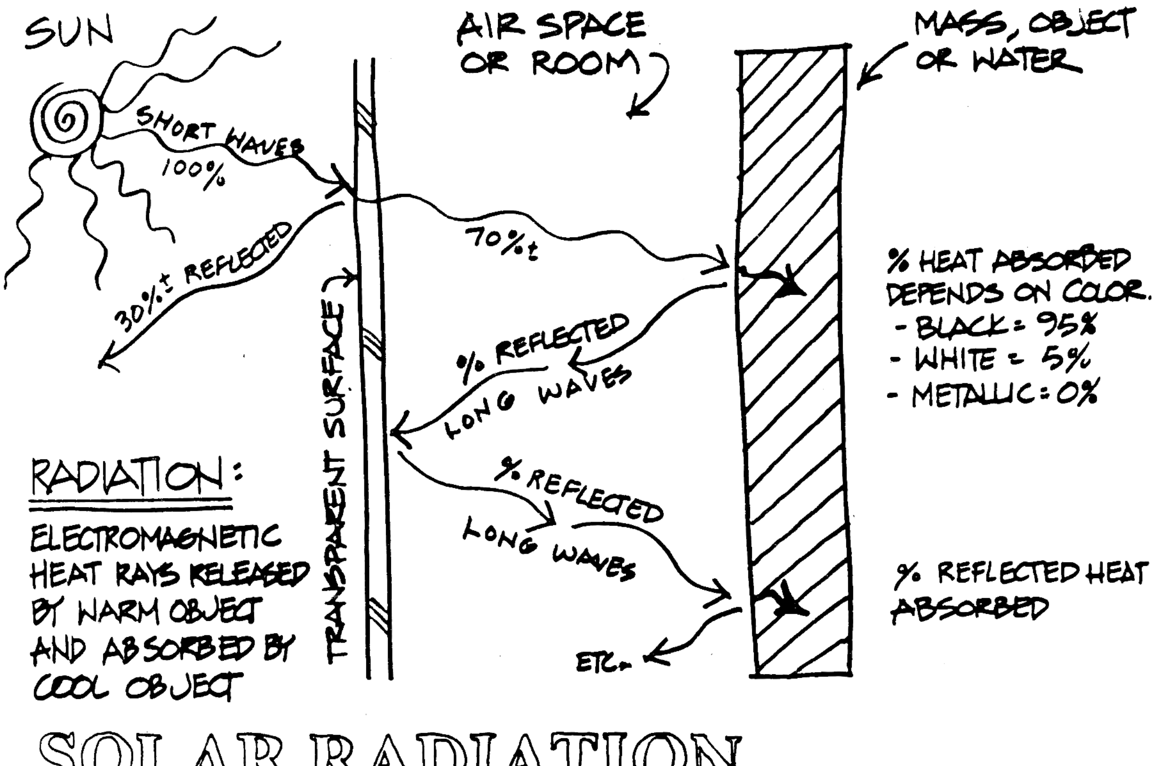
A properly designed passive solar home can actually cost the same or even less than a conventional home of the same size; and the resulting home is much more comfortable and pleasant to live in. Architect Sarah Holland shows here some of the basic design principles you can use to let the sun help heat your home.

THE THREE BASIC PRINCIPLES:

1. Bring the sun into the building, using windows, Trombe walls, or solar air heaters.
2. Store the solar heat, using direct thermal mass or maybe a fan blowing the heated air into a storage bed.
3. Superinsulate to keep the solar heat in the home all night. Insulated window covers are a very good idea.

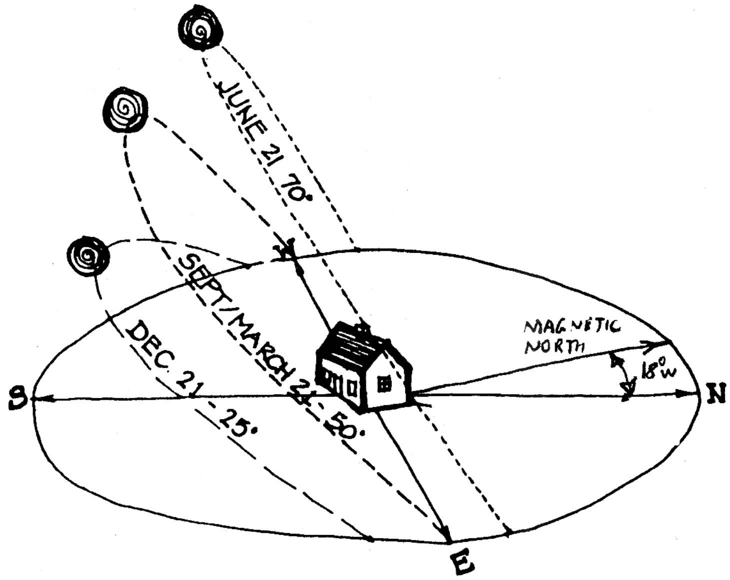


SITE LAYOUT



SOLAR RADIATION
(GREENHOUSE EFFECT)

MID-COAST MAINE SOLAR INFORMATION:



TRUE NORTH:
+18° E of MAG N.

LATITUDE: 44.5

DEGREE DAYS:
(TEMP DIFF BETWEEN OUTSIDE TEMP IN 24 HR @ 65° BASE TEMP & 35° AVG WINTER TEMP)
APPROX. 1350 (JAN)

PREVAILING WINDS:
IN WINTER = N.W.
IN SUMMER = S.E.

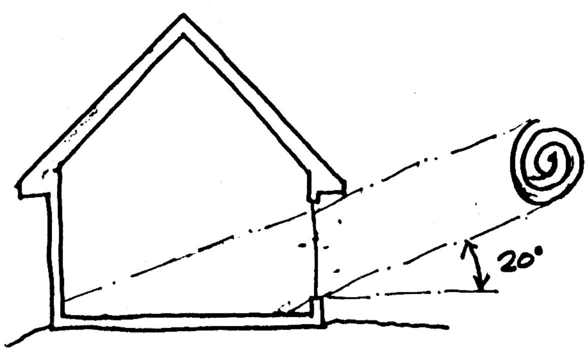
AVG WINTER:
TEMP = 30° F

DESIGN TEMP = 5° F

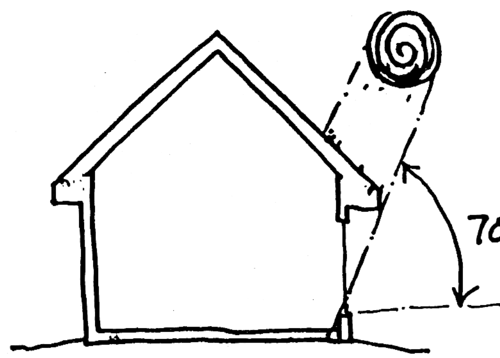
SARAH
HOL
ARCH
RR1 BO
CAMDEN,
207-23

DRAWN by
SARAH
HOLLAND

SOLAR ALTITUDE DIAGRAM

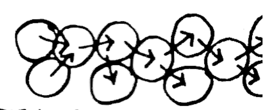


WINTER SOLSTICE · DEC 21

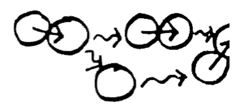


SUMMER SOLSTICE - JUNE 21

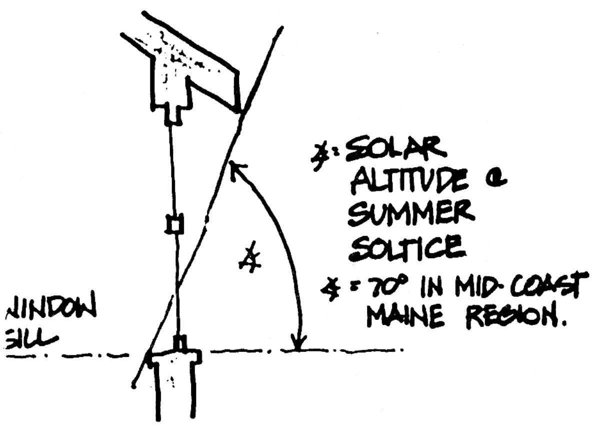
CONDUCTION:
HEAT TRANSFER THROUGH A SOLID OR COMPOSITE OF SOLID MATERIALS MOLECULE TO MOLE BY DIRECT CONTAC



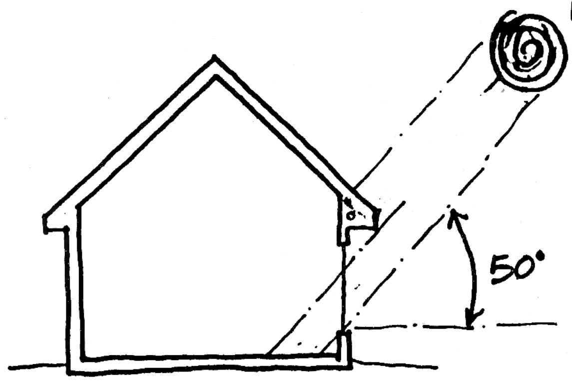
DENSE MATERIAL



NON·DENSE MATERI



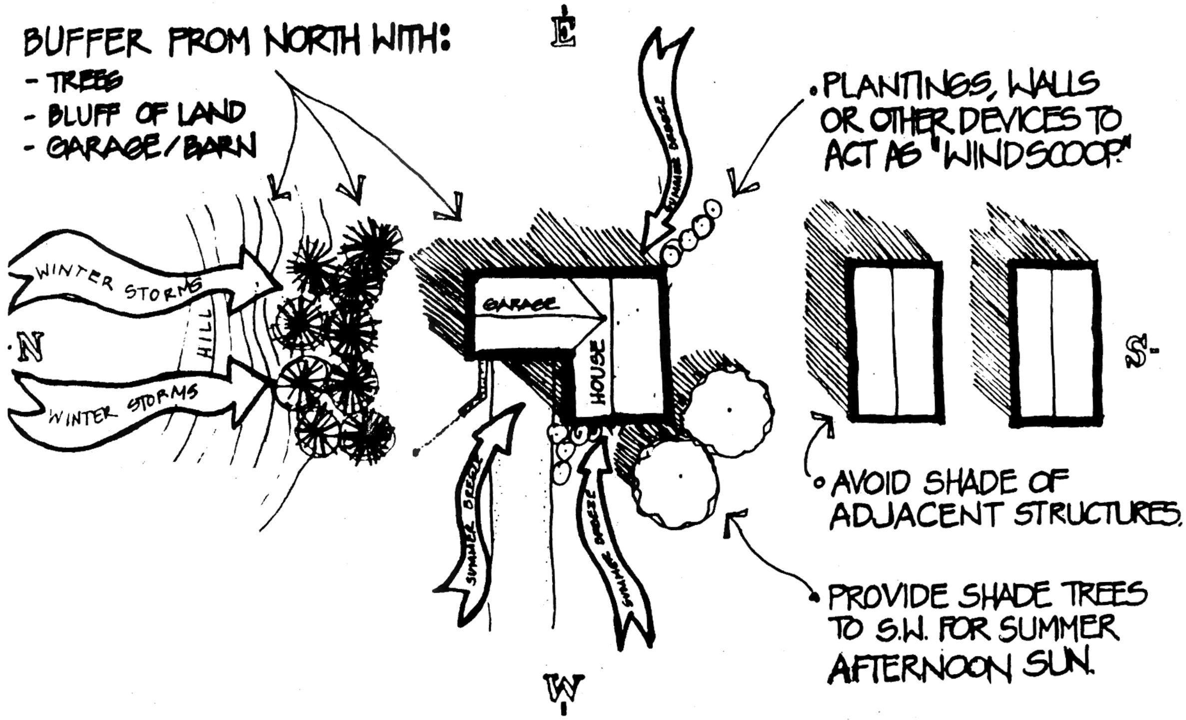
MINIMUM OVERHANG



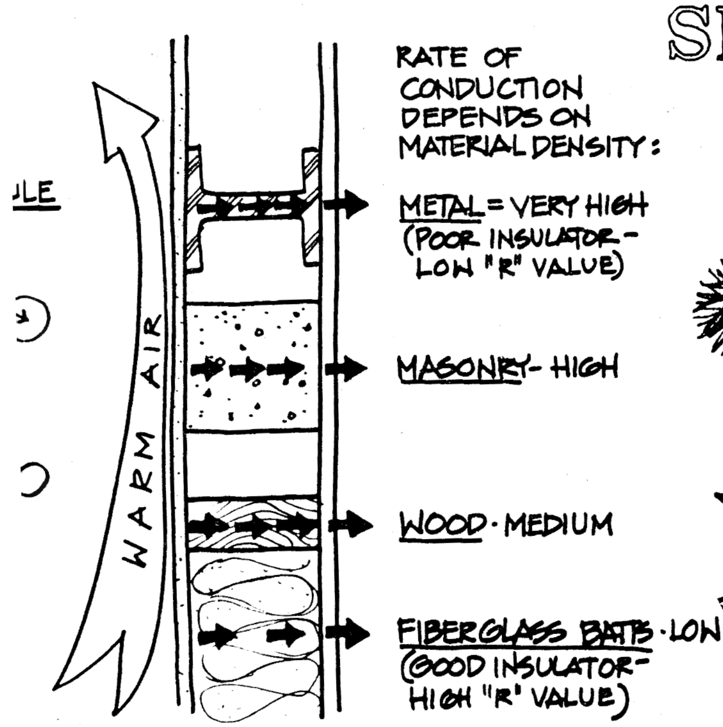
EQUINOX · SEPT/MARCH 21

CONDUC

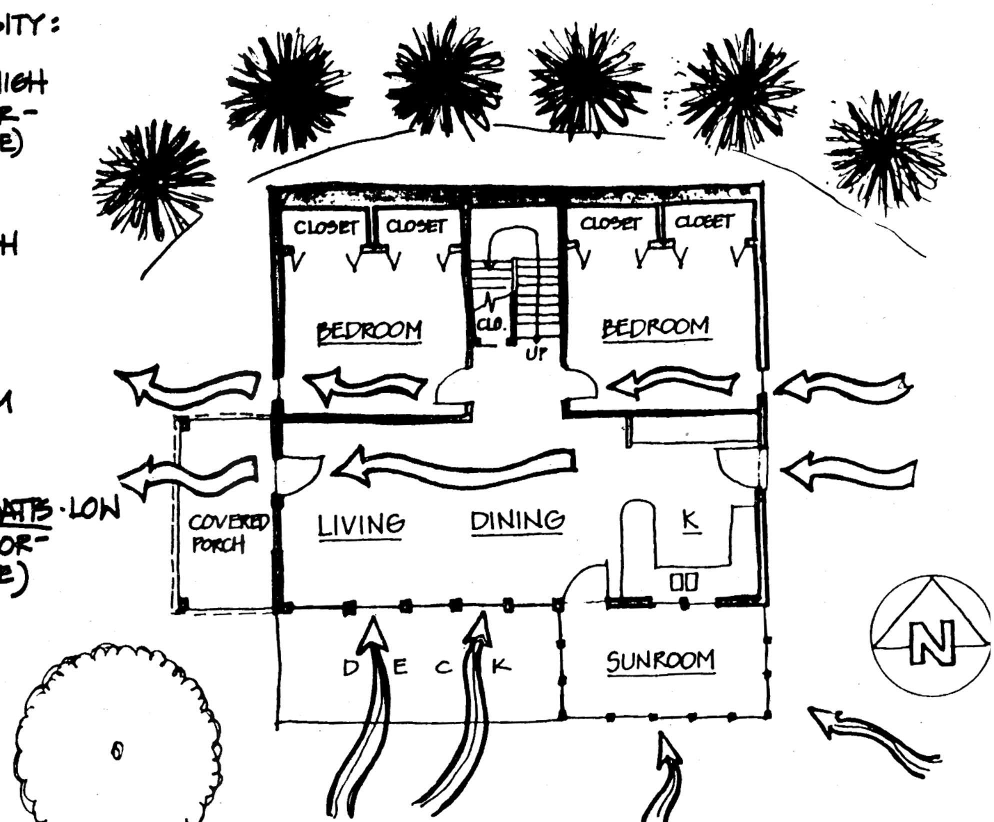
SHADING ANGLES



SITE PLAN LAYOUT



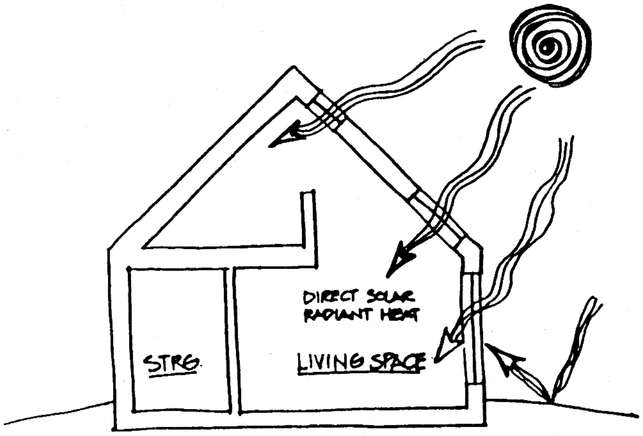
TION



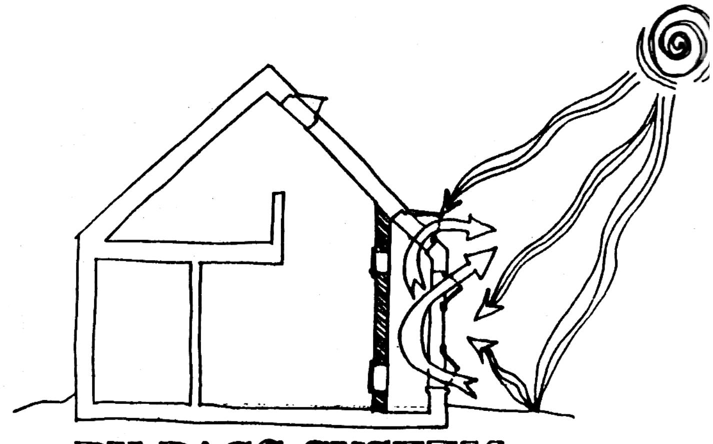
SOLAR LAYOUT

by SARAH HOLLAND

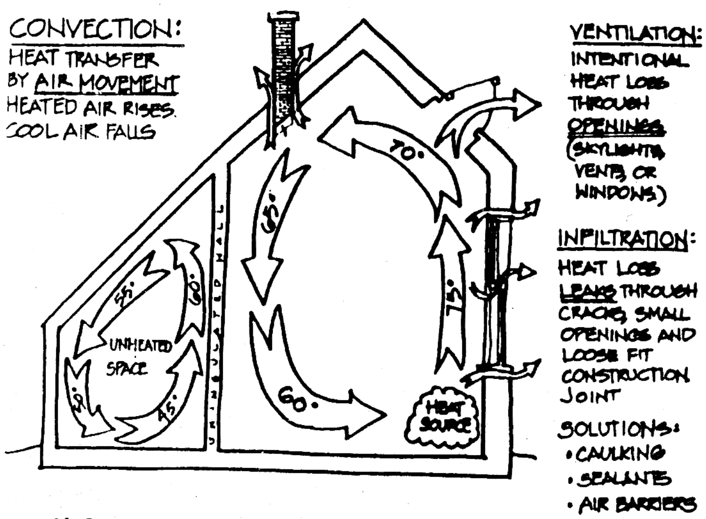
SOLAR DESIGNS



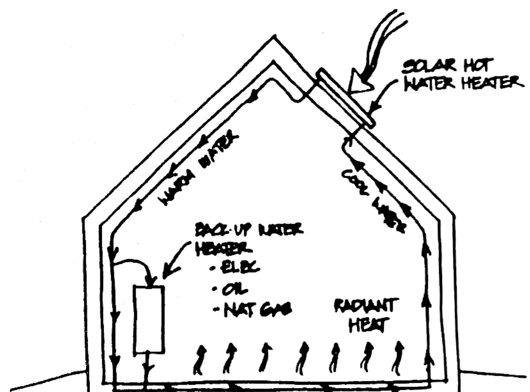
DIRECT GAIN



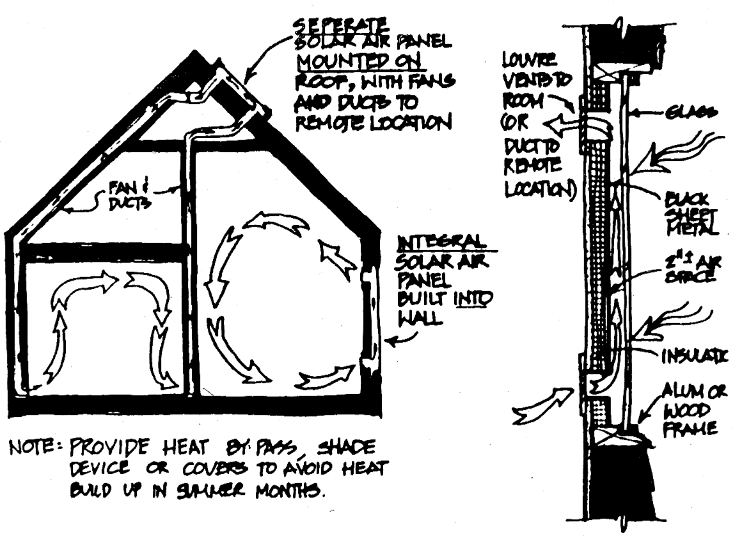
BY-PASS SYSTEM
TO AVOID HEAT BUILD UP IN SUMMER



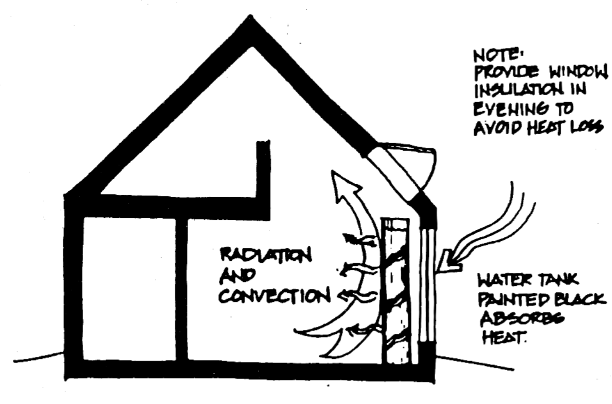
CONVECTION



IN-FLOOR RADIANT HEAT SYSTEM

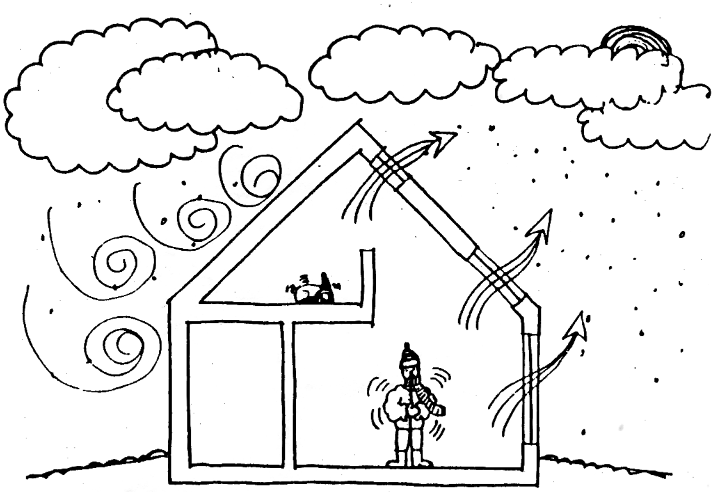


SOLAR AIR PANEL

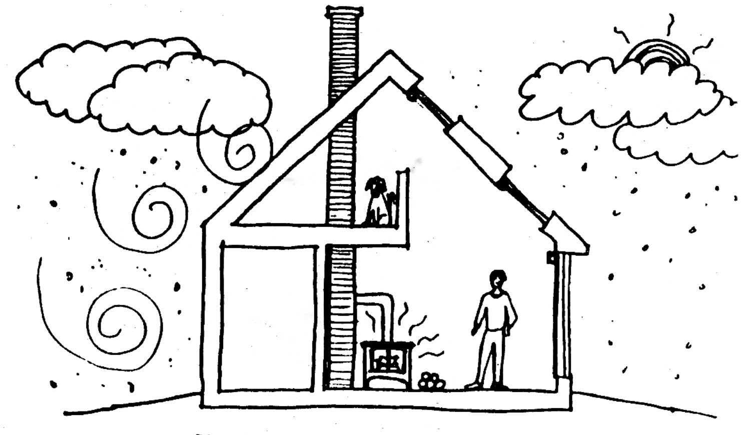


WATER STORAGE

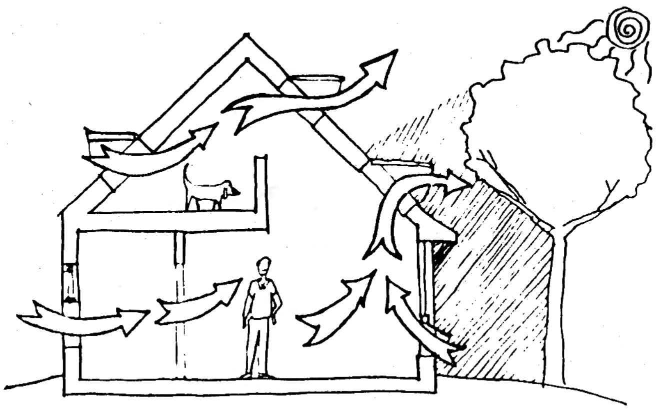
by SARAH



DON'T
∅ FORGET BACK-UP HEAT SYSTEM
∅ FORGET INSULATED WINDOW COVERS

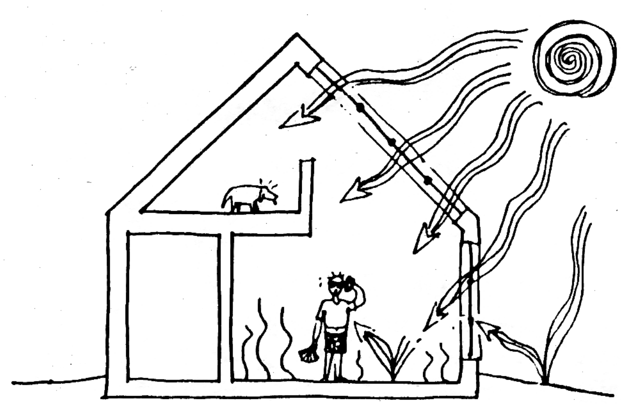


DO REMEMBER
✓ INSULATED WINDOW COVERS
✓ BACK-UP HEAT SYSTEM



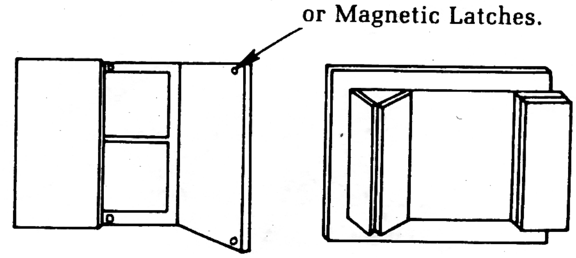
DO REMEMBER
✓ VENTILATION
✓ SHADING DEVICES

by SARAH HOLLAND

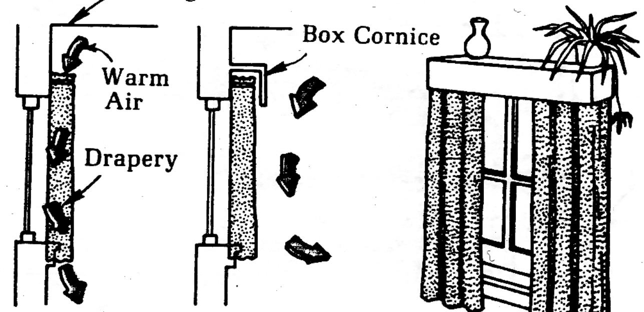


DON'T
∅ USE TOO MUCH FIXED GLASS
∅ FORGET SHADING DEVICES
∅ FORGET VENTILATION

INSULATING SHUTTERS Secure with Velcro dots or Magnetic Latches.

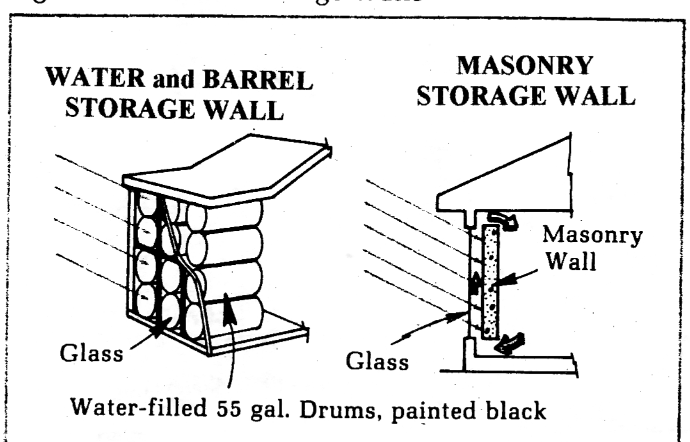


CORNICES



The box cornice stops the movement of heated air between the closed curtain and cold window.

Figure 7. *Thermal Storage Walls*



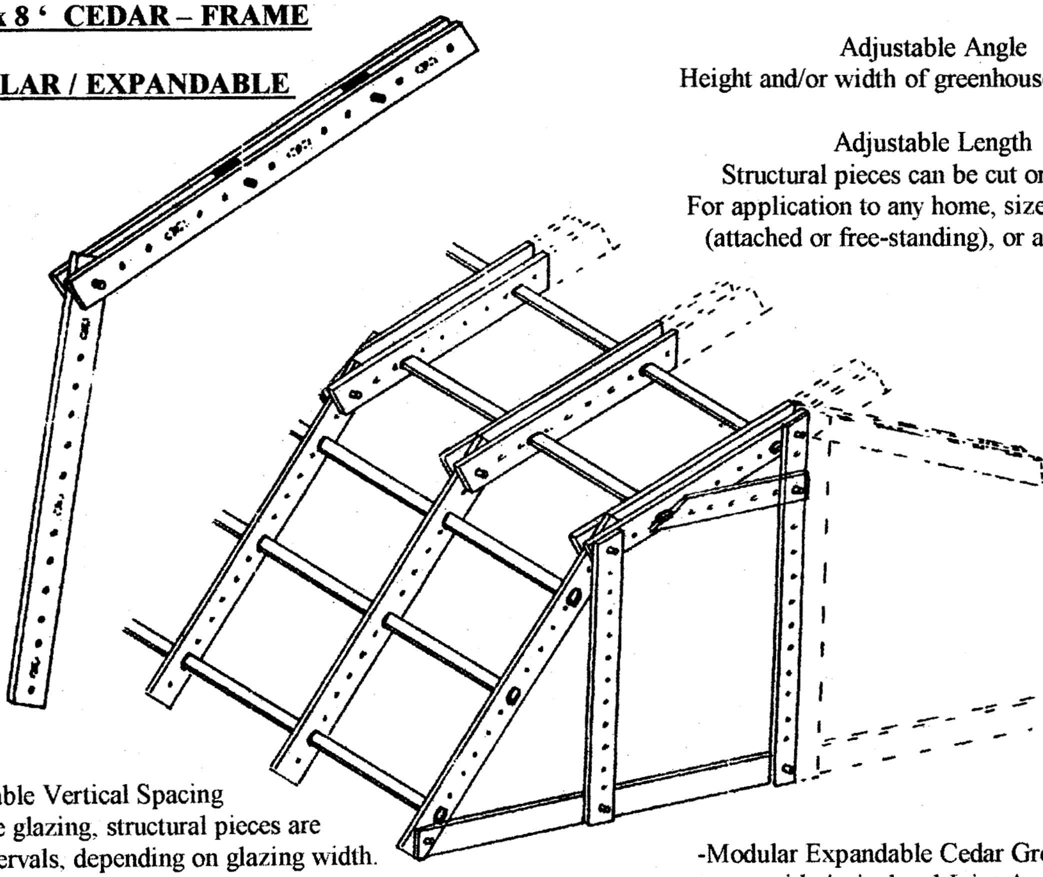
SOLAR HYBRID GREEN HOUSE
Free-standing or attached to home

5/4 " x 4 " x 8 ' CEDAR – FRAME

MODULAR / EXPANDABLE

Adjustable Angle
Height and/or width of greenhouse adjustable.

Adjustable Length
Structural pieces can be cut or added to
For application to any home, size greenhouse,
(attached or free-standing), or angles used.



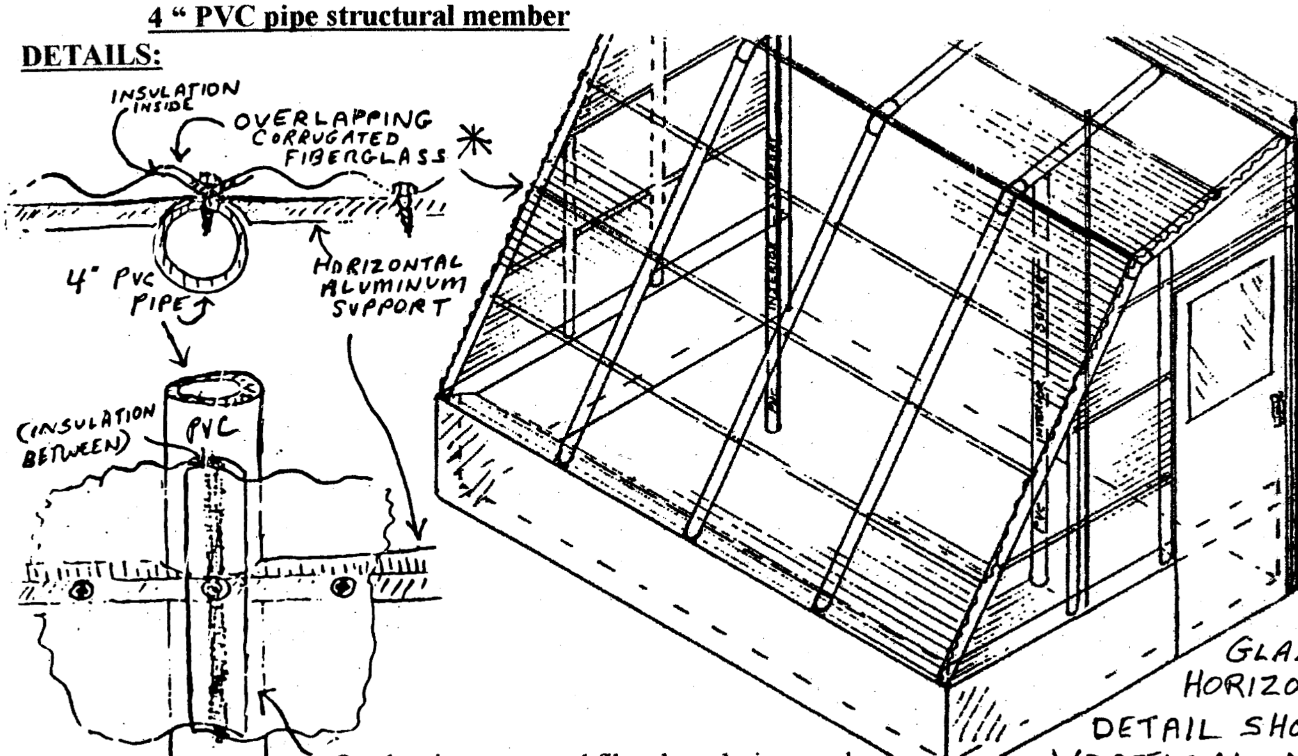
Adjustable Vertical Spacing
To accommodate glazing, structural pieces are
Placed at different intervals, depending on glazing width.

-Modular Expandable Cedar Greenhouse Kit
with Articulated Joint Assembly

LIGHTWEIGHT – PVC – FRAME

4 " PVC pipe structural member

DETAILS:

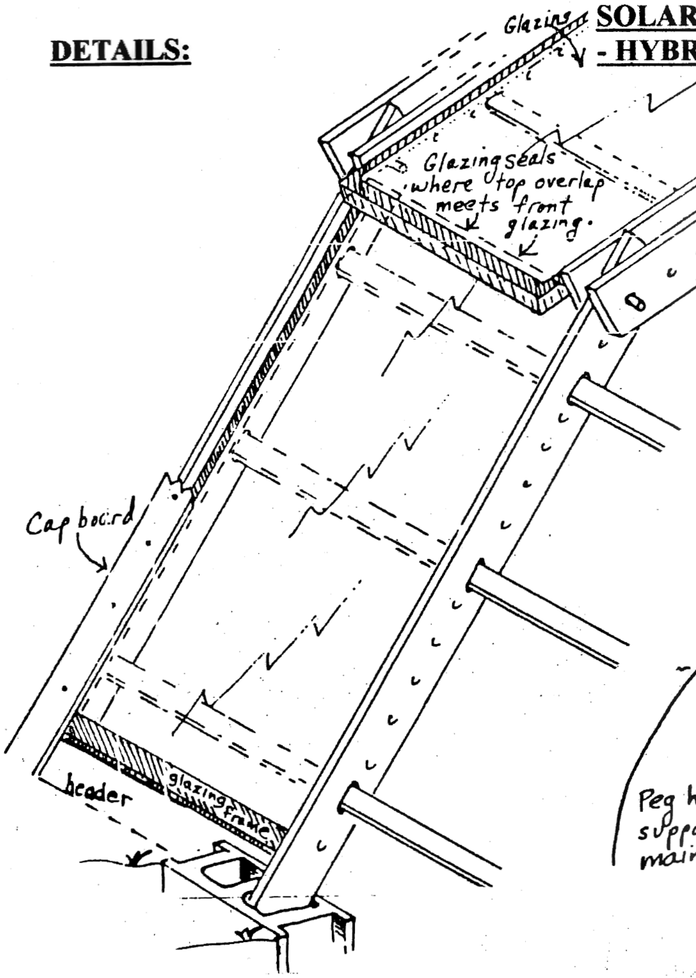


*
GLAZING SHOWN HORIZONTAL –
DETAIL SHOWS
VERTICAL INSTALLATION
FOR SNOW RUN-OFF.

Overlapping corrugated fiberglass glazing panels,
Horizontal aluminum supports,
Screw and donut washer secure overlapping

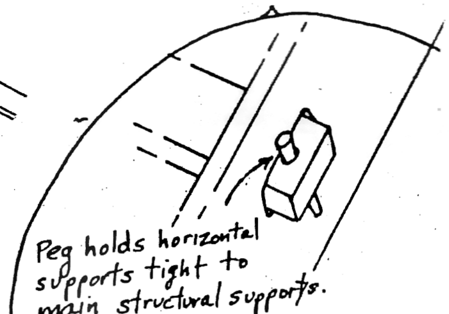
DETAILS:

SOLAR GREEN HOUSE
- HYBRID SUN ROOM -



Basic Modular Structural Piece
5/4"x4"x8' rough cut cedar,
1" holes - @ 6" center – for peg and pin application.

Cedar structural members supporting insulated glass,
Roof glazing sealing to front glazing,
Concrete blocks for low-tech foundation / footing,
Horizontal glazing supports,
Pegs holdingsupports to structural members,
Cedar capboard to secure top of glazing to structural member.



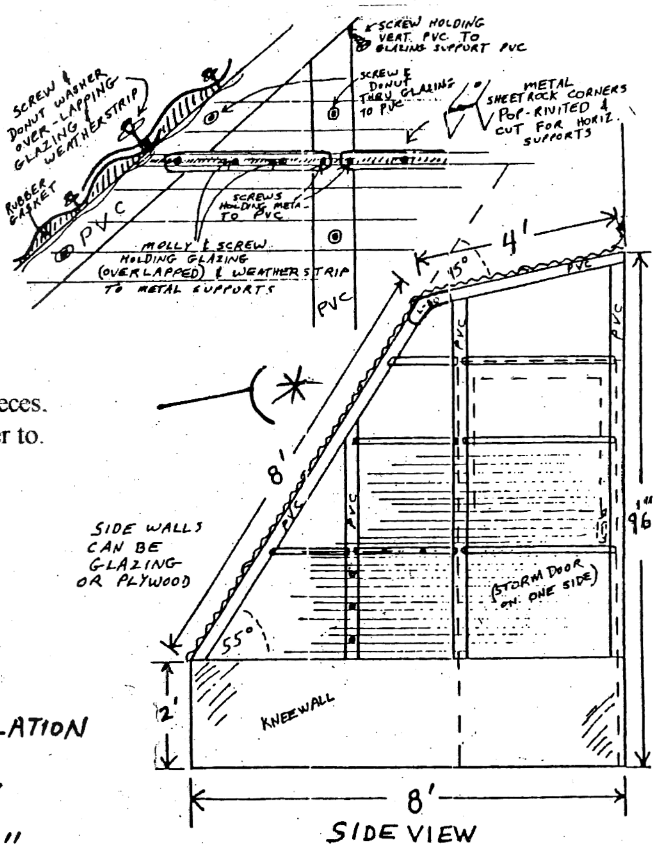
PV / DHW / HEAT GRABBER

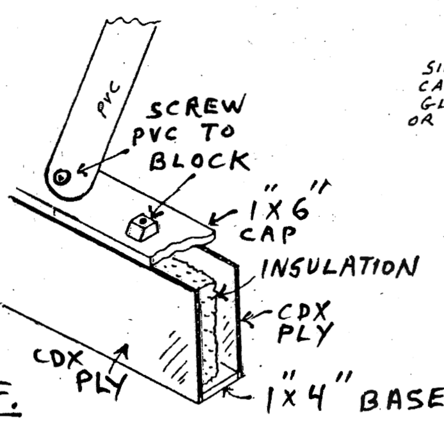
PV / HOT WATER & AIR PANELS
Can be situated on roof of greenhouse, or on wall above.

Molly and screw hold overlapped glazing and
Weatherstripping to horizontal aluminum

Side walls can be glazing or plywood

Kneewall detail of insulation between two plywood pieces.
Block attached to kneewall cap to secure PVC member to.



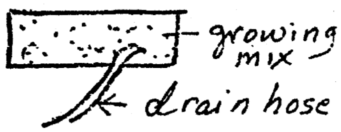


*) CORRUGATED GLAZING MAY BE INSTALLED VERTICALLY IN NORTHERN CLIMATES FOR SNOW RUN-OFF.

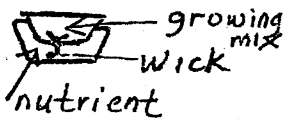
Design by Charles Ewing

HYDROPONIC-GROW SYSTEM: *

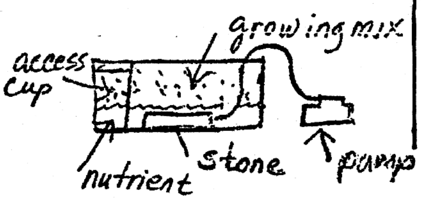
A.-Flood and Drain



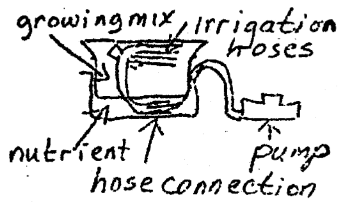
B.-Wicking



C.-Air Stone



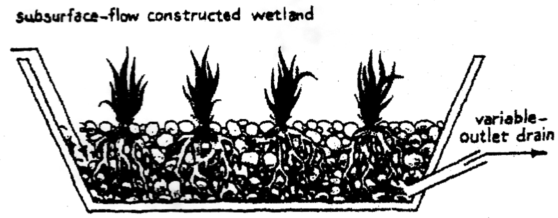
D.-Bubbler



* - SOIL-LESS, NUTRIENT SOLUTION, WATER-BASED, PLANT GROWING.

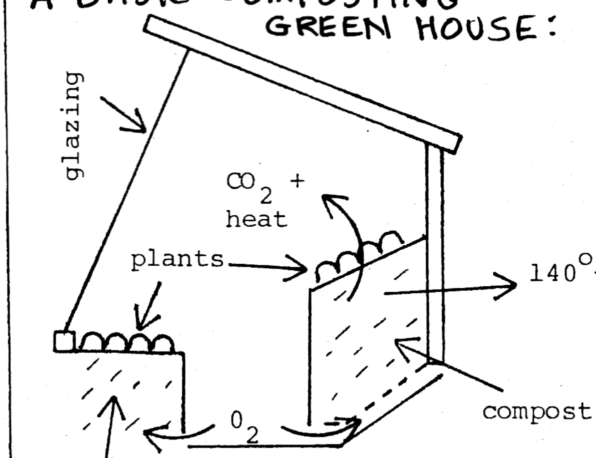
- PVC GREEN HOUSE FRAME CAN BE USED FOR GROWING HYDROPONIC CROPS.

AQUA-CULTURE SYSTEM

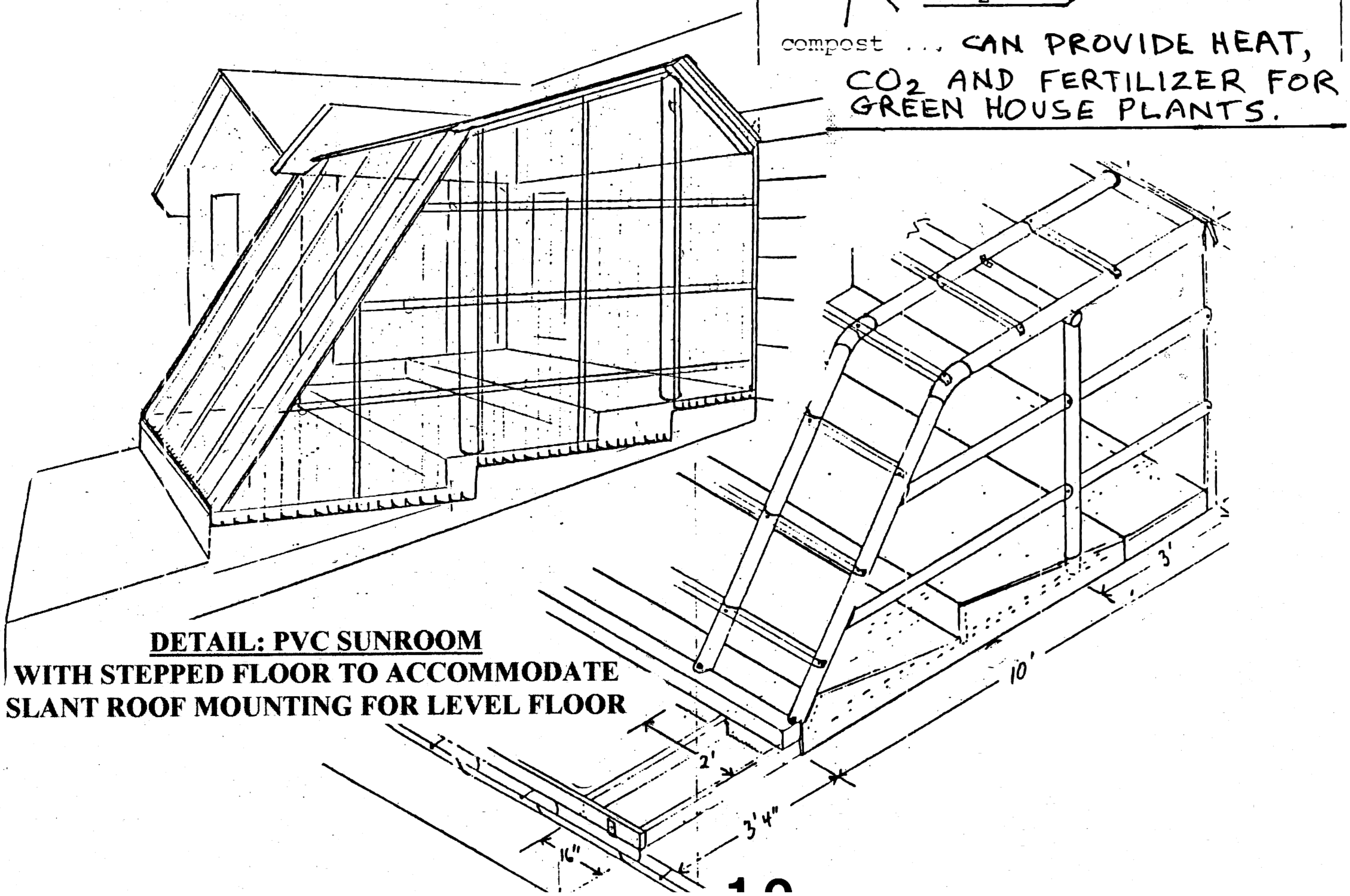


- REEDS AND GRASSES HELP IN WATER-TREATMENT, OTHER PLANTS CAN PROVIDE NUTRIENTS FOR FISH GROWTH, IN LARGE OR SMALL SCALE SYSTEM.

A BASIC COMPOSTING GREEN HOUSE:



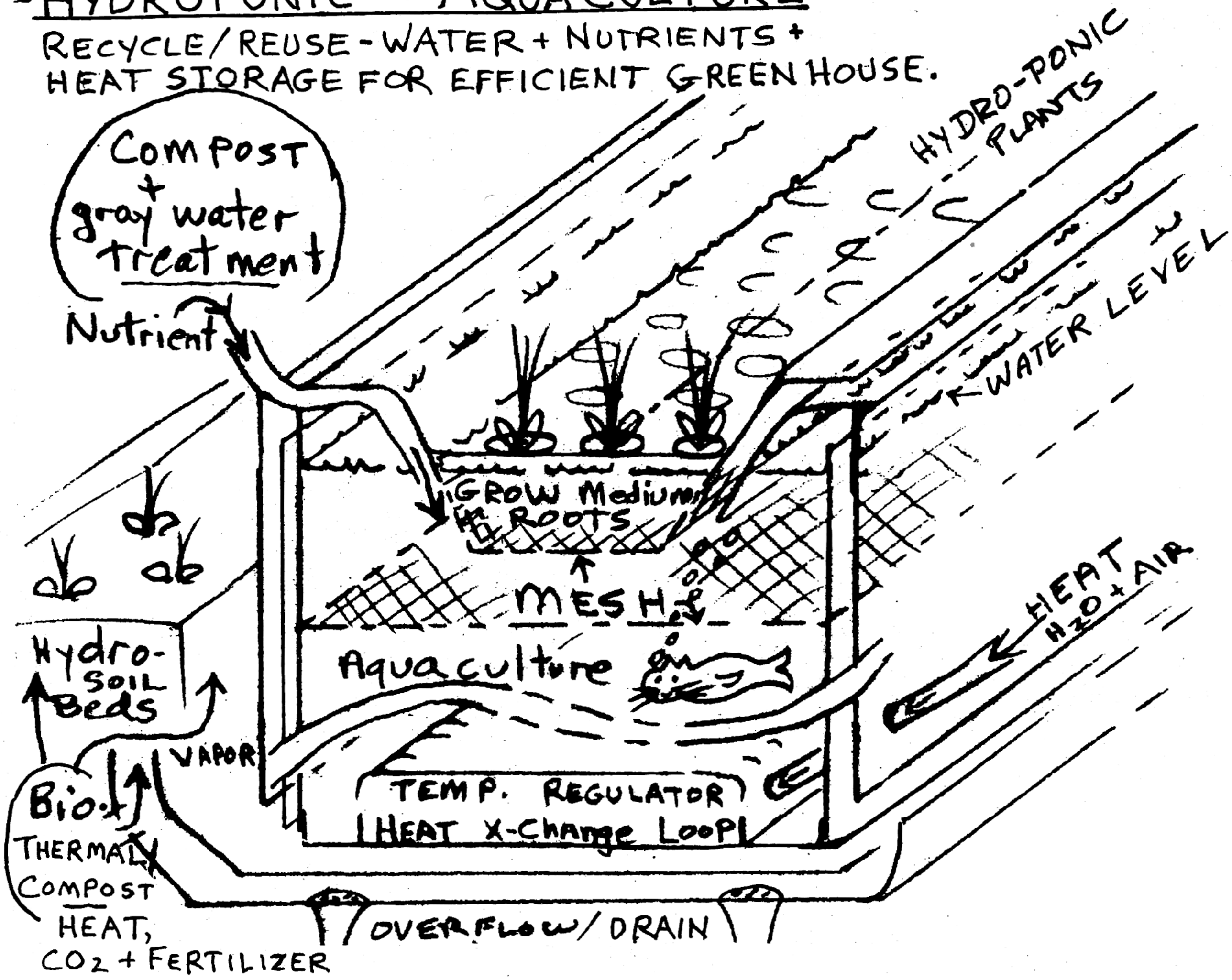
compost ... CAN PROVIDE HEAT, CO_2 AND FERTILIZER FOR GREEN HOUSE PLANTS.



DETAIL: PVC SUNROOM
WITH STEPPED FLOOR TO ACCOMMODATE SLANT ROOF MOUNTING FOR LEVEL FLOOR

-HYDROPONIC + AQUACULTURE-

RECYCLE/REUSE - WATER + NUTRIENTS + HEAT STORAGE FOR EFFICIENT GREEN HOUSE.



- **HEAT SOURCE**
  - Sun, direct gain to greenhouse heat sink
  - Composting unit
  - Active panels, hot air and hot water
- **HEAT STORAGE**
  - Water, hydroponic / aquaculture
  - Soil beds
  - Greenhouse heat sink
- **HEAT TRANSFER**
  - Air, (convection and fan), to living area and return to soil beds / compost unit
  - Water, (and non-toxic anti-freeze), from panels to hydroponic / aquaculture and heat sink
  - Thermostatic & photoelectric active control

Credits: Many thanks to John Todd, (Living Machines) water treatment systems;
Bruce Fulford, (Biothermal Energy Center), composting solar greenhouse;
Charles Ewing, (SEADS of Truth, Inc.), Peoples greenhouse kit..

OPTIONS :

You consider, you decide your unique aspects
Of your homebuilt Green House Kit.

Your Solar Greenhouse is:
Can be –
-Growing space / Sun Room , to relax, create, an
extension of your human environment,
with theraputic dimensions.
Hydroponic Grow System, soil-less, nutrient solution
In a lightweight growth medium.
Aquaculture - growing fish for fun and food,
(hydroponics and aquaculture can be combined
in a symbiotic system).
Heat Grabber – water and air heater.
Heat storage, and transfer / distribution to living space.
Solar panel support structure –
Hot air and water panels, PV/DHW Hybrid panel,
(PV and wind elec.generation and storage.)
Composting space – (green and human waste, composting toilet)
Heating, heat storage and nutrient (CO2) production
Gray-water treatment / cleaning / recovery / reuse
Other Human environment conciderations (Hot-tub, Spa, etc.)

SOLAR AIR HEATERS

While direct gain through windows is the most common way to collect the sun's heat in a passive solar home, thermosiphon air heaters are a good addition to the south wall of any home. They reduce the window area on the inside wall of the room, producing a normal appearing living space with smooth wall space for furniture and pictures. They are quite efficient and also can be easily closed off at night to retain heat. Thermosiphon air heaters also can be built in almost any size and shape and can be added to existing buildings. The Maine Solar Energy Association has had several successful air heater workshops where several of the participants took home the collectors constructed, paying the cost of the materials. The collectors built at the latest of the MESEA workshops cost $35 each; we were particularly good at recycling discarded materials at that workshop. Below is a set of calculations of the expected performance of a simple air heater constructed from a fogged-up panel from a sliding glass door. The design has moving air passing on both the front and back of the absorber plate, an important detail that improves the efficiency of this simple design. Double glazing is necessary with moving air passing directly behind the glass.

Several Maine dealers will supply you with completely finished, professionally made, solar air heaters. These can be hooked up to an existing forced air heating system. At the other end of the spectrum is a design on page 19 of a **Sun Grabber** that can be stuck into a window in a rented room or student dorm and taken with you when you move.

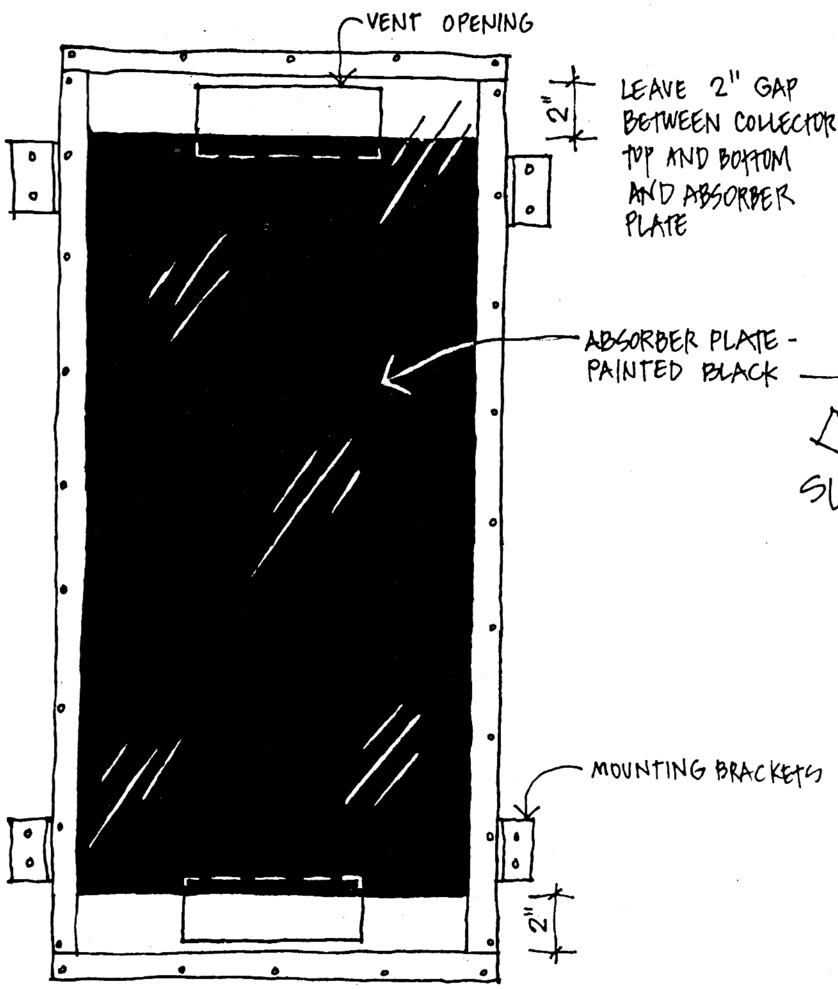
Filename: SOLARAIR		OUTPUT FROM SOLAR AIR HEATER SYSTEMS		
Version 2.1				
CITY	STATE	COUNTRY		
EASTPORT	ME	USA	Latitude:	45 degrees

Collector Tilt:	90 degrees	Oil cost/gal.	$0.85
Collector number	1	Electric cost/KWH	$0.12
Collector length	76 inches		
Collector width	34 inches	Room air temp. Deg. F	68
Collector area	18 sq. ft. =	1.66 sq. meters	

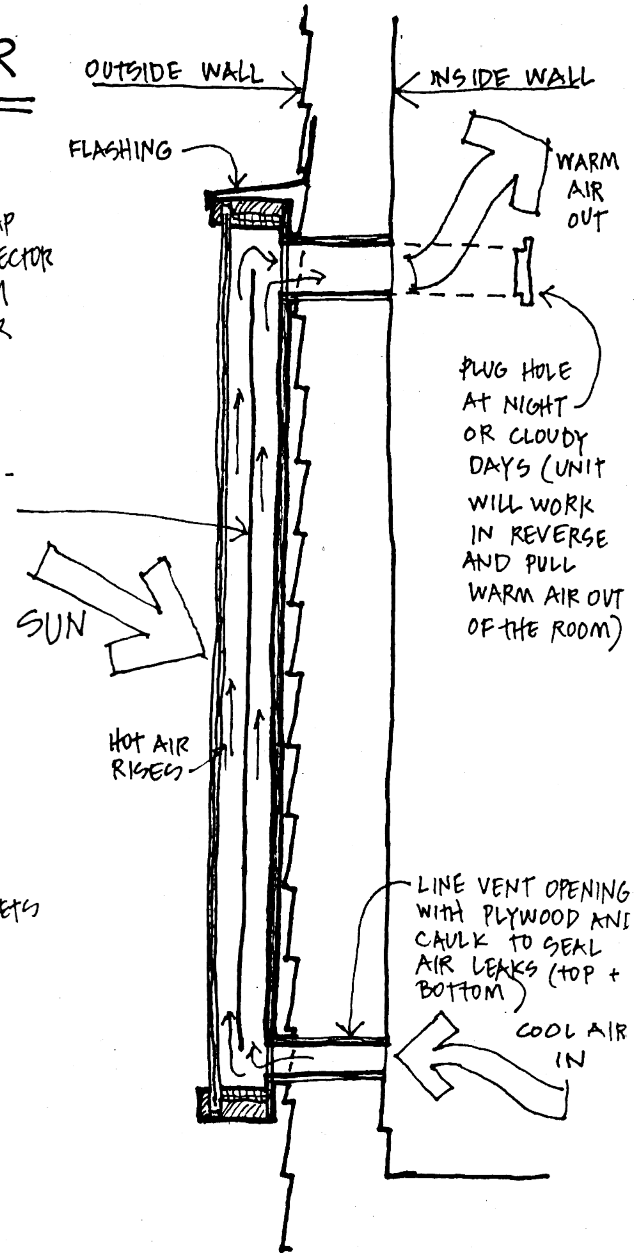
These calculations are just approximations based on the average weather in the area. The final savings will depend on your habits.

MONTH	Average Day. Temp.	Percent Sun	Collector Efficiency	BTU per day	BTU per mo. Output	Value vs Oil	Value vs Elec.
JAN	26.5	45.00	0.56	4183	129673	$0.78	$4.56
FEB	27.9	51.00	0.57	4770	133560	$0.81	$4.70
MAR	36.8	52.00	0.63	5014	155437	$0.94	$5.47
APR	47.7	52.00	0.69	4230	126898	$0.77	$4.47
MAY	57.7	51.00	0.76	3046	94437	$0.57	$3.32
JUN	67.2	53.00	0.82	2546	76379	$0.46	$2.69
JUL	73.0	55.00	0.85	3239	100409	$0.61	$3.53
AUG	71.4	57.00	0.84	5526	171316	$1.03	$6.03
SEP	63.7	54.00	0.79	7320	219598	$1.33	$7.73
OCT	54.1	50.00	0.73	7444	230751	$1.39	$8.12
NOV	43.6	37.00	0.67	4872	146157	$0.88	$5.14
DEC	30.7	40.00	0.59	4043	125328	$0.76	$4.41
TOTAL FOR YEAR				1686988	1709943	$10.32	$60.17

THERMOSIPHON SOLAR AIR HEATER

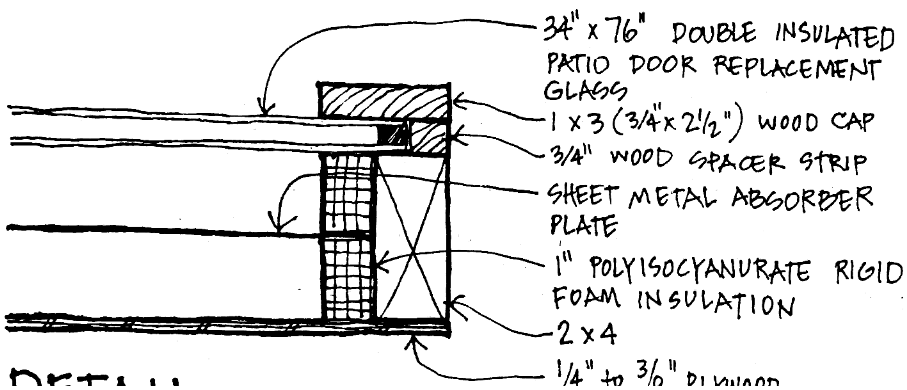


FRONT ELEVATION



NOTES:
- MOUNT COLLECTOR ON AN EXISTING SOUTH-FACING WALL.
- CAULK ALL JOINTS TO PREVENT AIR LEAKS.
- CASES CAN BE MADE TO FIT USED GLASS PANELS OF VARIOUS SIZES.
- DOUBLE GLAZING IS ESSENTIAL.
- UNIT WILL HEAT 1 to 2 ROOMS ON A SUNNY WINTER DAY.

SECTION

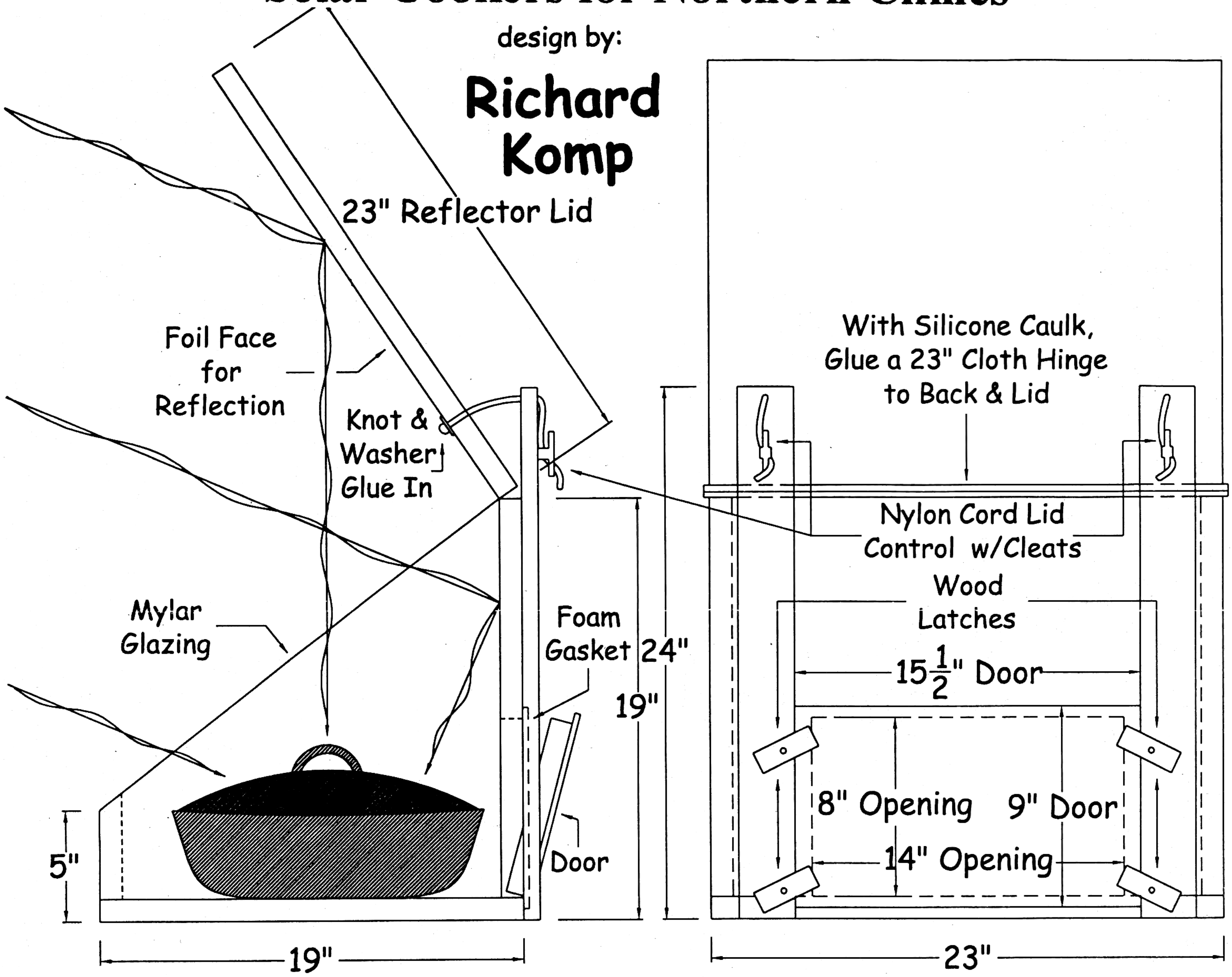


MeSEA
MAINE SOLAR ENERGY ASSOCIATION

Solar Cookers for Northern Climes

design by:

Richard Komp



Use 1" thick foil faced foam for all walls and floor. Glue & seal joints with silicone caulk.
Foil faced foam (isocyanurate) brand names: **Tuff-R** or **Celutex**. DO NOT USE STYROFOAM!!!
Glazing: Transparent Mylar or Polycarbonate Glass.
Reflector Supports: 1" x 3" wood strapping
Door: 1/4" plywood Glue: Silicone Caulk
Verify cooking pot will fit through door opening!!!!!

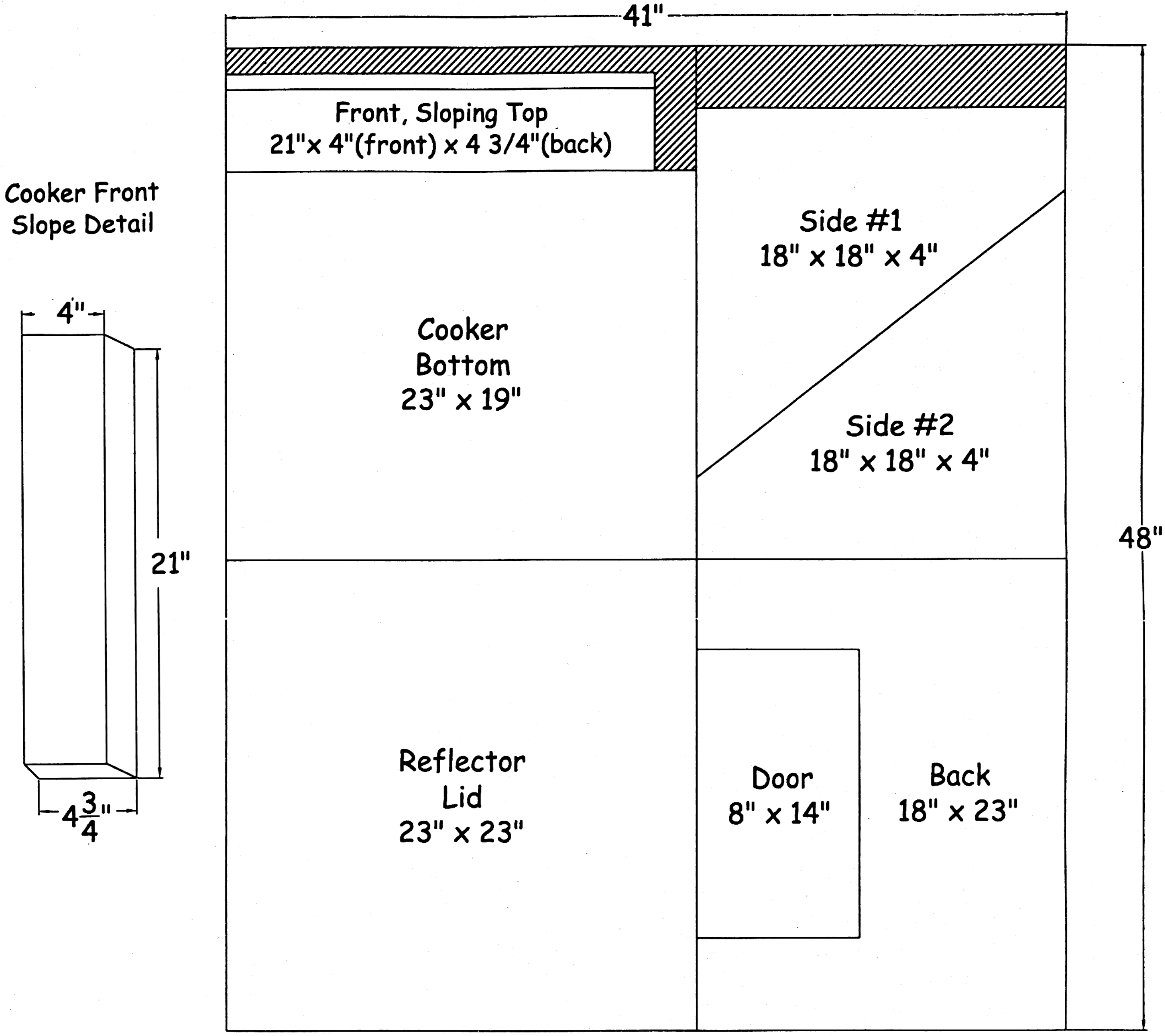
artwork by Jim Coder

The solar cooker plans in the Maine Solar Primer were first developed by Jared Crawford as the result of a series of solar cooker workshops he taught for MESEA back in the early 1990s. These were based on designs for cardboard solar ovens developed by Solar Box Cooker International over several decades. Since that time, I have been working with the Grupo Fenix in Nicaragua, who have been teaching solar cooker workshops to peasants in Central America; and we have developed more rugged and better working solar cooker designs as part of our program of bringing a better alternative to these people who normally use firewood as their cooking fuel

While this cooker is simpler than the ones we build in Nicaragua and is designed to be a light, portable, easy to use box cooker; the physical principles are similar to those in our successful tropical cookers. This cooker is based on a design by John Root from Iowa. It turns out that most of the energy needed to cook food is used to get the food up to the cooking temperature and to hold it there for the time needed to cause the chemical reactions that produce the cooked food. (These reactions can actually be exothermic, that is food while cooking, can actually give off rather than absorb heat.) Here is some physics of the four means of heat transfer, starting with:

RADIATION: All the energy available for operating the solar cooker comes from the sun's radiation. This is in the form of visible and near infrared light rays that have to come into the cooker through' the transparent glazing. The reflective cover bounces extra solar radiation into the box and onto the black cover and cooking pot, black being the color that. The transparent cover has to be nearly perpendicular to the sun, since glass or transparent plastic at a steep angle to the sun's rays will reflect a good deal of the light, instead of allowing it to enter. The sloping front is designed

Foam Cutting Pattern



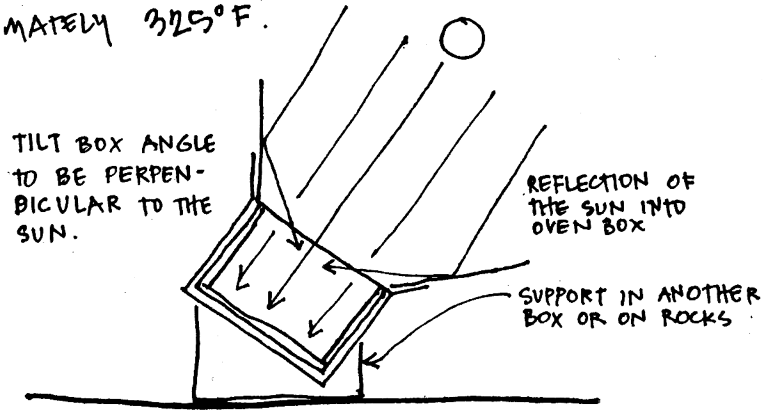
CONDUCTION: Once the solar energy is inside the box, it must be retained rather than leaking out of the box. One major way of losing heat is by conduction. The walls and floor of the box can conduct the heat out of the box, so we use an efficient insulating foam. This foil covered foam will take relatively high temperatures and doesn't outgas to contaminate the food. Since the rate of conduction is directly proportional to the temperature difference between the inside and outside wall surfaces, we keep the walls of the oven cooler by not painting them black. Instead they are highly reflective, bouncing the incoming light onto the black pot, which will be the hottest object in the cooker. This also cuts radiation losses. A black plate can be put into the bottom of the cooker instead of (or underneath) the pot to have a flat hot cooking surface for cookies and small items. This plate should be raised up by ½" insulated spacers (these can be made from small disks cut from wine corks).

CONVECTION: is the transfer of heat by the movement of air or liquids. This is the major source of heat loss in a solar cooker. Hot air rises and the air heated by contact with the hot, black pot will rise and attempt to escape. The transparent Mylar glazing prevents the air from completely escaping from the inside of the box, but the hot air heats the clear plastic, which in turn heats the air above the glazing. A double layer of glazing with a ½" dead air space would cut this loss by convection. (½" is too small a distance to start convection currents and air is a very poor conductor of heat, a good insulator.) Convection currents in the cooker also carry the heat from the pot to the walls of the box. This is primarily what heats the walls and can be minimized by keeping the box as low as possible. The loss of heat by hot air escaping through small cracks in the joints of the box can be very serious and must be eliminated by careful fitting and gluing of all the parts with the silicone RTV (GE or other 100% silicone caulk works very well in this application).

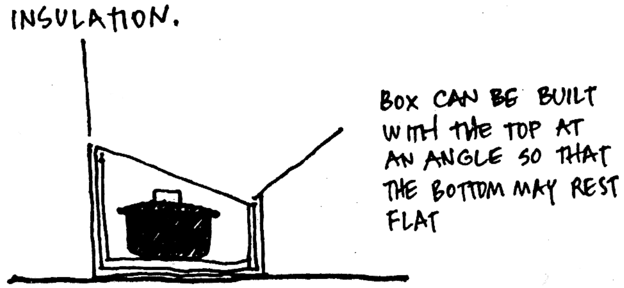
PHASE CHANGE: in the form of the evaporation of water from the pot and its condensation on the transparent glazing, will carry a lot of heat from the food (as well as dry the food out) and must be eliminated by a tight fitting cover. Use less water when cooking in a solar over, since the natural juices will be retained. The melting of butter or the fats in the food is another example of phase change, but this all takes place inside the pot and has a very small effect on the oven's efficiency. Ian, my assistant and I tested this oven on Halloween by cooking a very nice chicken stew, so

SUN STAR SOLAR COOKER

A SOLAR COOKER IS AN INSULATED BOX TO TRAP THE HEAT OF THE SUN FOR COOKING FOOD. SUNLIGHT PENETRATES THE GLASS COVER OF THE BOX, AND IS ABSORBED BY THE BLACK SURFACES INSIDE THE BOX. THE LIGHT'S ENERGY IS CONVERTED TO HEAT, WHICH IS RELEASED INTO THE BOX AS WARM AIR AND THERMAL RADIATION. GLASS HAS AN ADVANTAGEOUS PROPERTY – IT PERMITS THE SOLAR RADIATION TO PASS THROUGH, BUT RETARDS THE PASSAGE OF THERMAL RADIATION OUT. THE COLLECTORS ADDED TO THE BOX HAVE A REFLECTIVE SURFACE WHICH CONCENTRATES MORE OF THE SOLAR RADIATION INTO THE COOKER. MAXIMUM TEMPERATURE WITHOUT THE COLLECTORS IS APPROXIMATELY 190°F. WITH THE COLLECTORS TEMPERATURE IS INCREASED TO APPROXIMATELY 325°F.

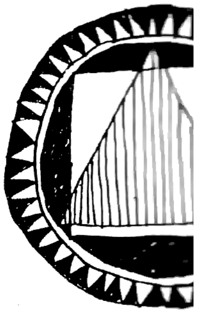


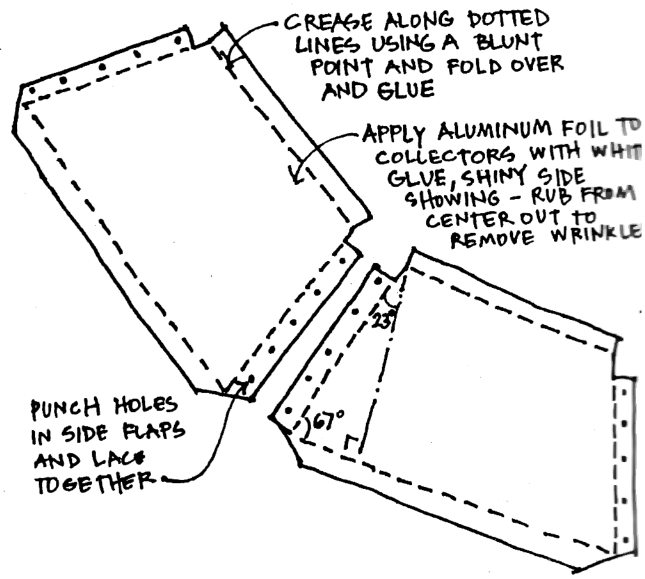
THESE DRAWINGS ARE NOT PLANS BUT A DESIGN – A CONCEPT. THIS PARTICULAR COOKER IS TO BE MADE OF CARDBOARD, BUT COOKERS CAN BE MADE OF PLYWOOD, WOOD, SHEET METAL, POSSIBLY EVEN PLASTIC. THEY CAN BE INSULATED WITH SEVERAL LAYERS OF DEAD AIR SPACE, CRUSHED NEWSPAPER, FOIL FACED ISOCYANURATE FOAM, CARDBOARD, FIBERGLASS, CELLULOSE. THEY CAN BE MADE AS LARGE AS THE GLASS YOU CAN GET. THEY CAN BE MADE MORE EFFICIENT BY ADDING MORE INSULATION.



(NOTE: DO NOT USE BLUE OR PINK OR WHITE FOAM INSULATION.)

THIS MAY INTEREST YOU .

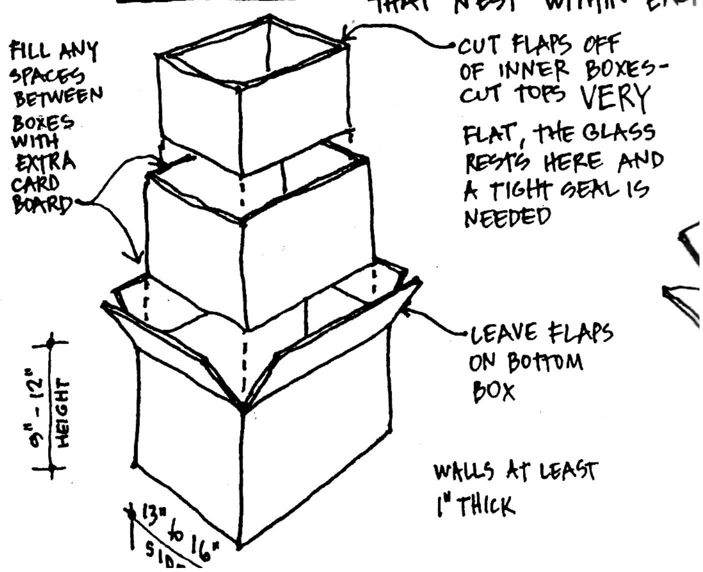


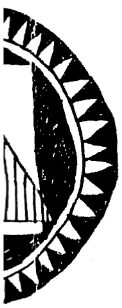


COLLE

REFLECT EXTRA
BOX: COOKER, IN
TEMPERATURE.

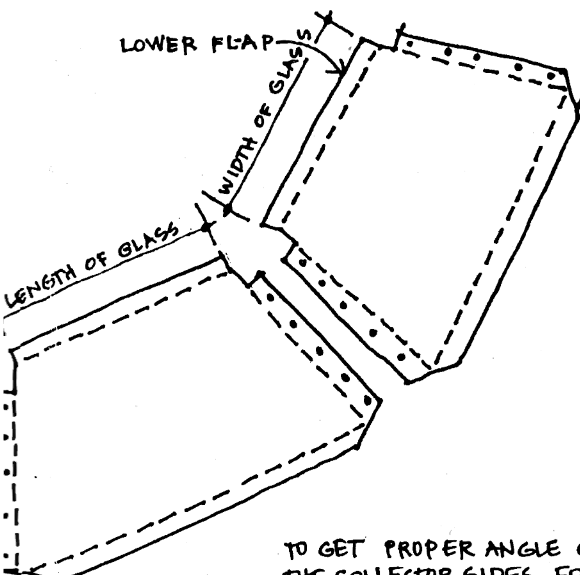
OVENBOX : USE 2 to 3 CARDBOARD THAT NEST WITHIN EACH





USE OF COOKER

- USE A DARK COOKIE SHEET OR OTHER BAKING PAN TO HOLD FOOD AND CATCH BOIL OVER.
- COOK IN DARK POTS — CAST IRON WORKS GREAT, ALSO BROWN GLASS - WITH COVER.
- GLASS JARS PAINTED BLACK LEAVING A STRIP CLEAR DOWN THE SIDE TO OBSERVE COOKING. POKE A SMALL HOLE IN LID TO RELIEVE STEAM PRESSURE.
- THESE OVENS COOK IN WINTER AND SUMMER.
- BRIGHT SUN WORKS BEST, HAZY DAYS ARE OKAY.
- START COOKING EARLY IN THE DAY.
- SET THE OVEN AHEAD OF SUN APPROXIMATELY 1 HOUR.
- MORE FOOD TAKES MORE TIME, LESS FOOD, LESS TIME.
- USE HOT PADS, OVEN GETS HOT!



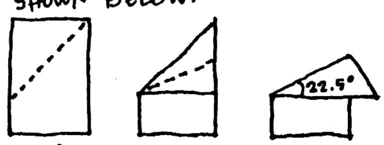
FOOD

- GRAINS AND LEGUMES — USE TYPICAL WATER RATIO
  - SOAK HARDER BEANS OVERNIGHT
- BREAD - PREHEAT OVEN 1 TO 2 HOURS
  - USE ROCK OR BRICK TO ABSORB HEAT
  - PLACE BREAD ON TOP OF HEAT SINK
- VEGGIES - COOK WITH LITTLE OR NO WATER
- PIZZA - PRECOOK CRUST
  - ADD TOPPINGS AND CHEESE TO MELT
- COOKIES, CAKES, CORNBREAD, CASSEROLES, ETC., ETC., ETC.

CTORS

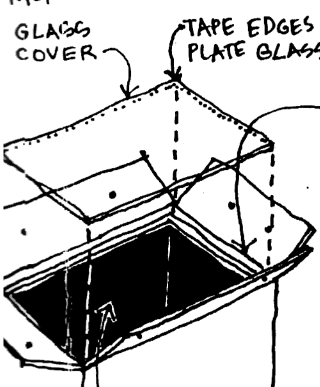
SUNLIGHT INTO
EASING OVEN

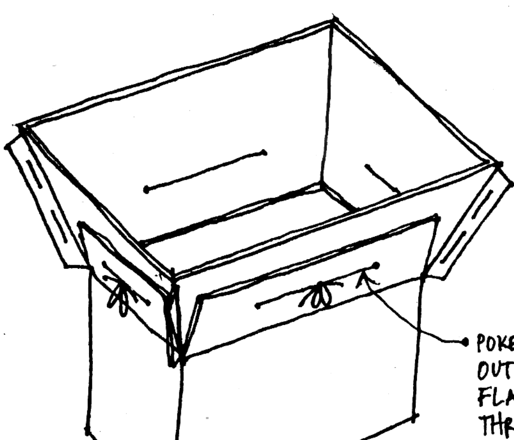
TO GET PROPER ANGLE OF THE COLLECTOR SIDES, FOLD A SHEET OF PAPER TWICE, AS SHOWN BELOW.



90° 45° 22.5° (CLOSE ENOUGH TO 23°)

BOXES
THER





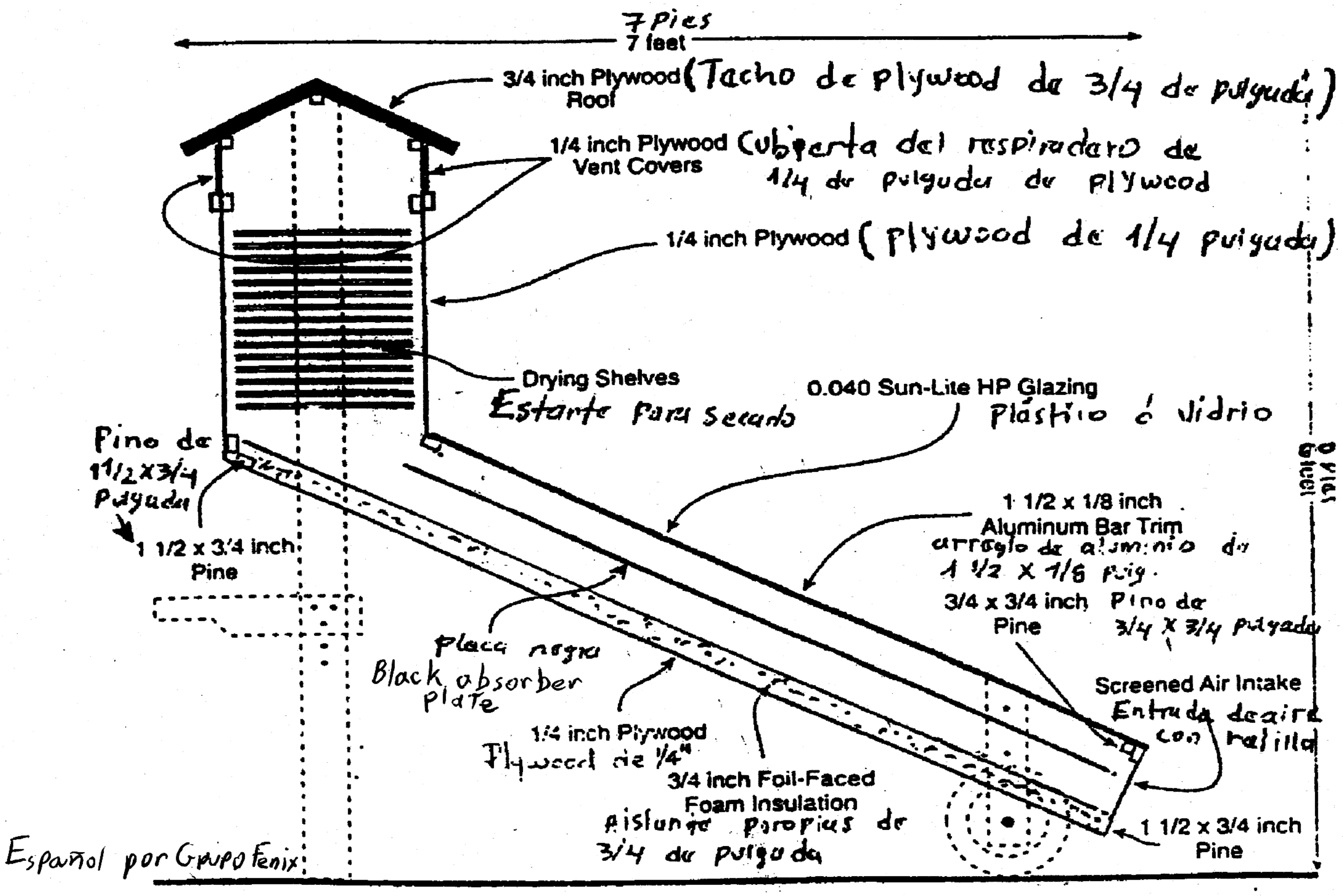
FOR MORE DETAILED INFORMATION ON THIS AND OTHER SOLAR COOKERS, REFER TO: <u>HEAVEN'S FLAME: A GUIDE TO SOLAR COOKING</u> by JOSEPH RADABAUGH, AVAILABLE for $10.00 THROUGH: HOME POWER INC.
P.O. BOX 275
ASHLAND, CA 97520
916.475.3179

THIS DRAWING BASED ON A DESIGN OF JOSEPH RADABAUGH
DRAWN BY
CALEB CRAWFORD

Solar Herb and Food Drier Diagram

Appalachian Mountain College Design

Modified by Richard Komp



The functioning of a solar herb drier is very simple: Outside air enters the screened opening at the bottom of the collector. The sunlight falling on the black metal plate heats up the plate, which in turn heats up the air which then rises. The black plate is in the middle of the collector chamber so that the air can go both in front of and behind the plate, giving twice the contact area for greater efficiency of heat transfer. The heated air enters the bottom of the drying chamber, which has a set of screen shelves, and rises through the chamber around and through the shelves to dry the medicinal herbs or the food placed on the shelves. The warm moist air escapes through the vent openings at the top of the chamber. The thermosyphon action continually draws fresh air in the bottom and can be controlled by sliding doors on the bottom and top air vents.

To dry herbal leaves, you want a large air flow and low temperatures so that the delicate medicinal compounds aren't damaged. The chamber is kept in the dark as many of these compounds can be damaged by light, especially the ultraviolet light from the sun. This means that the vents are kept just about wide open. For drying vegetables, you want warmer air and a lower flow rate, so you partially close the top air vents. However if the air inside gets too warm, the vegetables will cook instead of drying, so each type of vegetable will have its own vent settings, which may have to be adjusted, depending on how sunny and warm it is outside.

Following this design developed in a joint MESEA-Falls Brook Centre workshop in Jonesport. Maine and at the Falls Brook Centre in New Brunswick, several of these solar herb driers have been built by the Grupo Fenix in Nicaragua. The most notable of these is in the village of Apatule, where a women's cooperative have started a cottage industry in growing, drying, packaging and selling native medicinal herbs. They keep one of these herb driers going every day, drying batches of herbal leaves, flower petals and other plant materials. Other communities are starting to build their own driers, of this and other designs, to dry mangos and cashew fruit to preserve and not waste the abundant harvest of these easily spoiled fruits. Charles Ewing of SEADS has built two of these driers at workshops during the Wildgathering in Athens, Maine and I hope this plan encourages other people here in Maine to build their own herb and fruit drier.

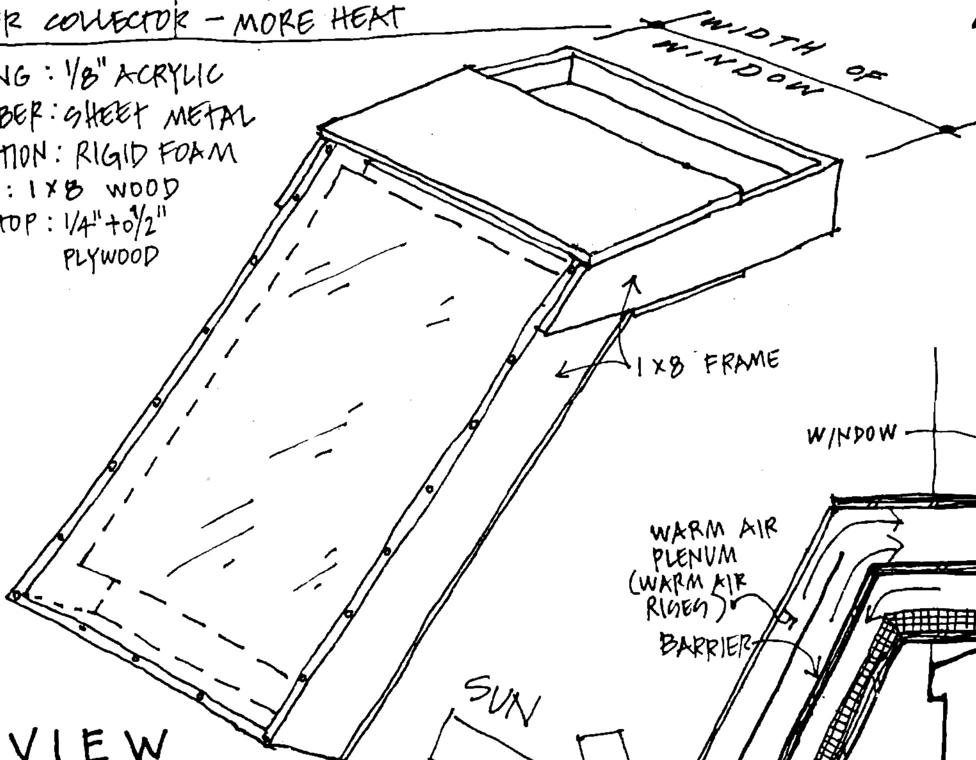
SUN GRABBER

THERMAL SIPHON SOLAR HOT AIR HEATER

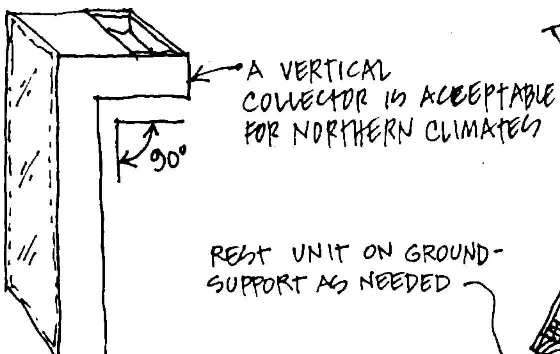
MATERIALS

QUANTITIES VARY ACCORDING TO COLLECTOR SIZE
BIGGER COLLECTOR – MORE HEAT

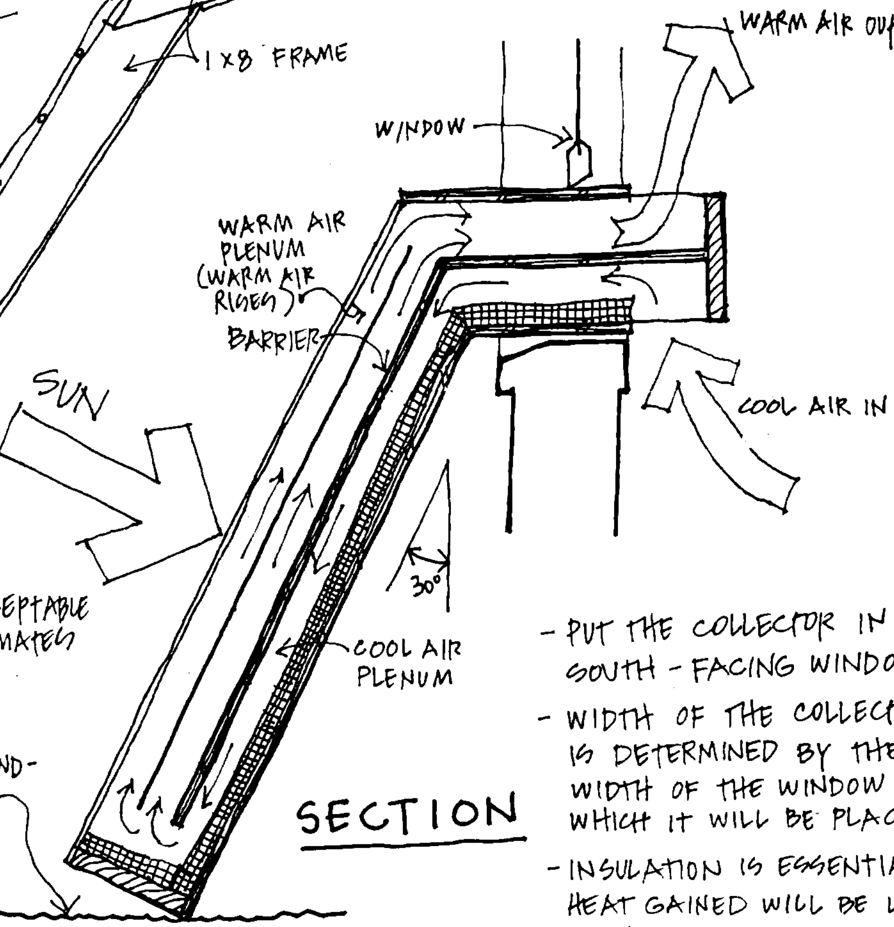
GLAZING : 1/8" ACRYLIC
ABSORBER : SHEET METAL
INSULATION : RIGID FOAM
FRAME : 1 X 8 WOOD
BACK, TOP : 1/4" to 1/2" PLYWOOD



VIEW

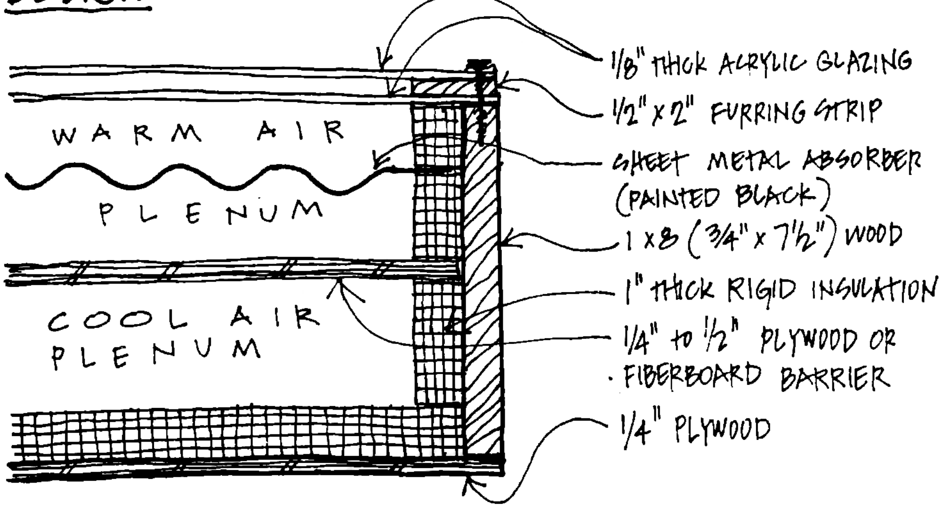


ALTERNATE DESIGN



SECTION

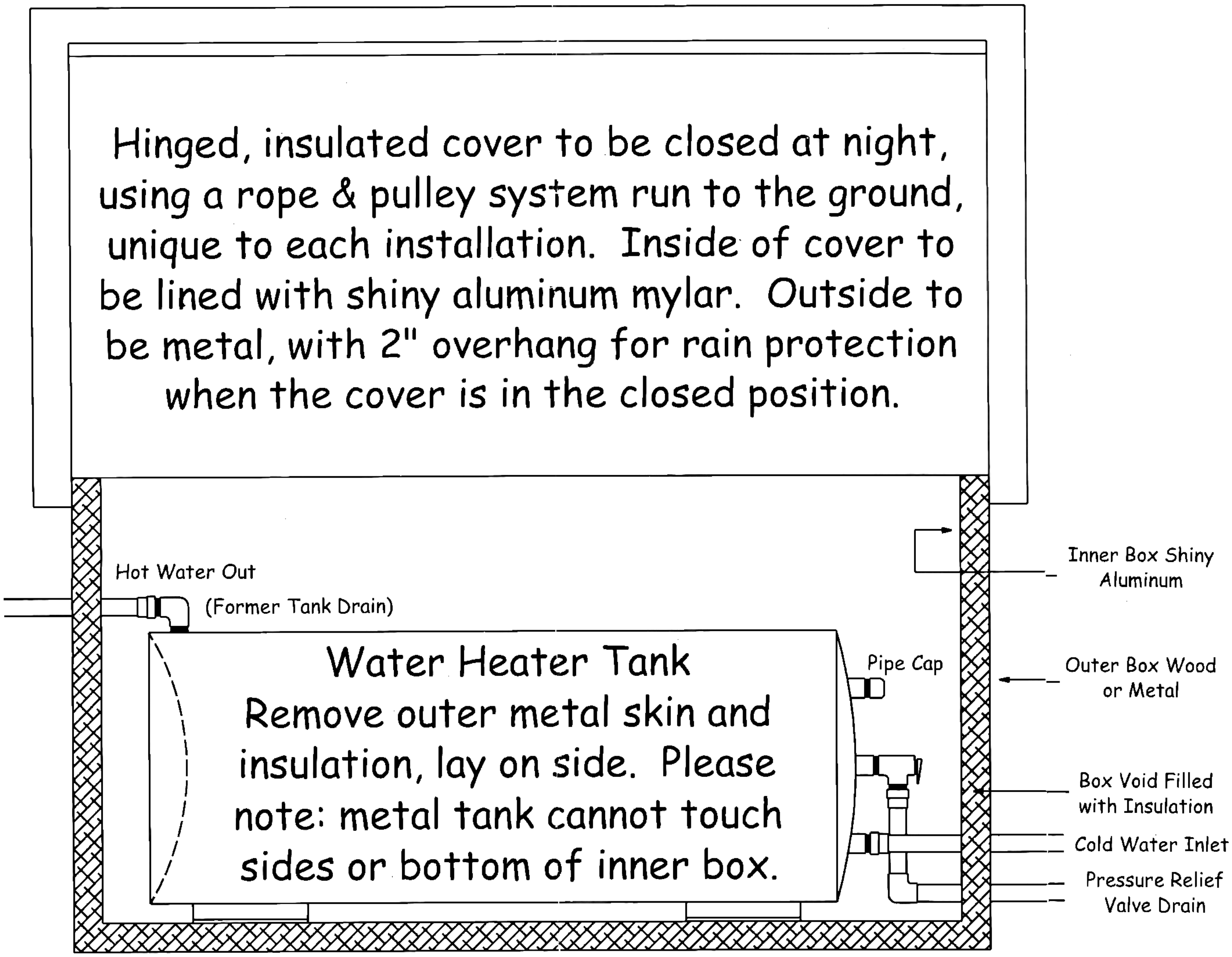
- PUT THE COLLECTOR IN A SOUTH-FACING WINDOW.
- WIDTH OF THE COLLECTOR IS DETERMINED BY THE WIDTH OF THE WINDOW IN WHICH IT WILL BE PLACED.
- INSULATION IS ESSENTIAL! HEAT GAINED WILL BE LOST WITHOUT IT.
- CAULK ALL JOINTS TO PREVENT HEAT LOSS THROUGH AIR LEAKS.
- A SMALL FAN CAN INCREASE THE OUTPUT OF THE COLLECTOR, BUT IS NOT NECESSARY.
- WEATHER STRIPPING SHOULD BE INSTALLED BETWEEN WINDOW FRAME AND COLLECTOR TO PREVENT AIR LEAKS.



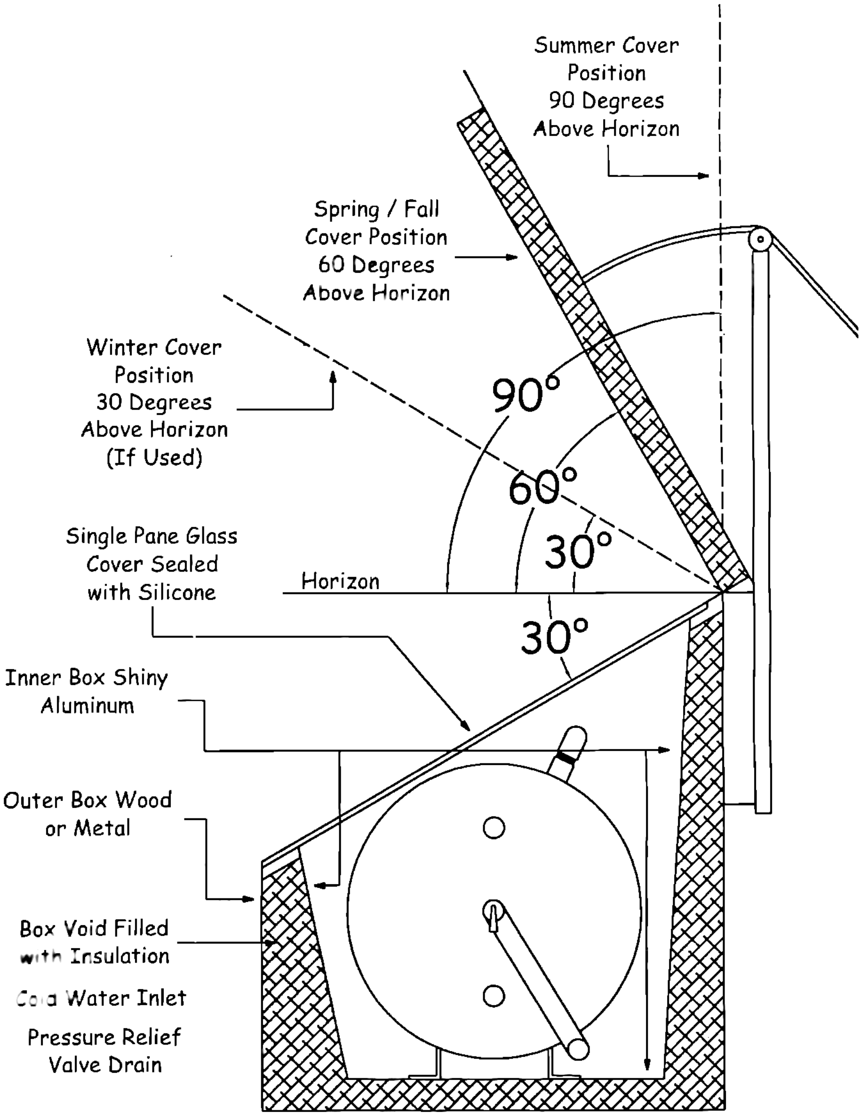
DETAIL

MESEA
MAINE SOLAR ENERGY ASSOCIATION

"Bread Box" Solar Water Heater



The single pane glass cover is sloped 30° from the horizon. The outer box is assembled using wood or sheet metal while the inner box is assembled from shiny aluminum (one good source of this metal is a large print shop, where they are used as printing plates for newspapers). The space between the boxes is filled with insulating material and sealed at the top with a wooden rim. The wood rim keeps the heat from leaking from the hot inner metal box to the cooler outer one. All construction joints and seams, plumbing entrance and exit holes, as well as the single pane glass cover are sealed with silicone RTV to prevent heat loss by air convection.



design by Richard Komp
artwork by Jim Coder

The box type solar water is one of the earliest solar heater designs. They were developed in the 18th century and thousands of these were built and used by the late 19th century. The Victorian middle class loved the idea, since they generally took their baths in the late afternoon just before dressing for dinner and the box had all day to heat up. However, Americans are used to taking their showers in the early morning when they get up and by then, the water was dead cold in these early solar heaters, which had no covers. The well insulated cover will keep the water warm until morning, but it is still better to plan to use the hot water in the evening.

Since this design has no real freeze protection, it is best used in a remote camp or other place where the solar water heating is only needed in the warmer months (from late May to mid October here in Maine). A year-round remote cottage can use a coil in the wood stove to furnish the hot water the rest of the year. The design is quite flexible and can be used with two smaller diameter tanks, (for example) laid next to each other in a wider shallower box for a more efficient design with a bigger solar aperture.

This drawing is not to scale. The correct BOX TYPE SOLAR WATER HEATER dimensions will be determined by the size of the water heater tank available. If installed on a sloping roof, legs or mounting brackets will be required to maintain the 30° (from the horizontal) slope of the glass pane cover. A single pane of glass is actually better than a double pane would be, since each pane absorbs or reflects about 10 % of the incoming light; and the extra insulation is not really useful in the warmer months when this Batch Type heater will be used.

SOLAR WATER HEATERS

Perhaps the best way for the average person to save money by using solar energy is installing a solar water heater. These self contained systems can be retrofitted onto almost any dwelling, and because of the rise in utility rates over the years, the "payback time" for a modern solar water heater is actually shorter than it was with the tax credits back when they were available. Unfortunately, solar water heaters are not currently fashionable; to most people, heating water is just a prosaic thing that happens automatically without any thought or work. There were also quite a number of poorly designed, over-expensive solar water heaters installed in the last days before the tax credits expired. These systems have left a legacy of abandoned rooftop collectors and the impression that solar never really worked. We at MESEA have been attempting to counter this misconception by offering workshops where the participants come for a saturday and build several solar hot water collectors as well as the heat exchanger and other parts necessary for a complete system. These systems typically cost about $1200 for the parts, plus your own labor to install. Below is a calculation of the expected performance of a two collector system; big enough for a small family. The following diagrams are based on this workshop kit, which we have developed for Maine's more rugged climate. The same system would work quite well elsewhere in New England and in Maritime Canada.

Filename: SOLARDHW   OUTPUT FROM SOLAR WATER HEATER SYST
Version 2.0

CITY	STATE	COUNTRY		
ROCKPORT	ME	USA	Latitude:	45 degrees

Collector Tilt:	45 degrees	Electric cost/KWH:	$0.12
Collector number	2	Cold water, deg. F	45
Collector length	76 inches	Hot water, deg. F	120
Collector width	34 inches		
Collector area	54 sq. ft. =	4.98 sq. meters	

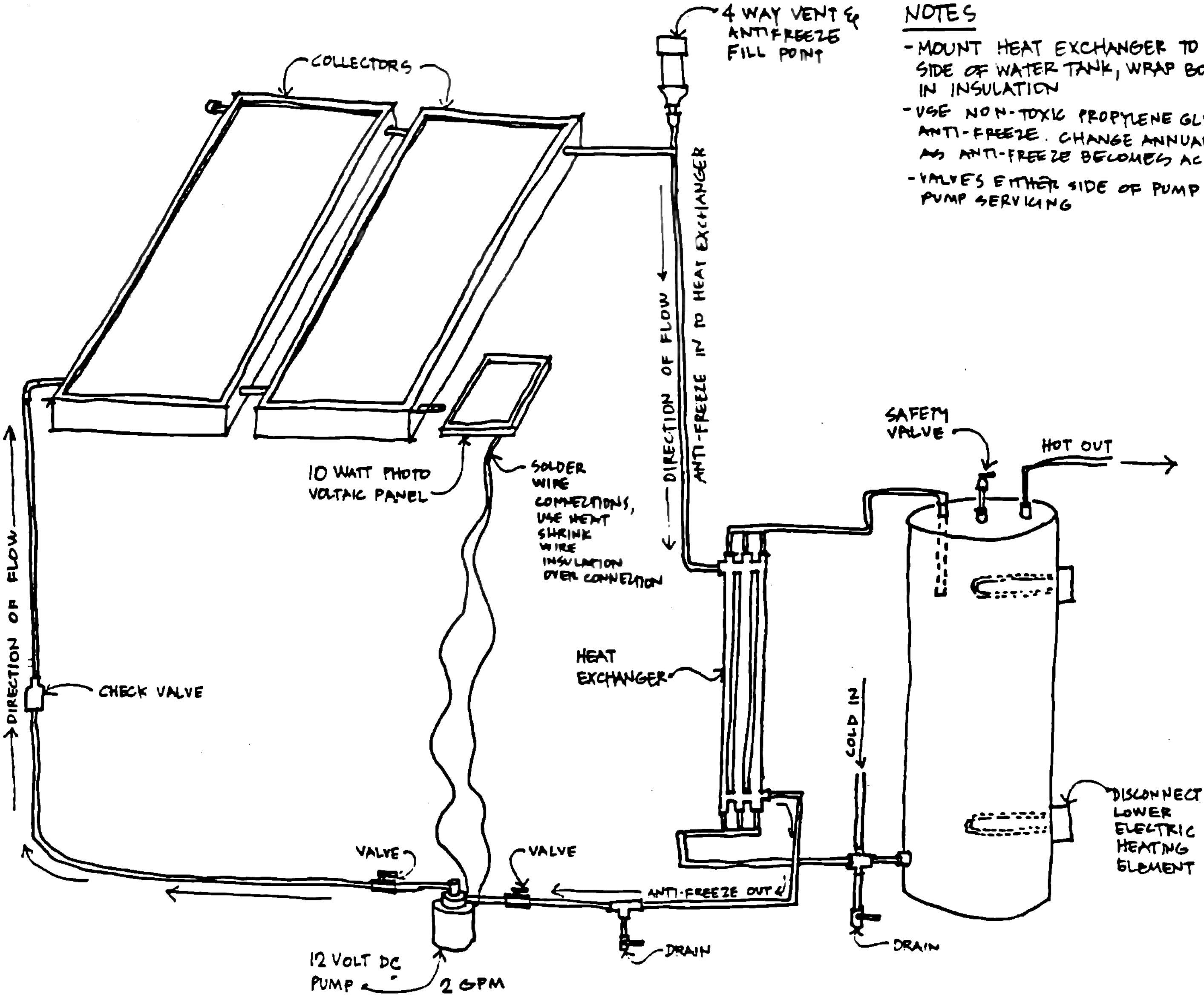
These calculations are just approximations based on the average weather in the area. The final savings will depend on your habits.

Month	Average Day. Temp.	Percent Sun	Collector Efficiency	Gal. HW per day	BTU per mo. Output	Output Value
JAN	26.5	45.00	0.45	15.64	232662	$8.19
FEB	27.9	51.00	0.46	20.35	273470	$9.62
MAR	36.8	52.00	0.52	27.95	415904	$14.64
APR	47.7	52.00	0.59	35.49	511022	$17.98
MAY	57.7	51.00	0.65	39.48	587443	$20.67
JUN	67.2	53.00	0.72	45.94	661517	$23.28
JUL	73.0	55.00	0.76	54.62	812792	$28.60
AUG	71.4	57.00	0.75	60.60	901677	$31.73
SEP	63.7	54.00	0.69	52.79	760189	$26.75
OCT	54.1	50.00	0.63	39.21	583458	$20.53
NOV	43.6	37.00	0.56	20.91	301039	$10.59
DEC	30.7	40.00	0.47	15.15	225386	$7.93
TOTAL FOR YEAR				12843	6266559	$220.52

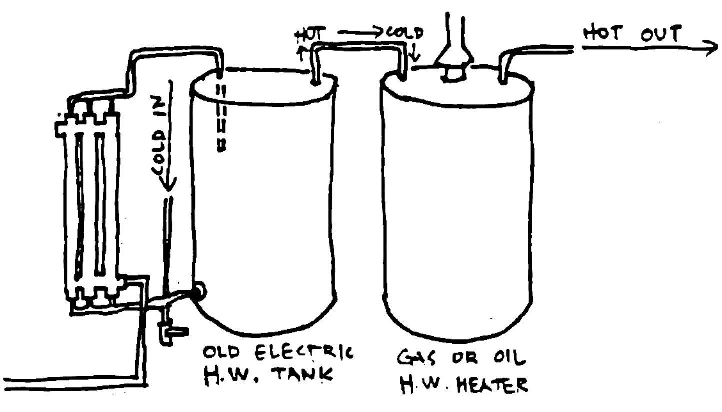
PLUMBING DIAGRAMS   MESEA SOLAR WATER HEATER KIT

NOTES

- MOUNT HEAT EXCHANGER TO SIDE OF WATER TANK, WRAP BOTH IN INSULATION
- USE NON-TOXIC PROPYLENE GLYCOL ANTI-FREEZE. CHANGE ANNUALLY AS ANTI-FREEZE BECOMES ACIDIC.
- VALVES EITHER SIDE OF PUMP FOR PUMP SERVICING



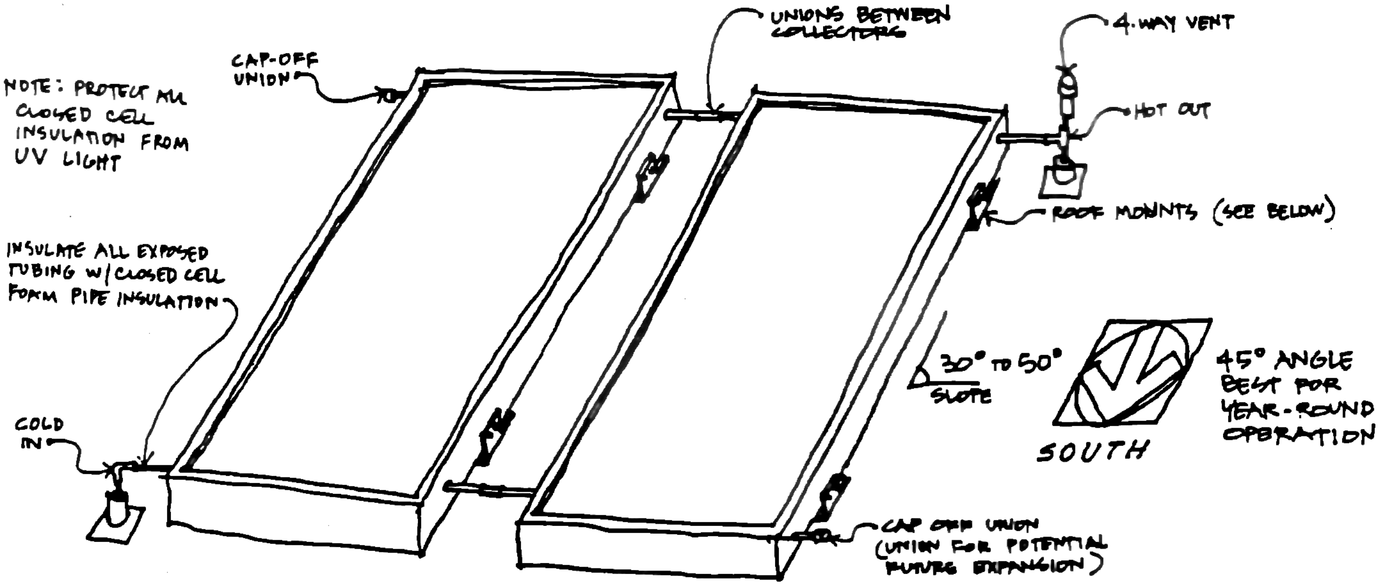
2 PANEL, 1 TANK SYSTEM



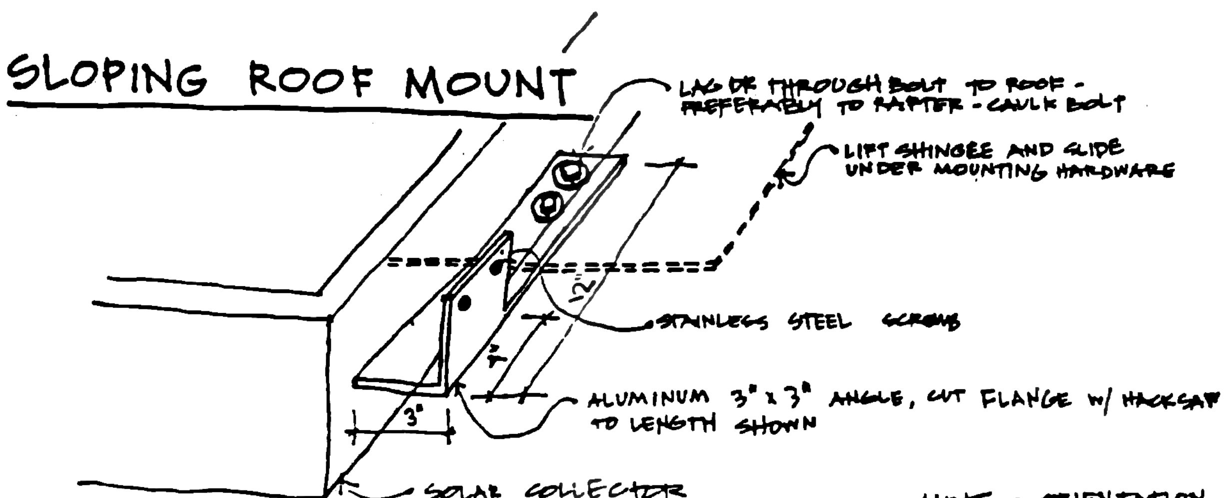
MAINE SOLAR ENERGY ASSOC.
17 Rockwell Rd SE
Jonesport ME 04649

2 TANK SYSTEM

MOUNTING SYSTEMS MeSEA SOLAR WATER HEATER KIT

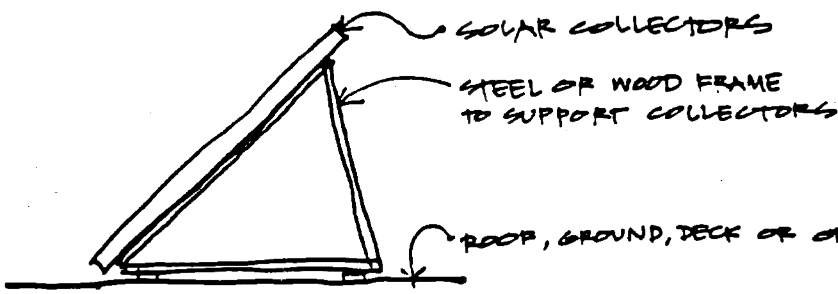


SLOPING ROOF MOUNT

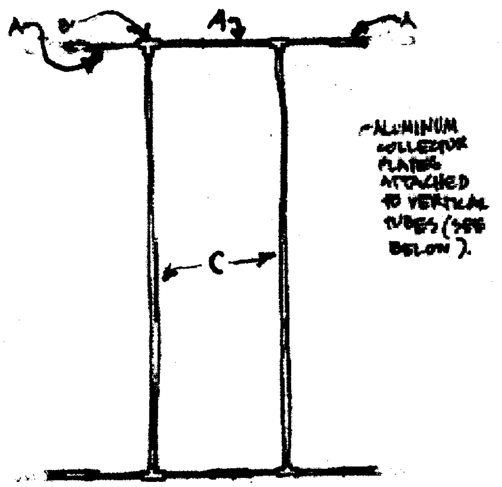


ROOF MOUNT

NOTE - ORIENTATION BEST AT DUE SOUTH. 85% EFFICIENC AT UP TO 30° TO EAST OR WEST
- 45° SLOPE BEST FOR YEAR-ROUND USE AT THIS LATITUDE.
- SLANT COLLECTORS SLIGHTL OFF HORIZONTAL TO ENSURE COMPLETE DRAINAGE OF ANTIFREEZE FROM PANELS.



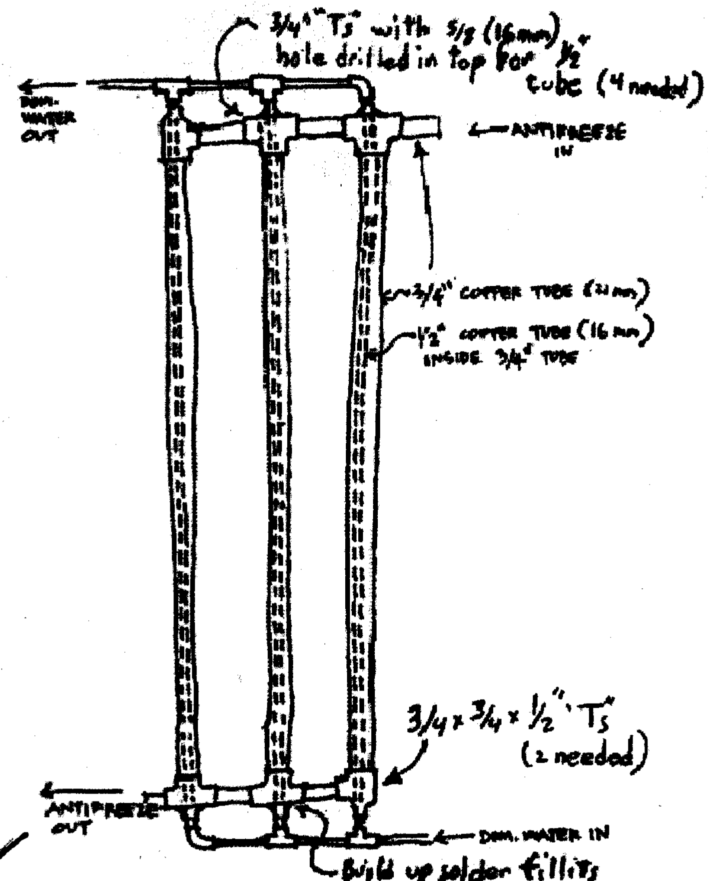
PLUMBING SYSTEMS MeSEA Solar Water Heater Kit



COLLECTOR PANEL MANIFOLD

ALL 1/2" TYPE "M" COPPER TUBE & FITTINGS

A) (6) 12" MANIFOLD PIECES
B) (4) TEES
C) (2) 72" RISERS

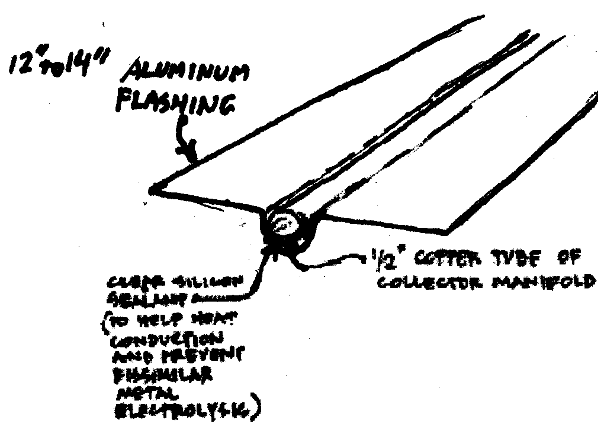


HEAT EXCHANGER MANIFOLD

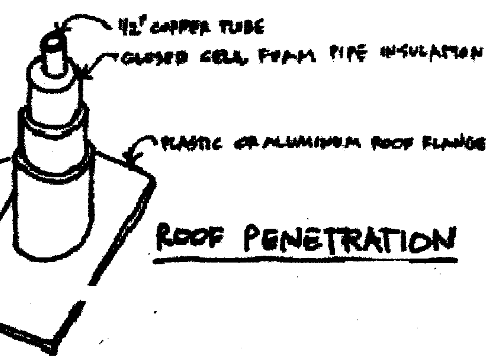
1/2" & 3/4" TYPE "M" COPPER TUBE & FITTINGS AS INDICATED.

FOR 2 PANEL EXCHANGER:

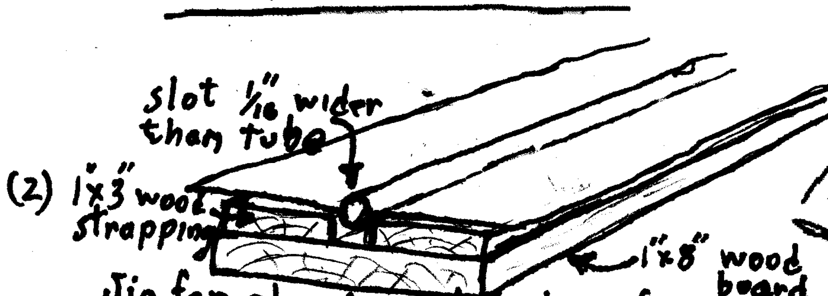
(2) 72 1/2" × 1/2" TUBE
(3) 36" × 3/4" "
(4) 2" × 1/2" "
(4) 1 1/2" × 3/4" "



SECTION OF COLLECTOR PLATE



ROOF PENETRATION



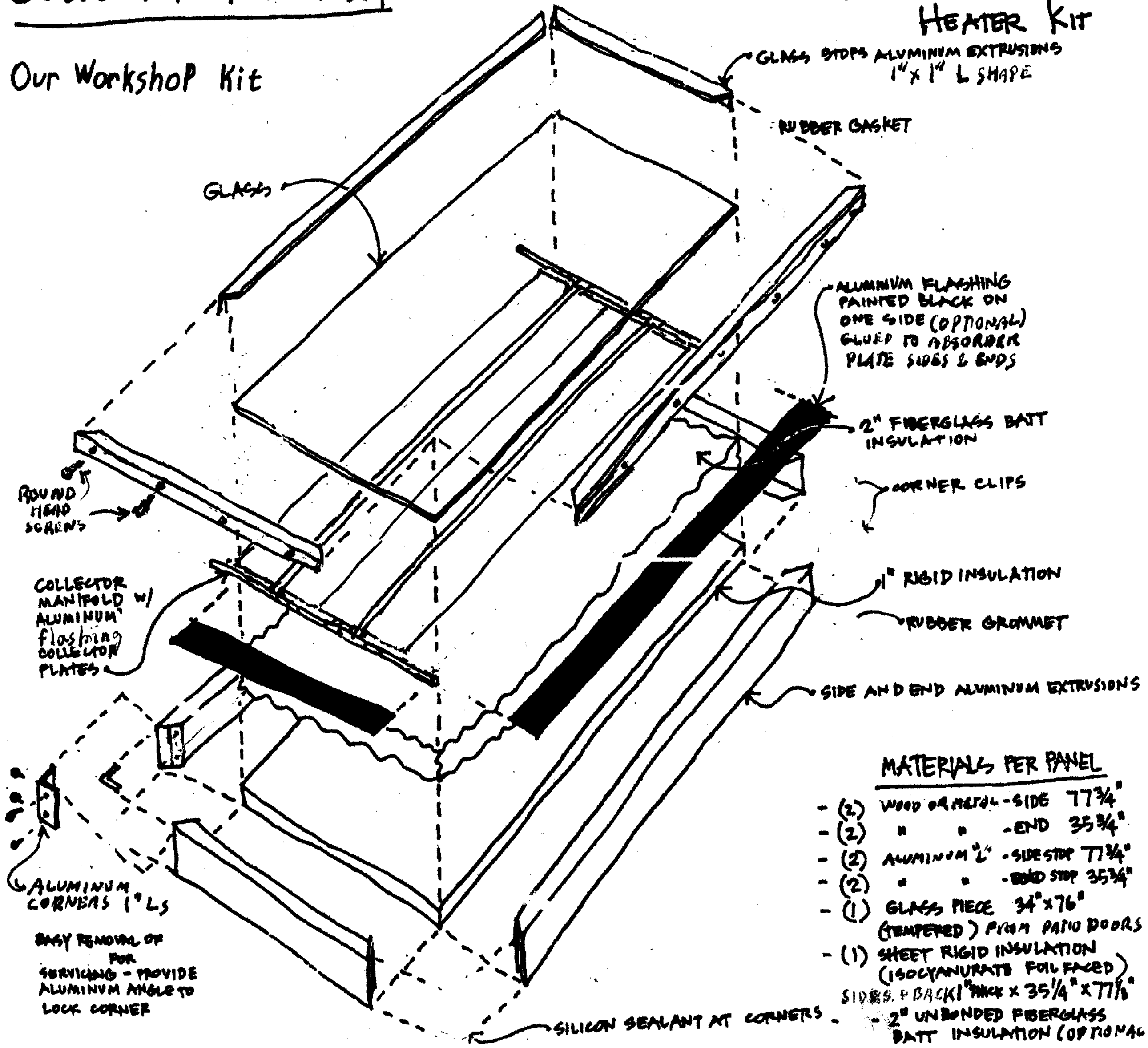
Jig for shaping absorber fins
nail or screw strapping to board

MAINE SOLAR ENERGY ASSOCIATION

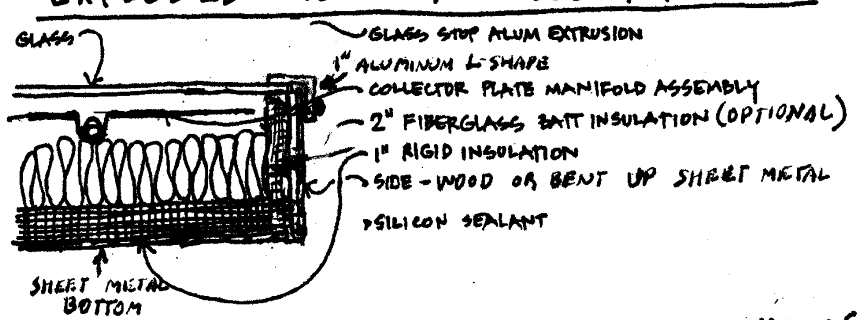
COLLECTOR ASSEMBLY

MeSEA SOLAR WATER HEATER KIT

Our Workshop Kit



EXPLODED VIEW OF COLLECTOR BOX



SECTION THROUGH COLLECTOR BOX

MATERIALS PER PANEL

- (2) WOOD OR METAL - SIDE 77¾"
- (2) " " - END 35¾"
- (2) ALUMINUM "L" - SIDE STOP 77¾"
- (2) " " - END STOP 35¾"
- (1) GLASS PIECE 34"x76" (TEMPERED) FROM PATIO DOORS
- (1) SHEET RIGID INSULATION (ISOCYANURATE FOIL FACED) SIDES + BACK 1" THICK x 35¼" x 77⅛"
- 2" UNBONDED FIBERGLASS BATT INSULATION (OPTIONAL
- " ALUMINUM FLASHING PAINTED BLACK ON ONE SIDE
- BLACK HIGH TEMPERATURE PAINT
- (4) RUBBER GROMMETS
- ( ) 1"x1" " ALUM ANGLES 1/16" THK
- (1) COLLECTOR PLATE MANIFOLD ASSEMBLY
- (25±) #8 x 5/8" SS ROUND HEAD SCREWS
- CLEAR SILICON SEALANT

MAINE SOLAR ENERGY ASSOCIATION
17 Rockwell Rd SE
Jonesport ME 04649
Phone: 207-497-2204

DRAWN BY CALEB CRAWFORD 1991
REVISED BY RICHARD KOMP 2003

The Basic PV Technology

Photovoltaics directly and continuously converts sunlight into DC electricity through semiconductor electronic processes. PV power elements, being solid-state devices, are highly amenable to mass production.

The basic power element of a photovoltaic system is the solar cell (Figure 9). Each cell has two or more specially prepared layers of semiconductor material whose atoms absorb light, freeing electrons and creating "holes" to carry current. Each cell has a junction between two dissimilar semiconductor materials that creates a voltage to drive electrons through a circuit.

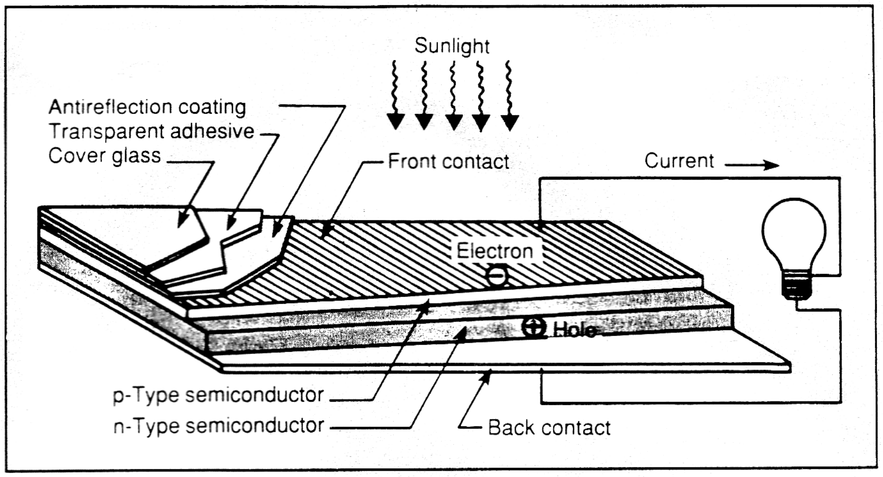


Figure 9. Solar cells have a built-in voltage produced by layers of dissimilar semiconductor materials.

Solar cells can be made from several different semiconductor materials, and these materials are available in a variety of physical states: single crystal, polycrystalline (many small crystals), or amorphous (noncrystalline or glasslike).

Multijunction cells, produced by stacking layers of semiconductor materials on top of each other, capture a larger portion of the solar spectrum than do single-junction cells. This enables higher device efficiencies to be obtained for the same amount of sunlight.

Connecting many cells together into a module, the building block of photovoltaic systems, produces more power output and provides protective packaging for the cells. Modules can also be made by depositing amorphous or polycrystalline semiconductor layers over a large area and then encapsulating the layers in protective coatings. Today's power module consists of a complete, enclosed package of solar cells, interconnects, power leads, and a transparent cover or optical concentrator, depending on the type of module. Modules fall into two broad categories: flat-plate modules, which are used under ordinary sunlight, and concentrator modules, which include lenses or reflectors to focus sunlight onto the solar cells (Figure 10). For large power needs, modules are grouped together to form arrays.

Few PV systems require only a module to operate. Many require other systems hardware such as batteries for energy storage, charge controllers, inverters to change from direct current to alternating current, or trackers that automatically follow the sun. Collectively this type of equipment is referred to as balance-of-systems hardware.

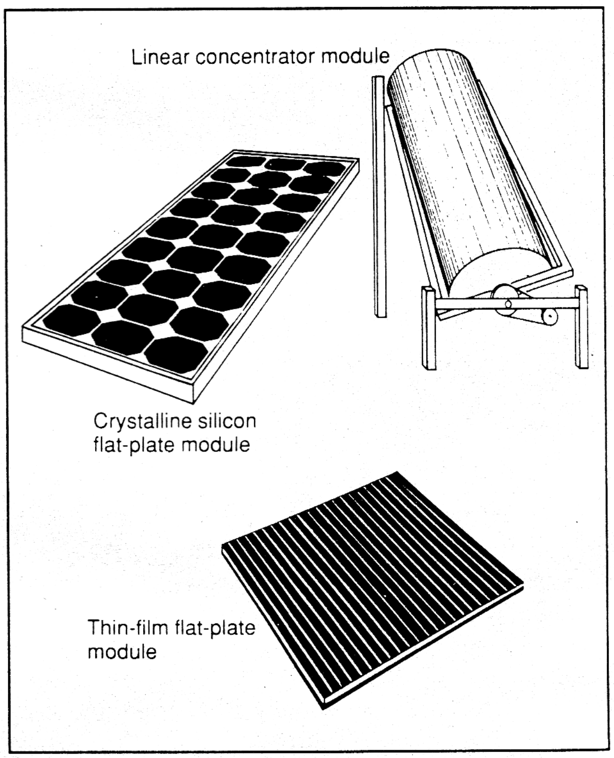
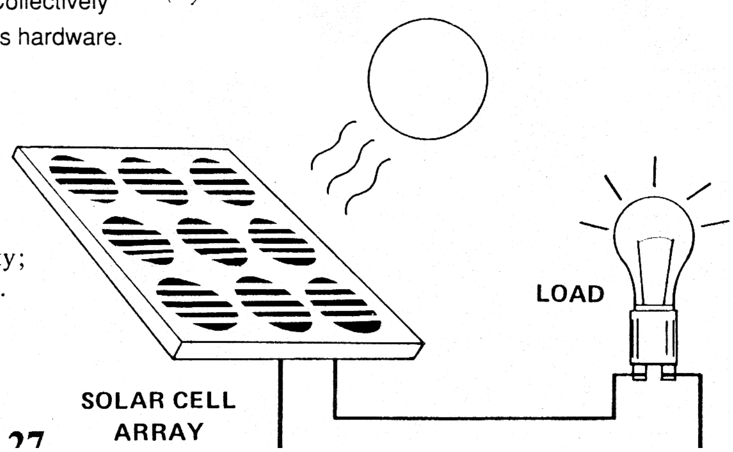


Figure 10. Modules are of two basic types: flat plates (crystalline silicon or thin-film) and concentrators.



A solar array converts light into electricity; nothing internal gets used up or wears out.

In a typical 12-volt solar module, 30 to 36 cells are connected in series to produce enough voltage to charge a 12-volt battery. The total voltage of the solar module must exceed the battery voltage to "push" the charge into the battery. Most solar panels produce 14 to 16 volts for battery charging. The battery can then store electricity for periods of cloudiness or darkness. For example, ARCO Solar modules have 33 solar cells each which produce 16 volts at 2 amps open circuit. By connecting modules in parallel to create a PV array, the amount of current is increased. Three ARCO Solar modules in parallel will produce 6 amps.

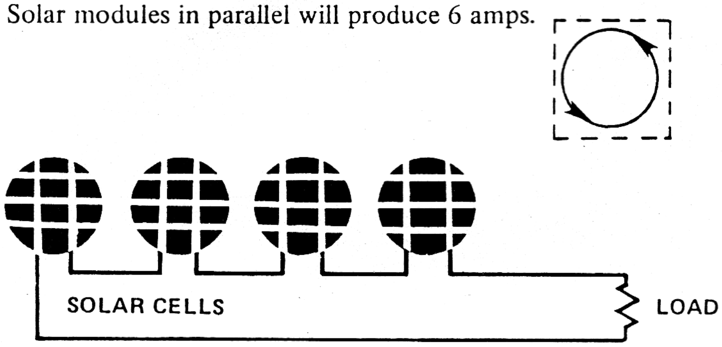


FIGURE 5.3a–Solar cells in series. The total voltage is the sum of the individual cell voltages, but the current is the same as that of a single cell.

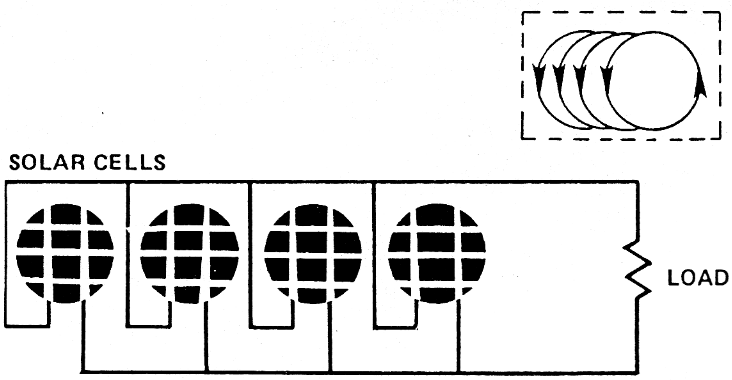
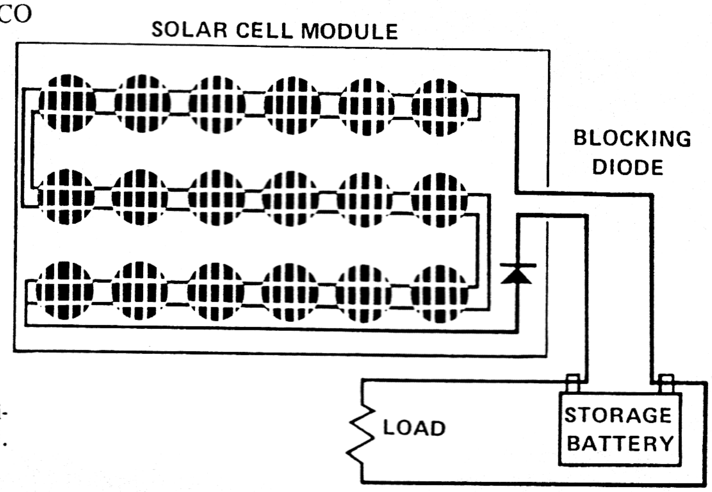


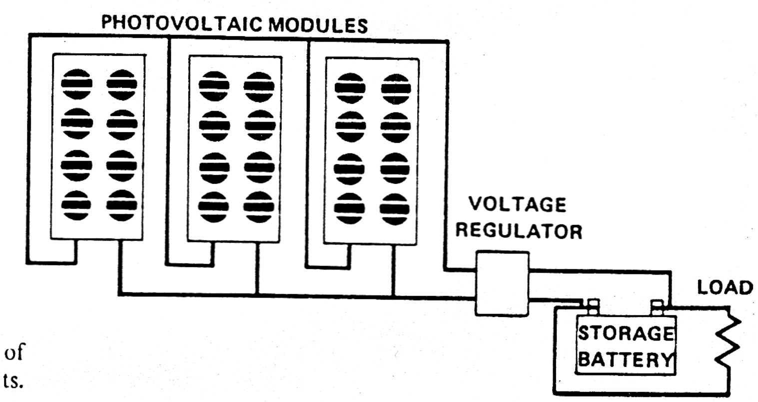
FIGURE 5.3b–Solar cells in parallel. Here the voltage would be that of only one cell, but the current is the sum of the individual cell currents.

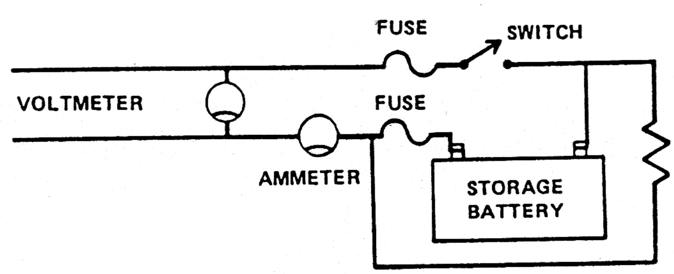
Solar modules require blocking diodes (see Figure 5.4). A diode is an electrical one-way gate which permits current to flow in one direction but prevents it from flowing in the opposite direction. The diode prevents the battery from being discharged backwards through the solar panel at night.

When several solar panels are connected in a group you have a solar array. Figure 5.5 shows three panels or modules connected in parallel to increase the current. As shown in this figure, a voltage regulator has been added between the battery and the solar array to prevent overcharging and to protect the battery. Any number of solar cells and batteries can be connected in both series and parallel to produce the needed voltage and current. Care must be taken to match solar cells and batteries because bad cells or low-power cells in both batteries and PV modules will pull down the entire output.

To monitor the PV system, voltmeters and ammeters are installed (see Figure 5.6). Voltmeters are connected parallel to the load. Ammeters are connected in series with the load. A fuse is added in the circuit to protect the load or equipment from damage from a current surge.





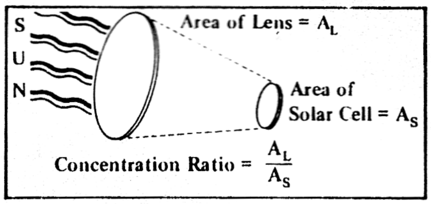


Drawings by Larry Kamp

THE SUNWATT HYBRID MODULE

The near-term solution to the high cost of photovoltaics.

One way to use expensive solar cells more efficiently is to concentrate more light onto the cells. The first characteristic of a photovoltaic concentrator system is the concentration ratio. This is simply the ratio between the area through which the sunlight enters and the area of the illuminated cell. The diagram below illustrates the simple lens-type concentrator similar to a magnifying glass used to start fires.



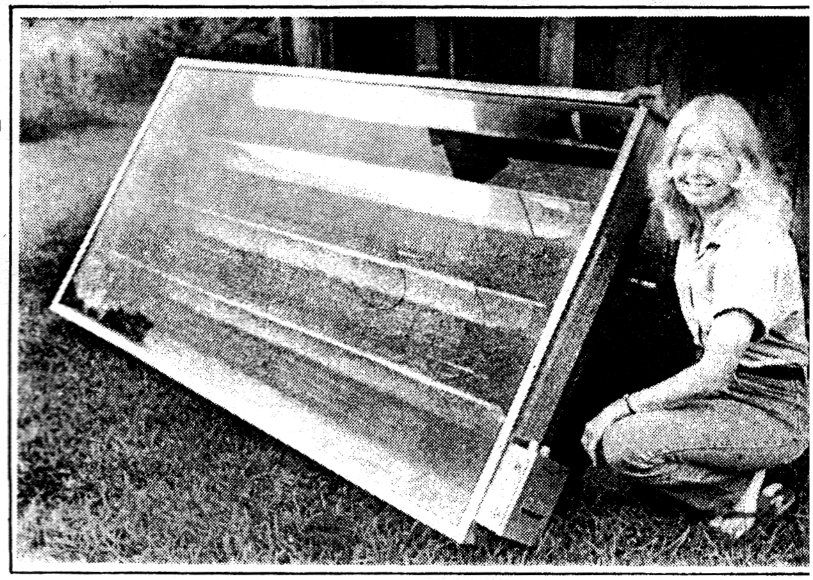
From *Practical Photovoltaics*, by Richard Komp, AATEC Publ. 1981.

If the lens is 200 cm. in diameter (area of 314 square cm.) and the cell is 50 mm. in diameter (area of 20 square cm.), the concentration ratio is 16 to 1 (sometimes expressed as a concentration ratio of 16 suns). This means that the cell receives 16 times the light and should put out 16 times the power of a similar cell used without the lens. Thus, a photovoltaic concentrator would appear to be much cheaper than the 16 cells it replaces. *It is this basic principle from which the SunWatt H-150 module has been designed.*

With all the extra sunlight pouring into it, the cell is going to heat up. With a concentration ratio of 3 suns or more, the cell *must* be cooled. Sometimes, simple cooling fins mounted on the back of the cell will suffice; but in hot climates, or with higher concentration ratios, water or forced-air cooling is necessary. The excess heat removed from the cells can be saved and utilized. A system that produces usable heat as well as electricity is called a hybrid system. *The SunWatt H-150 is a true photovoltaic-thermal hybrid, with a rated capacity of 150 watts electric and an additional 1600 watts thermal water heating capacity (under air mass 1 conditions).*

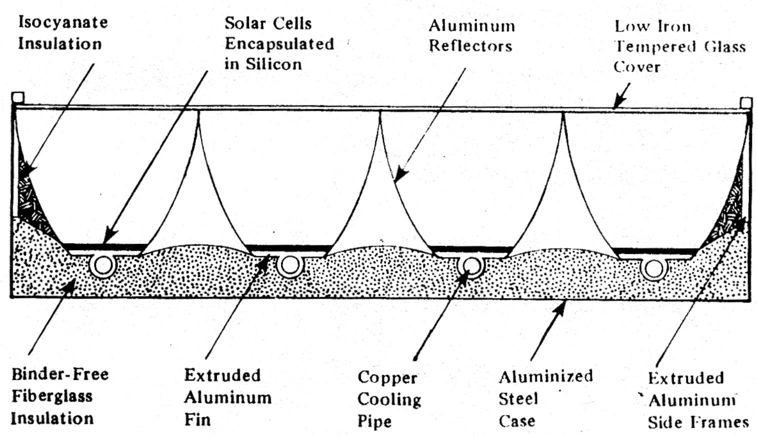
SunWatt has specifically avoided the problems encountered by high concentration ratio devices—the requirement of such systems to pivot and follow the sun as it travels daily from east to west. Such systems require constant adjustment or complex tracking mechanisms which are susceptible to mechanical breakdown.

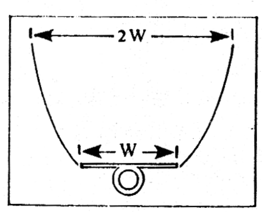
Hybrid systems can be cost-effective in situations where neither the heat nor the electricity generated separately would justify a solar system.



The internal configuration of the SunWatt H-150 is based on the Winston Concentrator concept. H-150's 2:1 concentration ratio requires no tracking or seasonal adjustment.

With the continued high cost of commercially-produced photovoltaic cells, the only practical means of reducing the cost of photovoltaic equipment . . . today . . . not next year . . . is to use as few cells as possible, without sacrificing the inherent reliability of non-tracking photovoltaic systems. The SunWatt H-150 hybrid module does just that, providing electricity from the sun and hot water—for no more money than many people now pay for solar water heating alone.





Sources for Solar Equipment:

In Maine:

Access Technology: PV systems and Installation: 349 Harlow St., Bangor ME 04041, 207-947-2750 e-mail: gocze@prodigy.net

Applied Solar Concepts: Energy conservation products and services, Solar heating, Solar electric systems: 108 3rd St. Bangor ME 04041, 207-942-8036

Dandy Solar Electric: PV systems and Installation: P.O. Box 142, Prospect Hbr. ME 04669, 207-963-7286

Energy Works: Design, installation and service of renewable and efficient energy systems. 91 W. Main St., Liberty ME 04949 207-589-4171 or 877-ENWORKS Web: www.enworks.net e-mail energyworksllc@pivot.net

The Greenstore: PV camp systems, energy efficient appliances and more. 71 Maine St., Belfast ME 04915 207-338-4045, Web: www.greenstore.com

Heliotrophic Technologies: Renewable energy systems and engineering. 60 Campbell St., Boothbay Harbor ME 04538 ph 207-633-1061, e-mail: m.j.mayhew@verizon.net

Independent Power: PV installation, Rick Thibadeau, P.O. Box 97, Greene ME 04236 207-946-4444

Penobscot Solar: PV systems and Installation: 569 Back Ridge Rd. Penobscot ME 04476, 207-326-0779 web: www.penobscotsolar.com e-mail info@penobscotsolar.com

SunWatt: Manufacturer and supplier of PV modules, PV consultant. 17 Rockwell Rd SE , Jonesport ME 04649 207-497-2204, Web : www.ecomall.com/biz/sunwatt.htm e-mail sunwatt@earthlink.net

Solar Mrket – Bluelinksolar.net : PV systems and Installation, mail order catalog: 25 Limerick Rd. Arundel ME 04046 ph: 877-785-0088 Web: www.solarmarket.com

Outside Maine, Mail Order Catalogs:

Alternative Energy Store: PV and wind systems, sales and design. 65 Water Street Worchester MA 01604 877-878-4060 Web: www.alterneregystore.com

Dawn Solar: Building integrated solar thermal systems and PV integration. 183 Route 125, Unit A7 Brentwood NH 03833, 800-803-1476, Web: www.dawnsolar.com

Global Resource Options: PV, wind and renewable energy options. 601 Old River Rd. Suite 3, White River Junction VT 05001, 800-374-4974 x107 Web: www.globalresourceoptions.com

New England Solar Electric: PV equipment and appliances. P.O. Box 435, Worthington MA 01098 413-238-5974 Web: www.newenglandsolar.com

Sunnyside Solar: The Gentle Electric Company – We bring good things from light. PV seminars, PV equipment and appliances. 1014 Green River Rd. Guilford VT 05301 802-254-4670 Web: www.sunnysidesolar.com

Sunweaver: PV systems, solar hot water, appliances, Traveling solar exhibits, 1049 First NH Turnpike Northwood NH 03261, 603-942-5863 or 800-Sunweaver Web: www.sunweaver.org e-mail: info@sunweaver.org

Sustainable Village: PV systems, appliances and more. P.O. Box 4616, Boulder CO 80306 ph: 800-442-1972, www.jademountain.com

Solar Architects & Healthy Home Builders

Roc Caivano: 38 Rodick St., Bar Harbor ME 04609, ph: 207-288-2333

Terry Cline, Sustainable Environments 2 Custom House Wharf, Portland ME 04101, ph: 207-774-1025

Holland and Foley Building Design 232 Beech Hill Rd. Northport ME 04849, ph: 207-338-9869

Thomas Peterson, Solar Design & Construction 48 Johnson Rd., Windham ME 04602, ph: 207-892-3658

Taggart Construction: Green design and construction Freeport ME 04032, ph: 207-865-2281 www.tagcon.com

Learn More:

Books:

A Golden Thread: 2500 Years of Solar Architecture Ken Butti and John Perlin: Cheshire Books, Palo Alto CA 1980

Independent Home Michael Potts, Chelsea Green Publishing Co., Post Mills Vt. 05058, 1993

Practical Photovoltaics, 3rd Edition Richard Komp, aatec publications, P.O. Box 7119 Ann Arbor MI 48107, 1995

The Solar Electric House Steve Strong & William Scheller, Rodale Press, Emmaus PA, 1987

Periodicals:
Home Power Magazine, P.O. Box 520, Ashland OR 97520
Web: www.homepower.com

Solar Today ASES 2400 Central Blvd. Suite G-1 Boulder CO 80301, www.ases.org/solar

The Maine Sun MESEA, RR2 Box 7751, Jonesport ME 04649
sunwatt@earthlink.net

Learn More (cont):

Organizations in Maine:

Maine Solar Energy Association (MESEA):
17 Rockwell Rd SE, Jonesport ME 04649
ph: 207-497-2204 www.mainesolar.org

SEADS of Truth: 156 Sacrap Rd. Columbia ME, P.O. Box 192 Harrington ME 04643 207-483-2764, seads@maineline.net

Skyheat Associates: 17 Rockwell Rd. SE, Jonesport ME 04649
207-497-2204 www.skyheat.org e-mail: sunwatt@earthlink.net

Organizations:

American Solar Energy Society (ASES):
2400 Central Ave. Suite A, Boulder CO 80301
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Northeast Sustainable Energy Association (NESEA):
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ph: 413-774-6051 fax: 413-774-6053 www.nesea.org

Solar Energy Industries Association (SEIA):
1616 H St. NW, 8th Floor, Washington DC 20006
202-628-7745 www.seia.org

National Renewable Energy Laboratory (NREL):
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www.eere.energy.gov www.nrel.gov

International Solar Energy Energy Society (ISES):
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Maine Solar Energy Association (MESEA)

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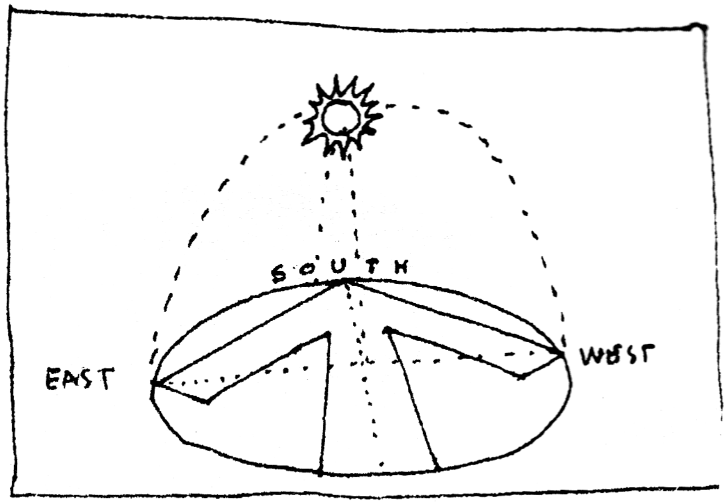
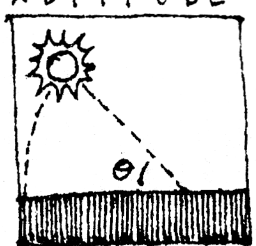


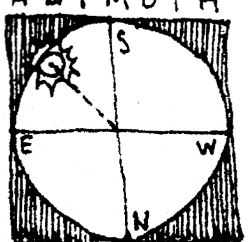
BECAUSE OF THE EARTH'S ROTATION, THE ALTITUDE AND AZIMUTH OF THE SUN IS CONSTANTLY CHANGING.

ALTITUDE



ANGLE OF THE SUN ABOVE THE HORIZON

AZIMUTH



ANGLE OF THE SUN RELATIVE TO NORTH

TABLE OF CONTENTS

While the information in this Primer is gathered from Maine Solar Energy members, the techniques and plans are equally usable elsewhere in New England and Maritime Canada.

from

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