Handbook for The Cape Cod Ark Bioshelter

House: First floor 1156 sq.ft.
Second floor 655 sq.ft.

House construction: modular - Energy Star
Manufacturer: Marcoux, Canada
Architect: Ate Atema, Atema Architecture, NYC
Date of construction: 1998-99

Photovoltaic: grid connected
360 sq.ft. of collectors
3 KW peak capacitiy
4 large storage batteries for back up

Solar hot water: 240 sq.ft. of panels
1422 gallons of water in storage tanks

Heating system: radiant floor heat in all floors
tubing in cement
bamboo flooring on top of cement

Lighting: passive solar during all daylight hours,
regardless of weather or time of year.
compact fluorescent light bulbs at night

Cooking: electric and gas

Toilet: Clivus Multrum waterless, composting system

ARK greenhouse: 1826 sq.ft. greenhouse space
253 sq.ft. workshop

Thermal mass: 6900 gallons of water in 9 above-ground fish ponds
2800 gallons of water in in-ground fish pond
stone walls and walks
soil, plants in beds and pots
steel frame

Irrigation water: preheated by sun, enriched by fish & plant wastes
water syphons through 7 solar fish ponds into
in-ground water storage fish pond.
pump brings water into irrigation lines and hoses.

Solar fish ponds: grow fish for food and fun
capture sunlight in daytime warming the water
release heat at night into the greenhouse

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8/11/08

CAPE COD ARK BIOSHELTER

From 1971 to 1991, the New Alchemy Institute conducted research and education on behalf of the planet. Among its major tasks was the creation of ecologically derived human support systems - renewable energy, agriculture, aquaculture, housing and landscapes. One of its major achievements was the testing of bioshelters – solar greenhouses which enclosed ecosystems - food crops, fish ponds, soil life, and indoor wildlife to control pests. The Cape Cod Ark is a research bioshelter built in 1976.

Earle Barnhart

The Cape Cod Ark in 1976.

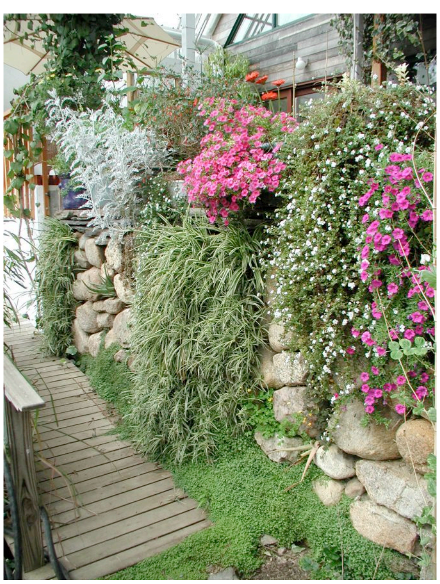
The Ark was an early exploration into ideas of solar heating, winter food production, fish farming, and indoor ecological agriculture. Built as a research bioshelter in 1976, it was used by New Alchemy to study the energy dynamics of solar structures, and the biochemistry and ecology of contained ecosystems. The research gradually showed that a specialized solar greenhouse in our climate could maintain a healthy, livable interior climate and could produce fresh food, needing minimal winter fuel.

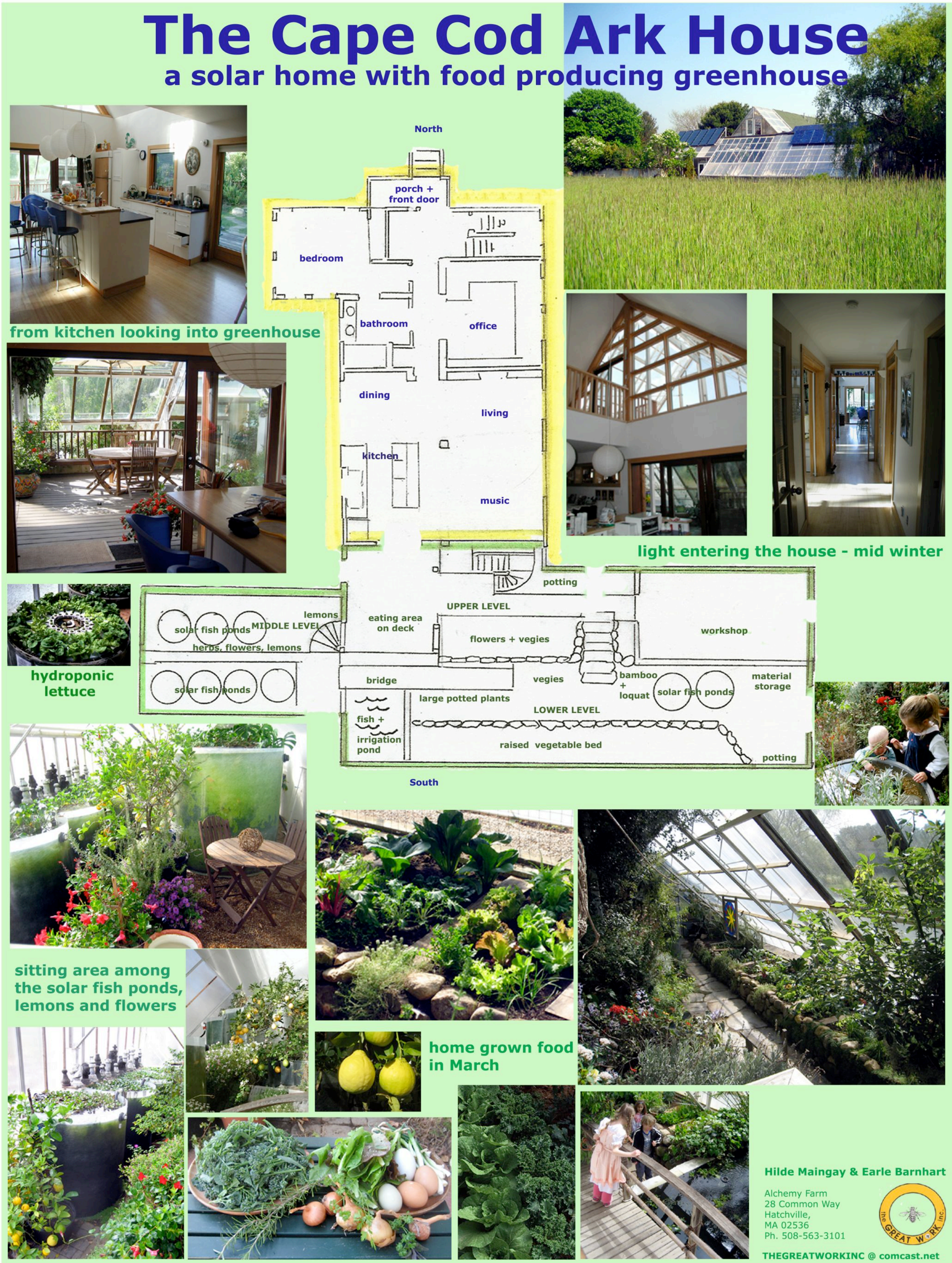
1976 original Ark structure -

The Cape Cod Ark in 2008.

The Ark has gone through several reglazings and renovations. It has been connected to an energy-efficient house on the north, and has solar panels to provide electricity and heat to the house. The Ark is 90 feet long, contains about 1800 square feet of growing space, and has enough height for small trees and overhead vines. Growing inside are a diverse community of plants and a number of large solar fish ponds that are also an important part of heating and cooling the greenhouse.

2008 Ark & House





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Leisure spaces are surrounded by plants and ponds, and food gardens produce fresh vegetables and cooking herbs year-round.

Cape Cod Ark Gardens

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Cape Cod Ark-House

Sunlight enters all the living spaces, using windows, skylights, glass doors, overhead door transoms and white surfaces.

Sunshine in the morning, mid-day or afternoon will light the whole house.

The modular house is very energy efficient, has radiant heat floors, PV solar electricity and both active and passive solar heating.

Architect: Atema Architecture NYC

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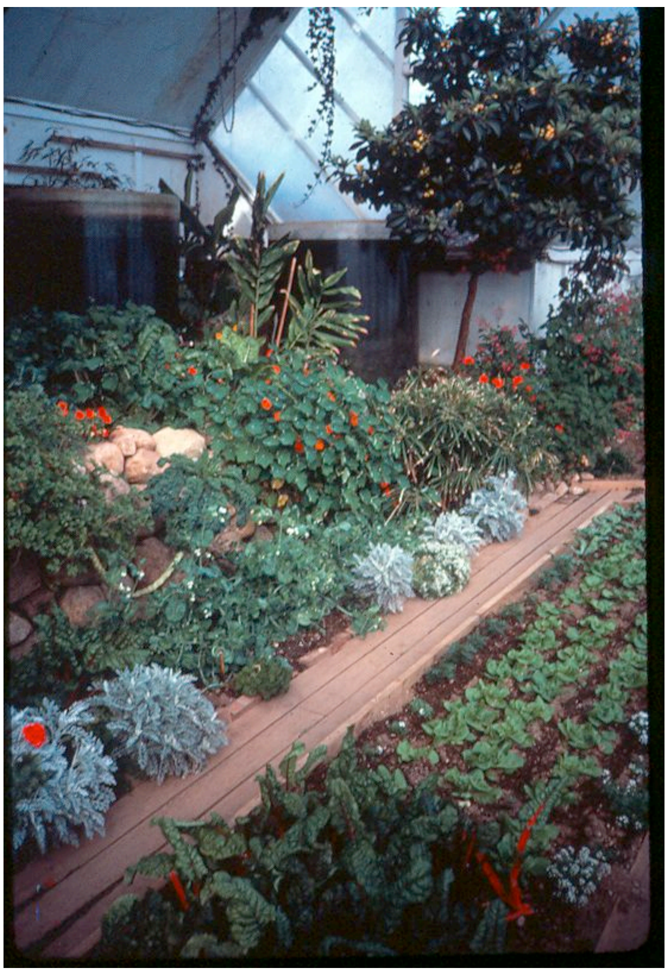
The Ark’s Ecosystem

The architecture of a bioshelter is only half the picture.
The other half is the biology, the life inside.

The gardens and ponds in the Cape Cod Ark bioshelter include a complex community of plants, pollinating insects, earthworms, dragonflies, frogs, soil life, diverse insects, toads, and others, seen and unseen. The same interactions of food chains, pest and predators, nutrient cycling and seasonality that happen outdoors happens indoors. Organic soil is a complex ecosystem in itself, and every aquatic pond contains an unique aquatic ecosystem.

Some plants are food plants, some are ornamental, and some are for beneficial insects. There are trees, vines, shrubs, herbs and aquatic plants. Some plants are changed each season, and some remain permanently.



In a temperate climate, an agricultural bioshelter can provide fresh green vegetables and fresh fish throughout the year, even when outdoor gardens are dormant. Bioshelter food production typically consists of winter vegetables grown for their vitamins, protein and flavorings. The freshness and purity of food grown in a bioshelter ecosystem can be known with assurance. Using solar energy to produce food locally in winter is a good alternative to normal fossil-fuel-dependent winter food supplies.

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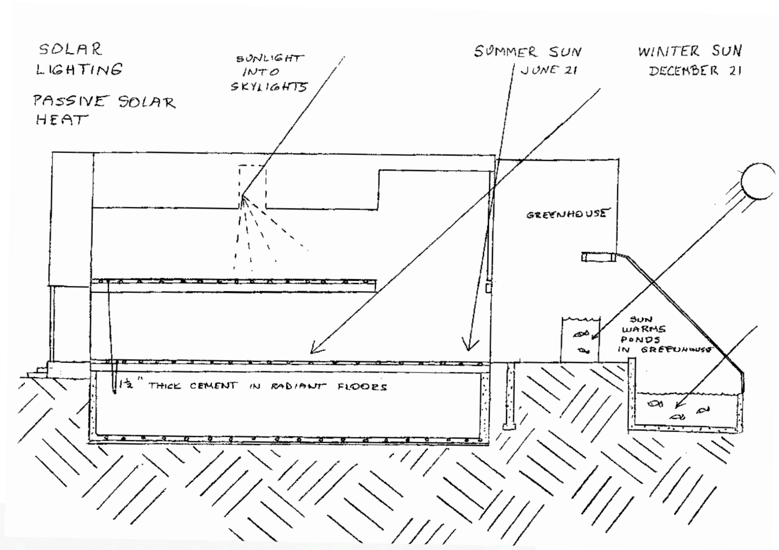
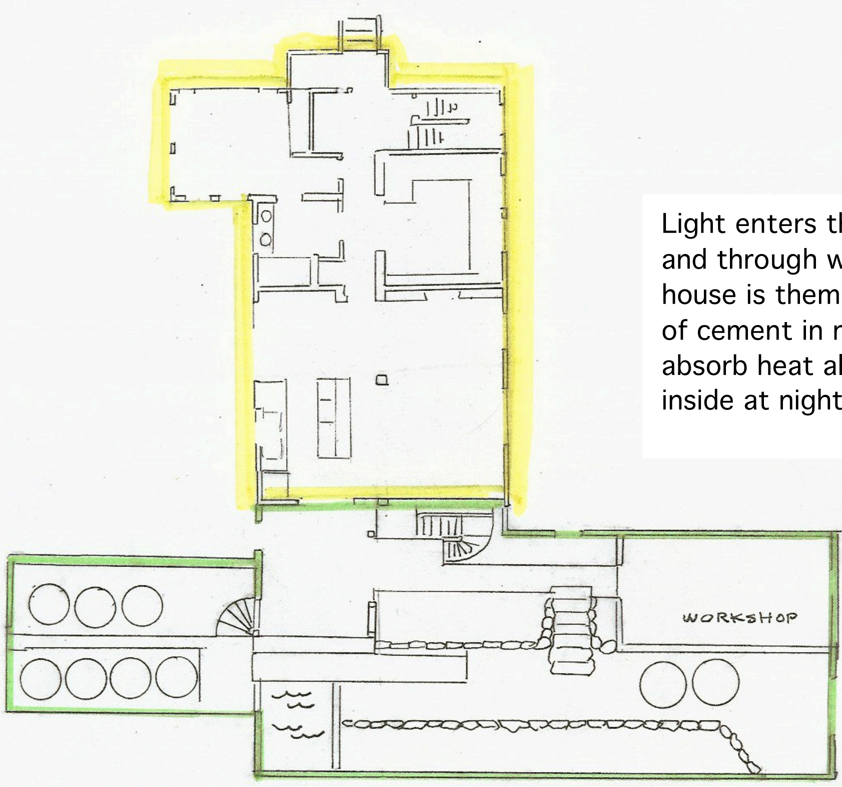
Light





Light enters the house from the greenhouse and through windows and skylights. Inside the house is themal mass of furnishings and layers of cement in radiant floors which passively absorb heat all day, and passively release it inside at night.

The greenhouse is designed so that full sunlight falls on most of the plants and ponds throughout the day, coming from many directions and overhead. Some plants can live in shaded conditions or in or reflected-light areas. A few plants can live in light levels of 5-10% full sunlight.

Sunlight that gets through the glazing strikes plants, soil, water, wood, stone masonry, and other surfaces. Most of the sunlight energy entering a bioshelter ends up as heat stored in thermal mass - plants, soil, materials, air or as water vapor in the air.

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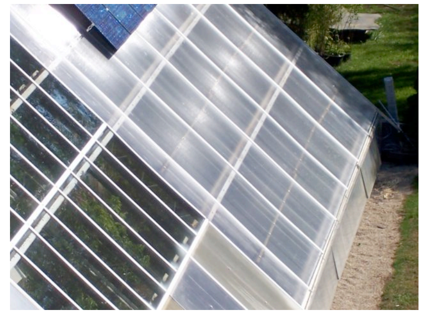
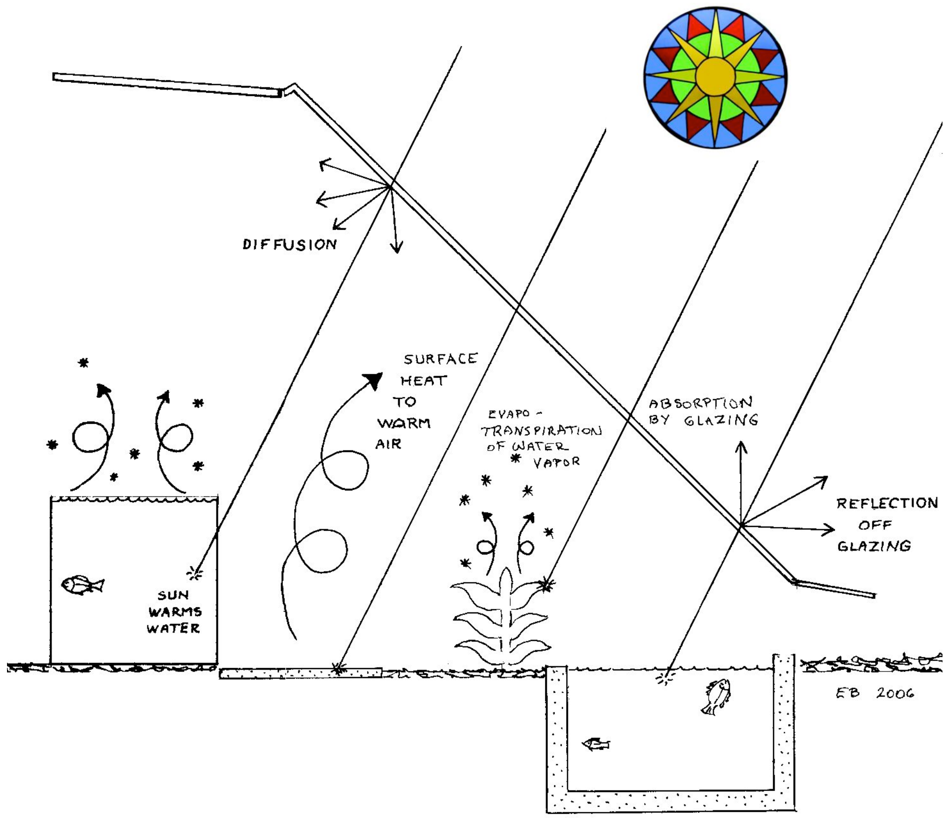
Heat

"Alchemical processes depend on the maintenance of steady temperatures, and much experience is needed in the design of furnaces to precisely regulate the heat and draft ...."

quote from old alchemy





When sunlight strikes a material, the material becomes warmer. In a bioshelter, materials like water, soil, stone, cement, and plants absorb incoming solar energy and store it as heat as they warm up.
The heat stored in thermal mass is later passively released by radiation or air convection. Passive absorption and release of heat is simple, automatic, and dependable, and requires no machinery.

Sunlight on green plant leaves is mostly absorbed, but most of the energy turns to heat, heating the leaf and evaporating water from the leaf.

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Solar Heat

In a conventional greenhouse, there is not enough mass in the building to absorb all the solar energy, so the materials and the air becomes very hot, and the heat is vented out of the building during the day. But then on cold nights the greenhouse must be heated.

Thermal Mass

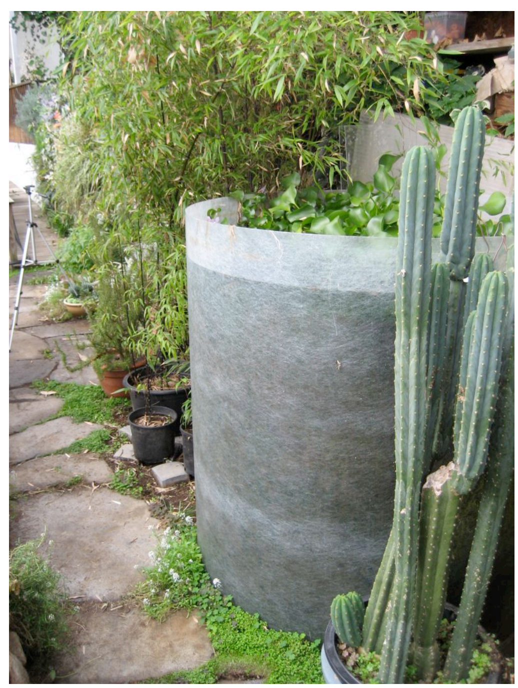
With enough thermal mass, heat stored from the day can keep the greenhouse warm at night.

Water is the cheapest, most effective thermal mass for storing heat. Ponds of water can store enormous amounts of solar heat. Dark water and dark containers of water absorb sunlight better than clear water. Ideally the sunlight should strike the ponds directly. Solar ponds absorb sunlight on the sides, and as water along the side gets warm, it rises and circulates, efficiently storing heat in the entire water volume.

Any water in a bioshelter acts as thermal mass - water in the soil, water in plants, water in ponds, and even water vapor.

Water is most effective when :
-- it is distributed rather than being in a single container,
-- sunlight strikes the water or container directly,

Other important thermal mass materials in the greenhouse are stone walls and walks, cement pavers and foundation walls, steel framework and all the plants.



Most plants are 95% water. Plants are excellent thermal mass, being distributed in space in thin layers with a large surface area, and able to quickly absorb and release heat. Plant leaves also transfer heat to water vapor.

Heat Management

The Cape Cod Ark relies largely on passive solar heating and ventilation. It is insulated and sealed to reduce heat loss.

-- the Ark is glazed with triple-layered polycarbonate and thermopane glass.
-- the north ceilings are insulated with fiberglass; all cement foundation is insulated with exterior rigid foam.
-- there are 2 large high vents, 5 mid-level door vents, and a row of ground-level south vents.

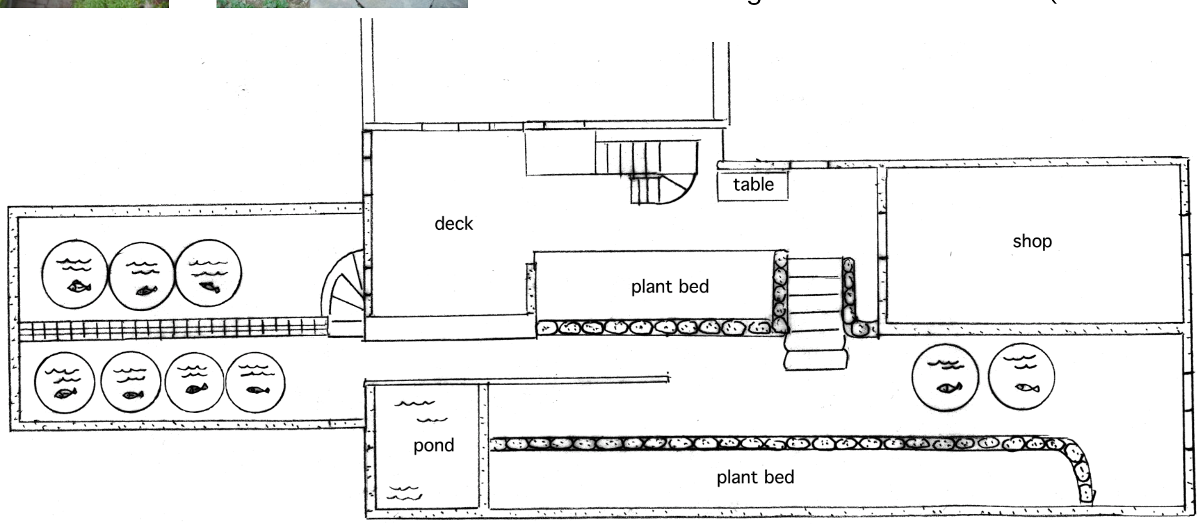
The Ark is :
-- 91 feet long
-- varies in width from 17 to 30 feet wide
-- is 30 feet at the center peak.

The Ark contains :
-- 1826 square feet of greenhouse area
-- 253 square feet of shop area

Ark glazing :
-- 1555 square feet south, 45 degree slope
-- 450 square feet south, vertical
-- 140 square feet east, vertical
-- 288 square feet east, sloped
-- 174 square feet west, vertical
-- 288 square feet west, sloped

The attached house :
-- main floor is 1193 square feet
-- total house is 3041 square feet.

Thermal mass in the Ark :
- - 6900 gallons of water in 9 above-ground fish ponds; 2800 gallon cement pond
- - stone walls and walks, cement foundations, and cement pavers (880 cubic feet)
- - soil and plants in beds and pots (575 cubic feet)
- - steel framing structures (22 cubic feet)



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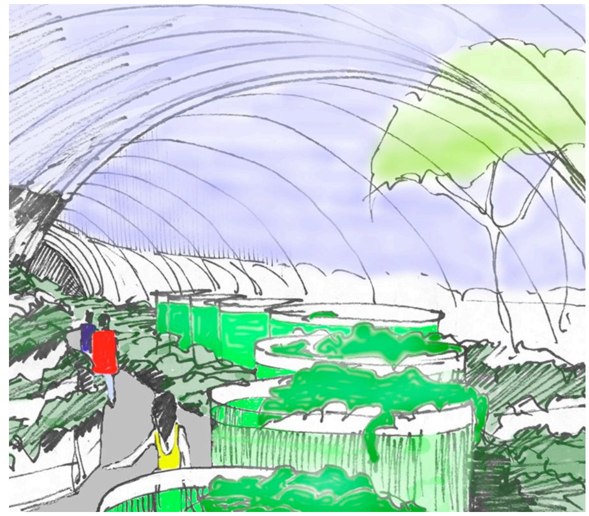
Water

"The role of water symbolizes the contrast between conventional greenhouses and bioshelters. In conventional greenhouses there is no standing water, while in bioshelters silos of water, (known as solar algae ponds) store solar heat , raise fish protein, and supply warm fertile water to hydroponic and terrestrial agriculture."

1982. New Alchemy Quarterly No.9
"Second Generation Bioshelters"



Inside a bioshelter, no rain falls. Conventional practice, however, is to send the rainwater to a drain and bring in other water to irrigate the plants and soil. Ideally, rainwater should be caught on the roof, channeled inside, and distributed by gravity to the plants, ponds, and soil.

The amount of water needed for plants in a greenhouse is roughly equal to 2 inches of rainfall per week, applied to the soil. Most irrigation water is eventually evaporated by plants, with a lesser amount draining downward.

Some water vapor eventually leaves the building in ventilation air (summer), or condenses on cold inside surfaces (winter).

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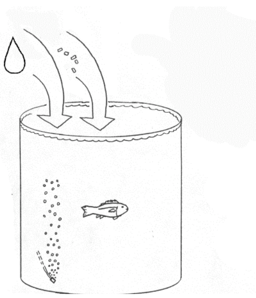
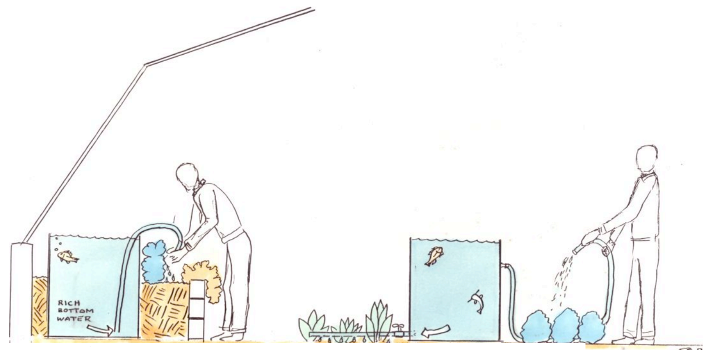
Aquaculture Water

Water can serve several purposes at once in a bioshelter. All the water in a building acts as thermal mass. Water can also be used in fish ponds on its way to being used for irrigating plants.

In the Ark, each day fresh water enters a connected series of solar fish ponds, passing through them and carrying away waste nutrients. The water gradually becomes warmer and richer as it goes from pond to pond, and finally flows into a large cement fish pond. This water is used to irrigate crops and other plants. Ultimately all water leaves the greenhouse either as water vapor in the air or as drainage water down through the soil under the plant beds.





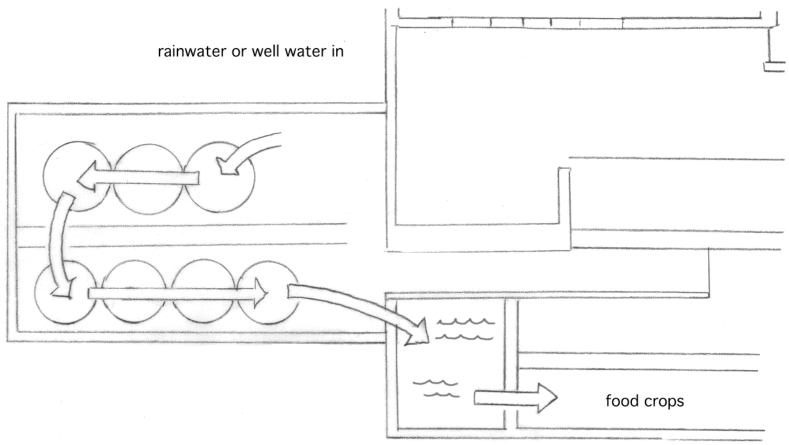
Water Flowing Through Aquaculture and Agriculture

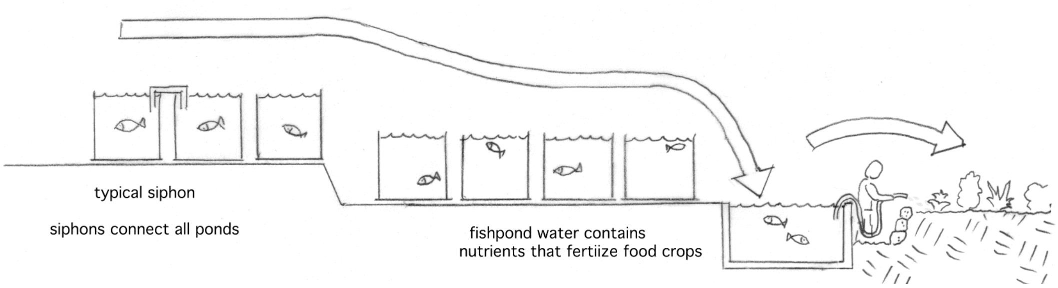
Water enters one solar pond at end.

Water flows from one pond to the next through siphons.

Water from the last solar pond over-flows into a larger pond.

Water from the last pond is used to irrigate plants in the greenhouse.





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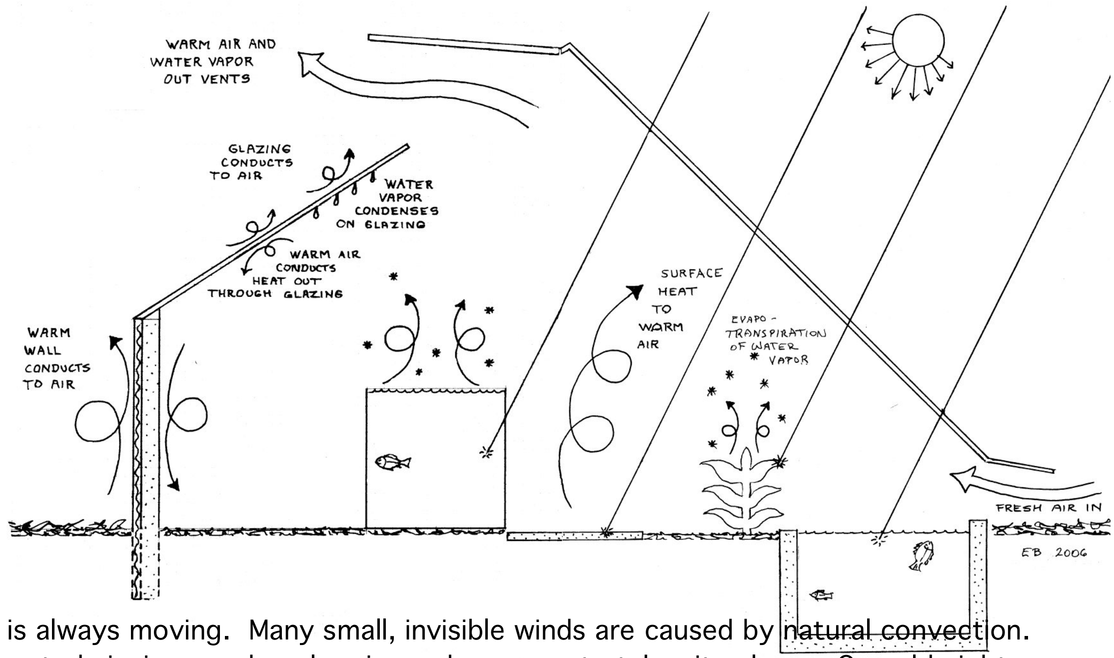
Air



The air in a bioshelter is always moving. Many small, invisible winds are caused by natural convection. On sunny days, solar heated air rises, and cooler air nearby moves to takes its place. On cold nights, heavy cold air flows down the inside surfaces of the glazing as it loses heat out through the glazing. Cold air flows like water and settles in low places. On a cold night, warm air rises from around solar ponds that have been warmed by the day's sunlight.

While dry air can contain a certain amount of heat, air humid with water vapor can contain much more heat. The heat involved is stored in the water vapor and moves with the air.
Consequently:

- whenever air is vented outdoors, heat energy is also vented out.
- when humid air is vented out, more heat is removed than if it were dry air.
- when water vapor condenses on a cold surface, it loses heat to the cooler surface.
- on winter nights, condensation on cold glazing is one form of heat loss from the building.

Many other gases are in bioshelter air and they also change constantly. Of particular interest is $CO2$. Plants take in $CO2$ in sunny periods as they grow. On bright sunny days plants absorb virtually all of the $CO2$ from the air that passes by their leaves. A closed greenhouse full of plants can deplete all of the available $CO2$ by mid-day. Soil in a bioshelter is full of soil life that constantly produces $CO2$ as they live and eat and grow. When the soil is warmer, soil-life activity increases and more $CO2$ is produced. Greenhouses containing particularly rich organic soil do not become depleted of $CO2$ on sunny days. Other studies have shown that plants benefit from higher-than-ambient $CO2$ levels, and extra $CO2$ in the air can improve plant growth and partially compensate for low light levels.

Some air pollutants, such as formaldehyde and carbon monoxide, can be removed by plants. As air passes through plant leaves, these toxic gases are metabolized inside the leaf and converted to other less harmful materials. Air inside a bioshelter is continually purified by this process. Air from a house can be passed though a bioshelter and return cleaner.

Fragrances - from citrus blossoms in January, jasmine flowers in June, alyssum flowers year-round - are also part of bioshelter air

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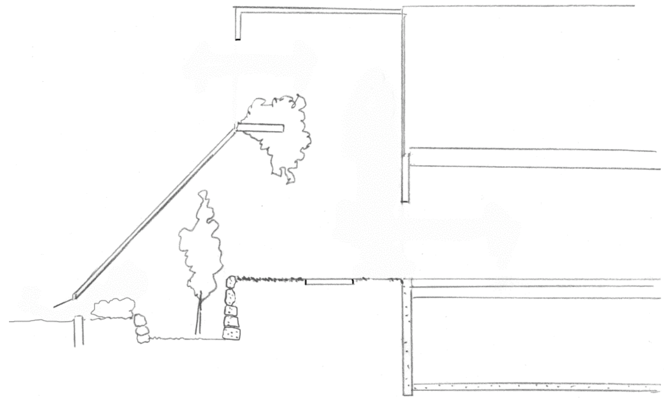
Air Movement in the Ark



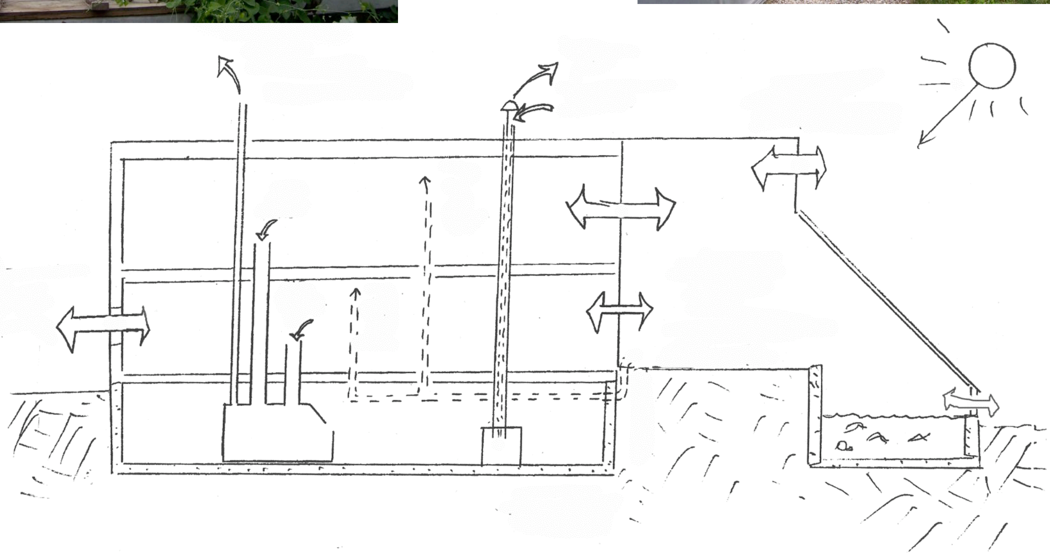
Vent openings allow air to move freely by wind or convection :
- door vents at the top
- 5 doors (north, east, south west) at mid-level
- low vents at the south.
- optional double-doors intohouse

The greenhouse is normally closed off from the house. In summer all vents and doors to the outside are completely open.

In spring and fall, top vents and lower vents are open, and middle doors are manually adjusted daily.
Hot air (above 90 degrees) is vented outdoors.

In winter, all doors and vents are closed.

It is necessary to have vents high in the building for air to go out and to have intake vents near ground level for cool air to come in at the same time.



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Earle Barnhart and Hilde Maingay live in the solar house attached to the Cape Cod Ark greenhouse. As long-term researchers at the New Alchemy Institute, they have incorporated many of New Alchemy's concepts into their house, greenhouse and landscape.

Earle and Hilde are partners in The Great Work Inc.. They design and install ecological landscapes which include food production, wildlife habitat, ponds and methods that promote rich organic soil. They also provide environmental education programs.

They live at the Alchemy Farm cohousing community on Cape Cod, which they helped design and establish.

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The Cape Cod Ark is one of a series of bioshelters tested by New Alchemy Institute from 1971 to 1991.
For more information about the New Alchemy Institute, search the internet for
"The Green Center – New Alchemy Institute"