Greenhouses for a Cold Climate

Introduction to greenhouse design, materials, construction and production methods

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The Climate

Designs for a Cold Climate

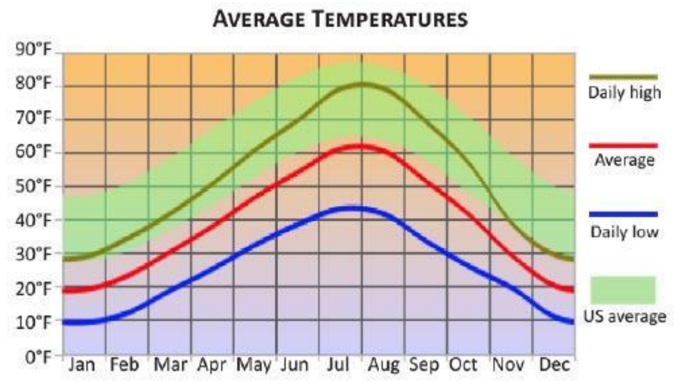
Scope

This study introduces the technology for cold climate greenhouse production. It considers three sites, one with access to geothermal water and two without. In each case the goal is use passive solar energy and insulation to minimize the need for artificial heating.

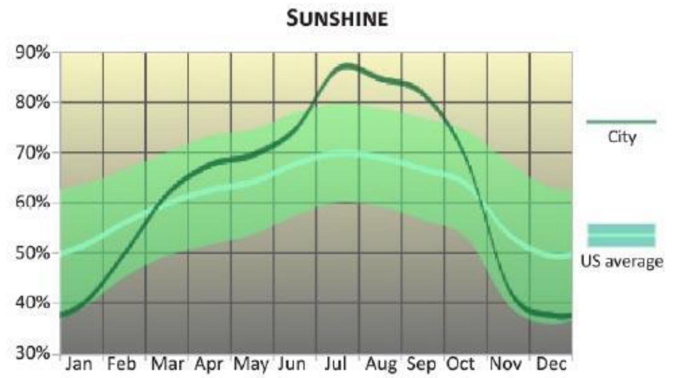
Hydroponic and Aquaponic production technologies are introduced for the proposed greenhouses.

For one site a greywater treatment and reuse system in proposed.

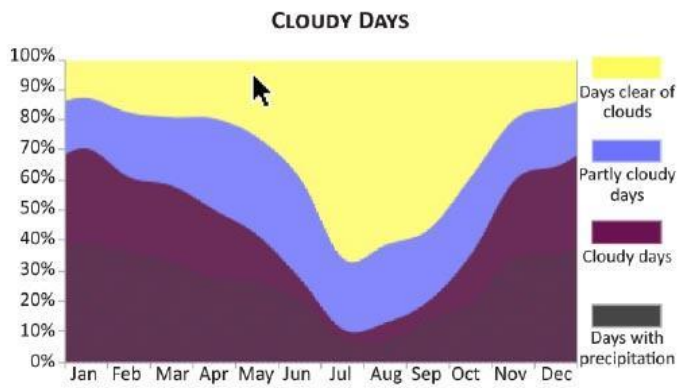
Climate



The average and low temperature in Cascade are below the national average

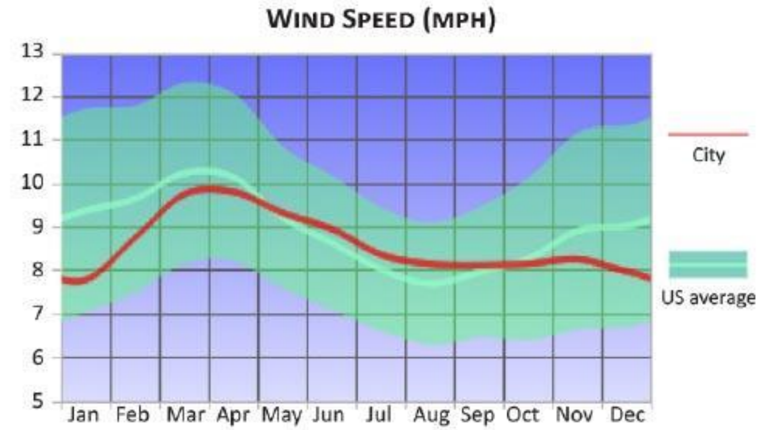


The amount of sunshine is positive for most of the year



Climate

The average snowfall is above the national average in November, December and January



Wind speed is low in the winter months and near the national average in the other seasons

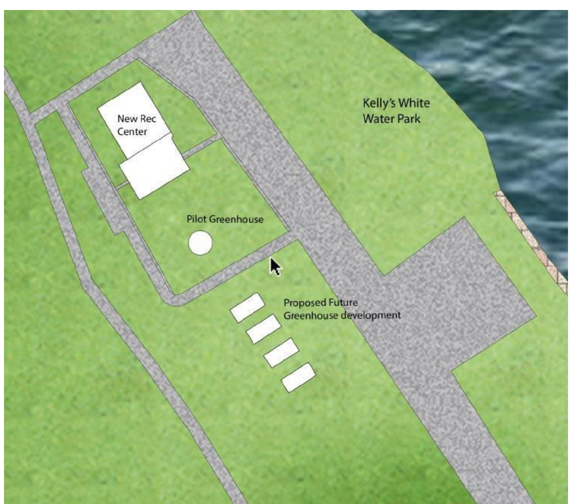
Site Locations

Commercial or production greenhouses for Valley County were considered for three sites. One in McCall at the McCall Outdoor Science School (MOSS) and two in Cascade. One of these would be at, or adjacent to, the Recreation Center in Cascade and the other at the existing Food Pantry. The McCall and Food Pantry greenhouses would not use geothermal water while the Recreation Center site has ready access to a geothermal well.

Site Location

The new Recreation Center of Cascade has the infrastructure in place to take full advantage of the geothermal well west of the building. Proposed uses for the geothermal water in the Recreation Center will require approximately one half of the available flow from the geothermal well.

A greenhouse, or series of greenhouses, could benefit from the remaining capacity of the geothermal well output, warming the greenhouses via geothermally heated forced air, radiant floor heating and bench heating. As with the Recreation Center, a plate heat exchange method may be utilized.



The image below shows the site for the recreation center (top left), the proposed site for commercial greenhouses (center), the discharge pond (bottom) and the swale for geothermal effluent (left). Kelly's Whitewater Park is at the upper right.

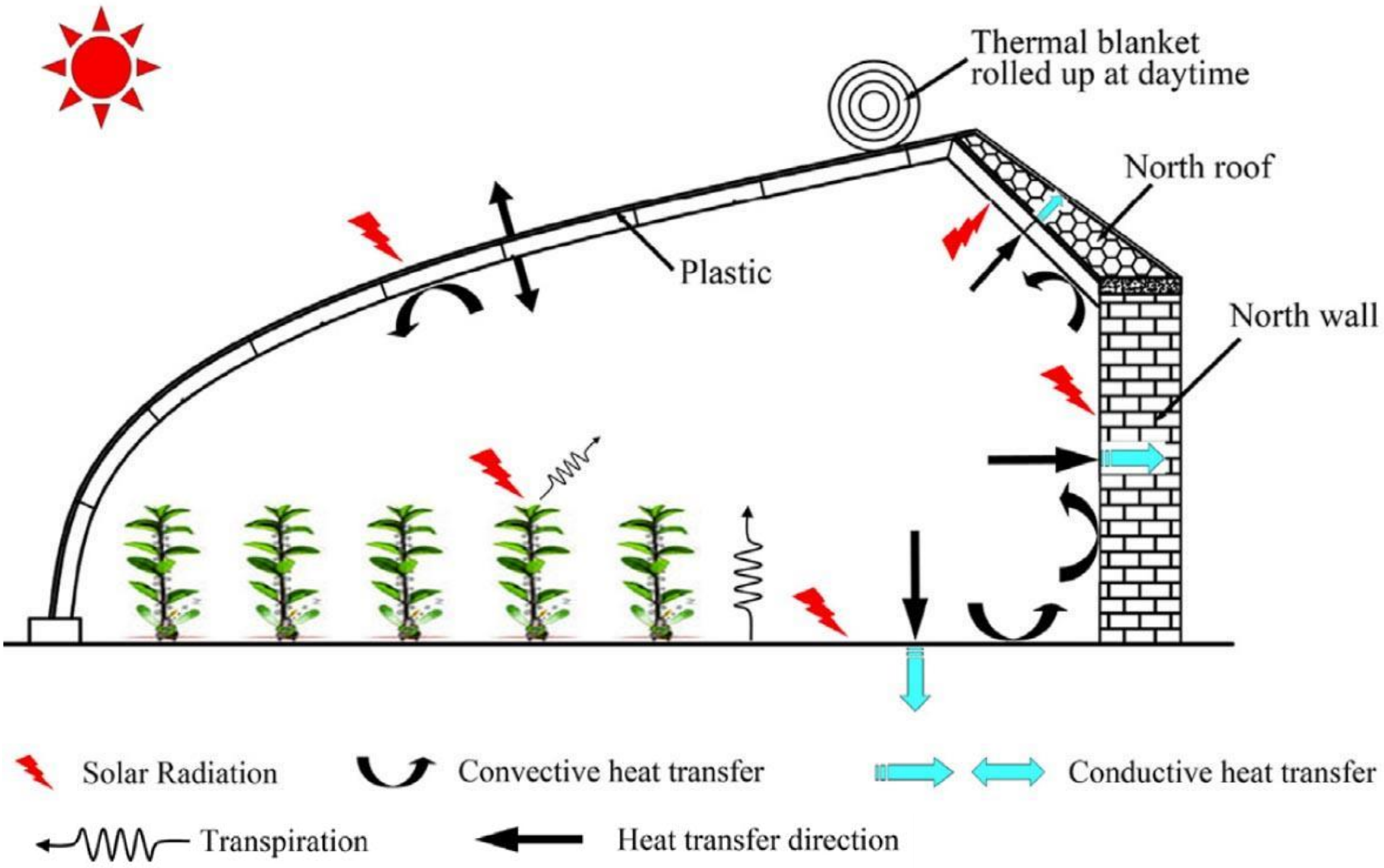
The Greenhouse

Designs for a Cold Climate.

Overview

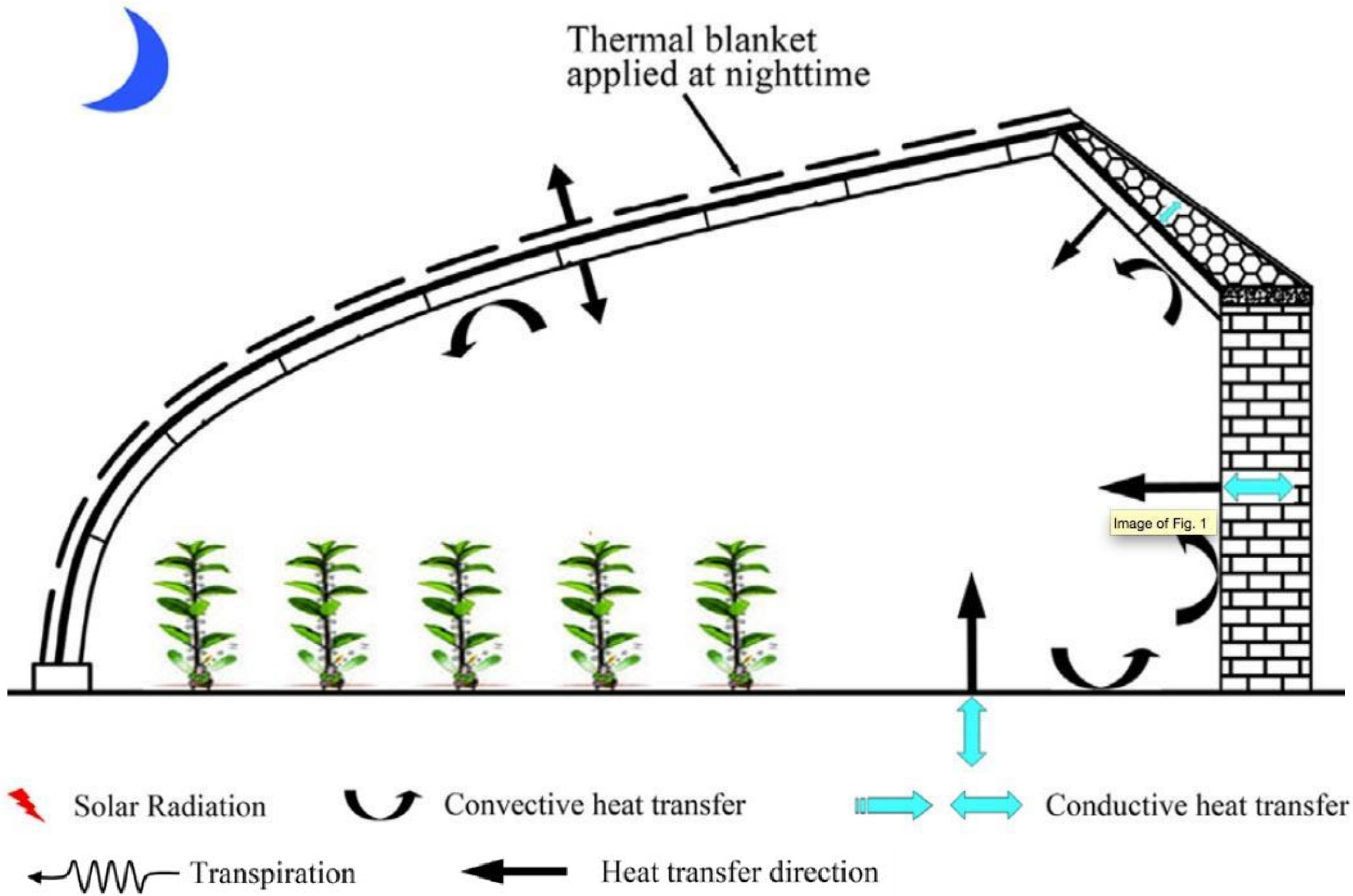
The design and technology for a cold climate greenhouse will apply, or can be adapted to, any of the three project sites. Greenhouses are solar energy collectors that convert solar radiation into long wave radiation (heat) that is captured inside the structure. Unfortunately, this heat is rapidly dissipated at night in a standard greenhouse. Special design considerations for a cold climate greenhouse include shape, materials, insulation and heating measures.

Daytime Heat Budget



Source: Wang, Junwei, Shuhai Li, Shirong Guo, Chengwei Ma, Jian Wang, and Sun Jin. "Simulation and Optimization of Solar Greenhouses in Northern Jiangsu Province of China." *Energy and Buildings* 78 (August 2014): 143–52. doi:10.1016/j.enbuild.2014.04.006.

Night Heat Budget



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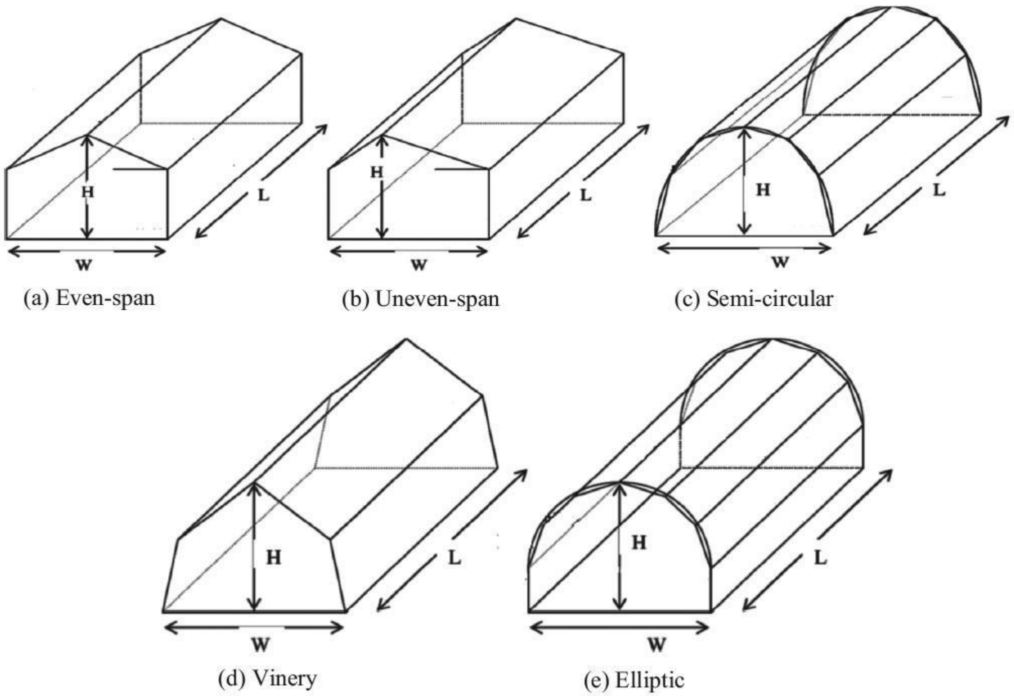
Special Requirements

- Strength to support a snow load
- Reduced glazing area
- Reduced artificial heat
- Increased thermal storage and insulation
- Separation from adjacent frozen soil

Shapes

- The roof needs to be steep enough to shed snow so that the structure doesn't collapse.
- To efficiently collect solar radiation the cold climate should be long and narrow.
- The optimum orientation is slightly east of south.

Heat gain and loss has been studied for a number of greenhouse shapes, sizes and orientations. The elliptic was the most efficient in each parameter followed by the uneven span for use in a cold climate (latitude of 40 in Turkey). Daily performance was better when the greenhouses were oriented toward the southeast rather than directly south. Larger greenhouses were more efficient than smaller ones.



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Shapes

The Gothic Arch provides a desirable greenhouse shape where snow loads are heavy.

Structural Material

Cold climate greenhouses have to made of material sturdy enough to withstand wind and snow loads. The material should also be inexpensive or long lasting.



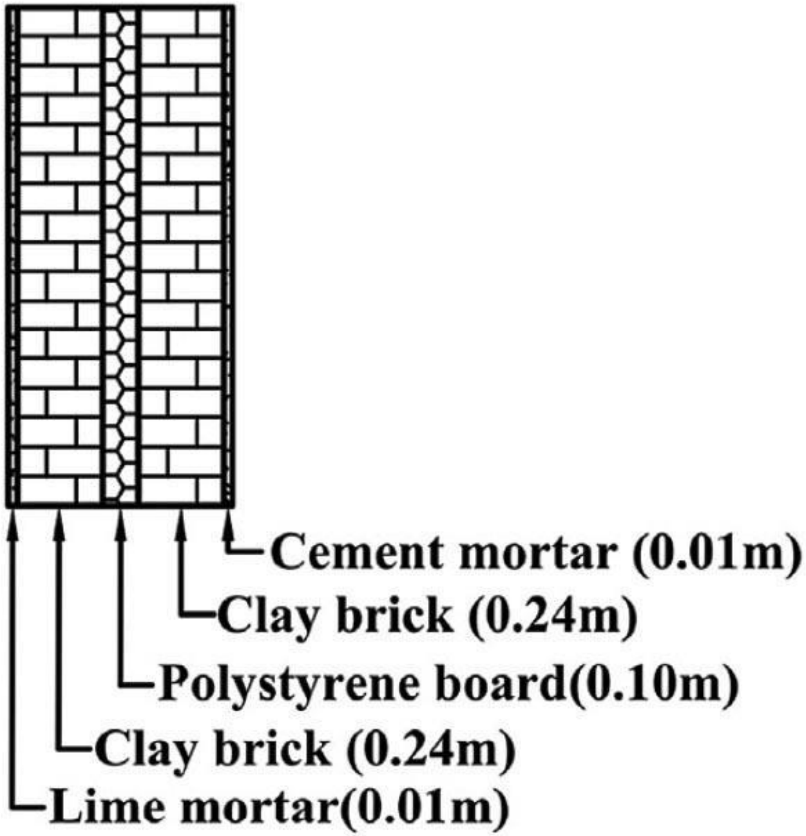

- Plastic - Its low cost is compromised by short life, high embodied energy and solid waste impact
- Wood - This has the advantage of being local, carbon neutral and moderately long lasting
- Steel - Although very long lasting, steel is expensive and has a moderate environmental impact

Glazing

- Single wall PVC - This is unsuitable for a cold climate.
- Double wall PVC - Providing two layers allows an insulating layer of air several inches wide. A simple blower can inflate the outer layer and hold the sheets apart. Alternatively the space between the sheets can be filled with a soap bubble mixture to decrease decrease solar radiation in the summer and increase insulation in the winter.
- Polycarbonate - This is a more rigid double wall material that is more translucent than PVC sheets but less than glass. It is expensive but less costly than glass.
- Glass - This is rarely used in modern cold climate greenhouses since it is costly and poorly insulating.

Insulation

Insulated Wall



- Insulation and thermal storage is necessary to allow production throughout the winter in cold climates
- Sunken greenhouses can utilize the constant temperature of soil.
- Air trapped between dual walls of PVC or polycarbonate extend the production season
- Solid foam insulation adjacent to the outside surface of the greenhouse footings
- Constructing a thick or insulated wall on the north side of the greenhouse may be necessary to keep the temperature from falling below freezing at night in the winter.

Wall Insulation

Rigid foam insulation against the exterior walls and footings prevents frozen soil from reducing interior greenhouse temperatures.

Denise Clarke https://www.flickr.com/photos/funlovers/24840006231/ No copyrights

Thermal Storage

- Materials inside the greenhouse absorb heat during the day and radiate it during the night
- Sunken greenhouses can utilize the constant temperature of soil.
- Air trapped between dual walls of PVC or polycarbonate extend the production season
- Solid foam insulation adjacent to the outside surface of the greenhouse footings

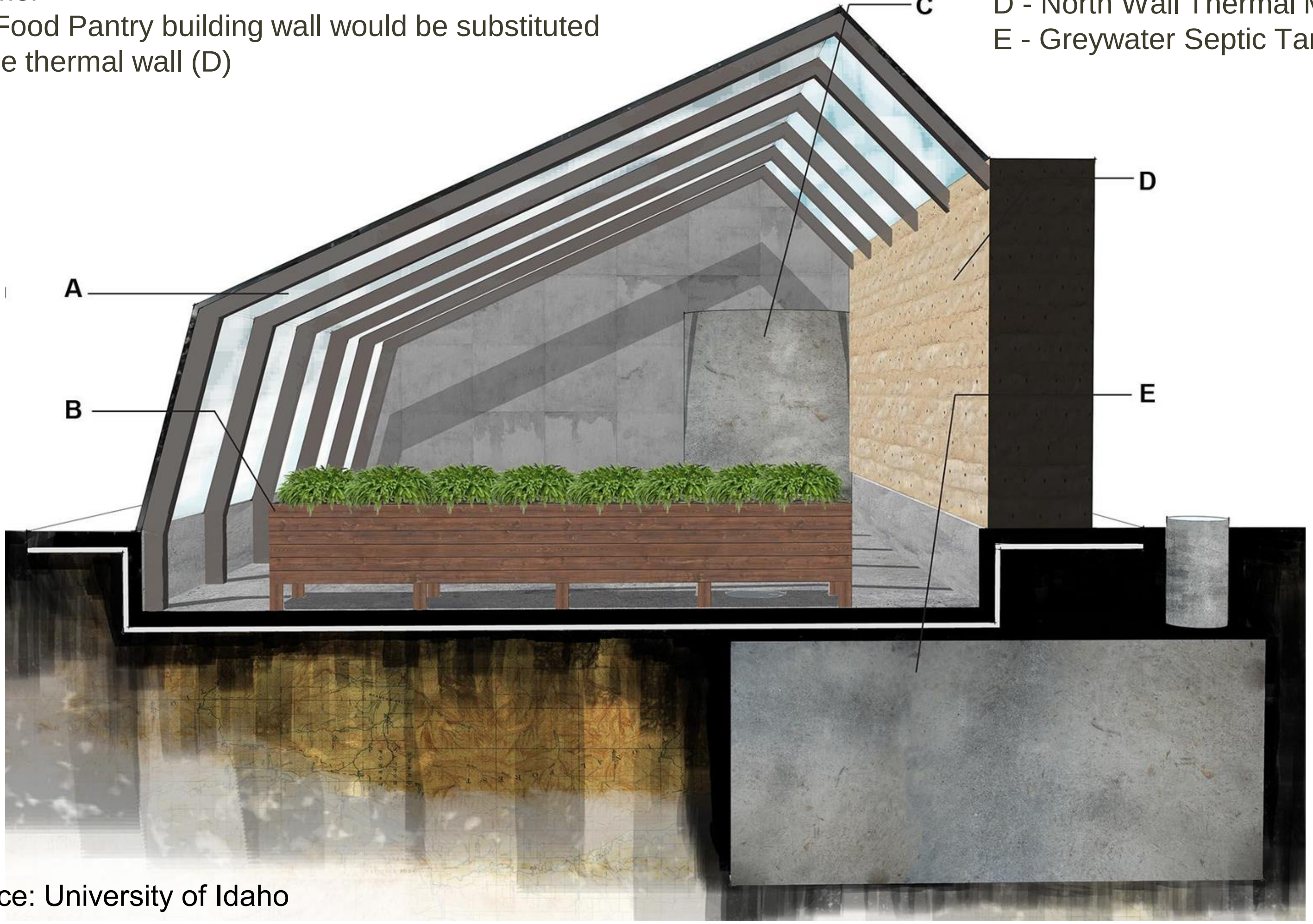
Greenhouse Section

Proposed Cold Climate Greenhouse

A thermal blanket could be added for additional protection.
End or roof vents are necessary to limit heat gain in summer
The Food Pantry building wall would be substituted for the thermal wall (D)

A - Polycarbonate glazing
B - Raised Beds
C - Thermal Mass and Water Storage

D - North Wall Thermal Mass
E - Greywater Septic Tank



Source: University of Idaho

Thermal Mass

Here is a sunken greenhouse where the northern roof is insulated and water filled barrels to provide thermal storage.

Bud Weber www.flickr.com/photos/131542313@N02/16013555313/ No copyrights

Geothermal Air

Geothermal air or solar hot water are options for the MOSS and the Food Pantry sites. A geothermal air systems uses 4” ABS pipe spaced 12” apart in a 4’ wide, 8’ deep trench. These pipes are covered with 18” of soil and two additional layers of pipe are then installed in the trench. The top layer of should be covered with 5’ of soil and the the sides of the trench should be insulated with rigid foam from the surface to the frost line. The insulation creates a 20˚F difference in temperature between the outside and inside of the trench.

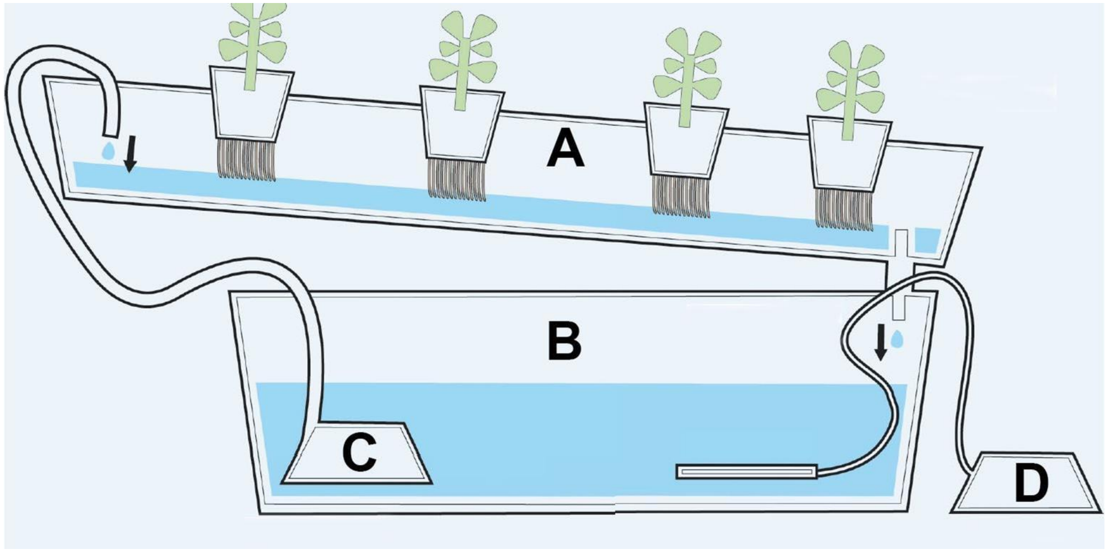
The air within the underground pipe should equal 10% of the volume of the greenhouse.

For a hoop greenhouse with an inflated dual wall and this geothermal air system the outside of 8 degrees is compared to an interior greenhouse temperature well above freezing.

https://www.youtube.com/watch?v=TY5pMBG7c5Y&list=PL-DEAjSTk8vOJpCXY5kMTnaaPLYgOfItz&index=2

Production Systems

- A - Growing tray
- B - Water and nutrient reservoir
- C - Water supply pump
- D - Aeration pump to increase dissolved oxygen



Plant Production

ARS USDA KenHammond

Conventional raised bed, hydroponic or aquaponic operations are production options within the proposed greenhouse. In this image berries are produced in suspended hydroponic trays.

Hydroponic Greenhouse

This system shows hydroponic production of tomatoes in pumice filled tubes (right) and within straw bales in Italy.

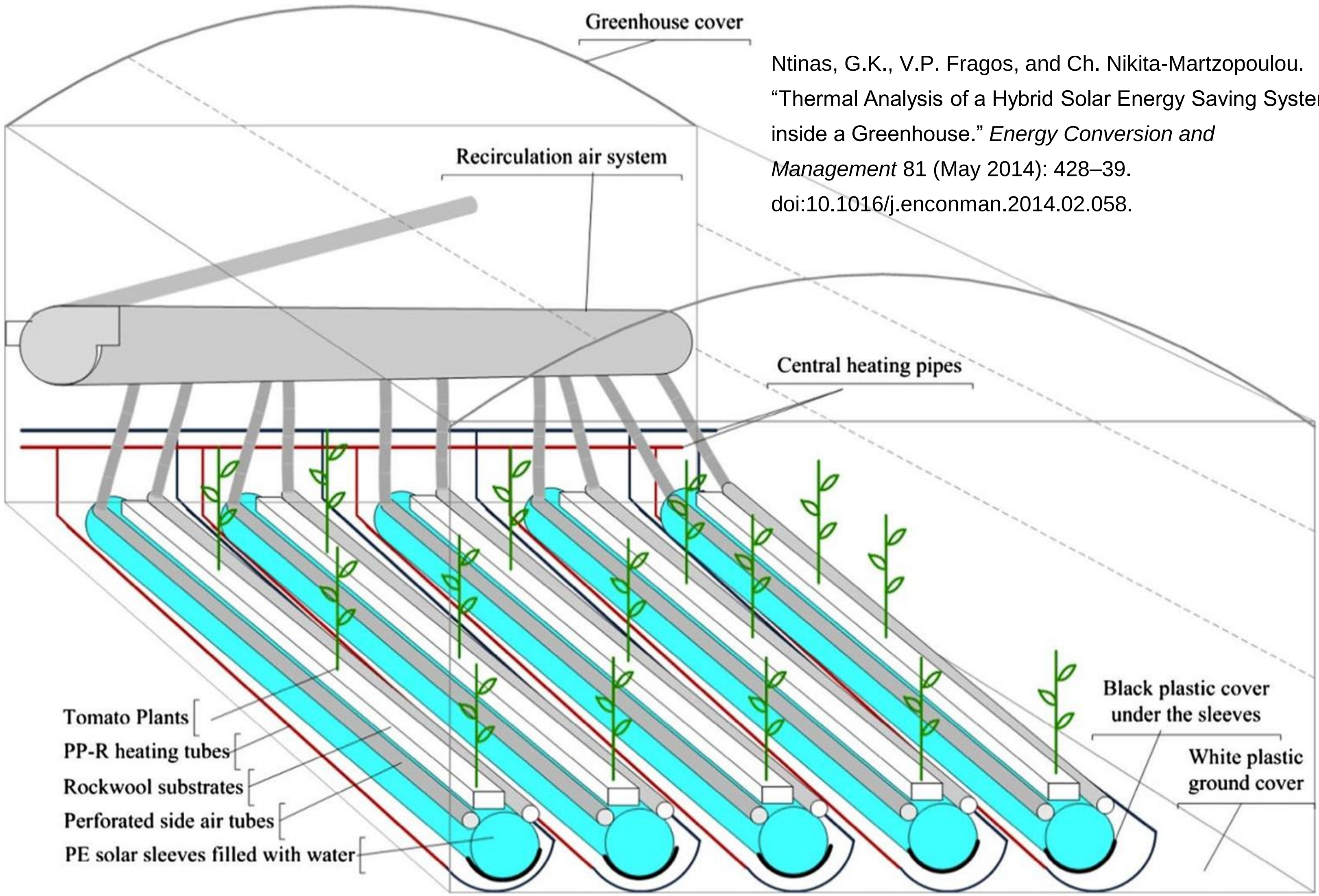
HydrpPumiceGiancarlo DessìCC_SA3Sm

Containers

Hydroponic lettuce in a container filled with vitrified ceramic pebbles.

Microclimate Hydroponics

Water filled tubes could contain geothermal water or water from the aquaculture tanks. The forced air tubes with warm air could come from a heat exchanger activated by the geothermal water flow.



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Floating Plants

Hydroponic plants are often produced on floating disks or rafts.

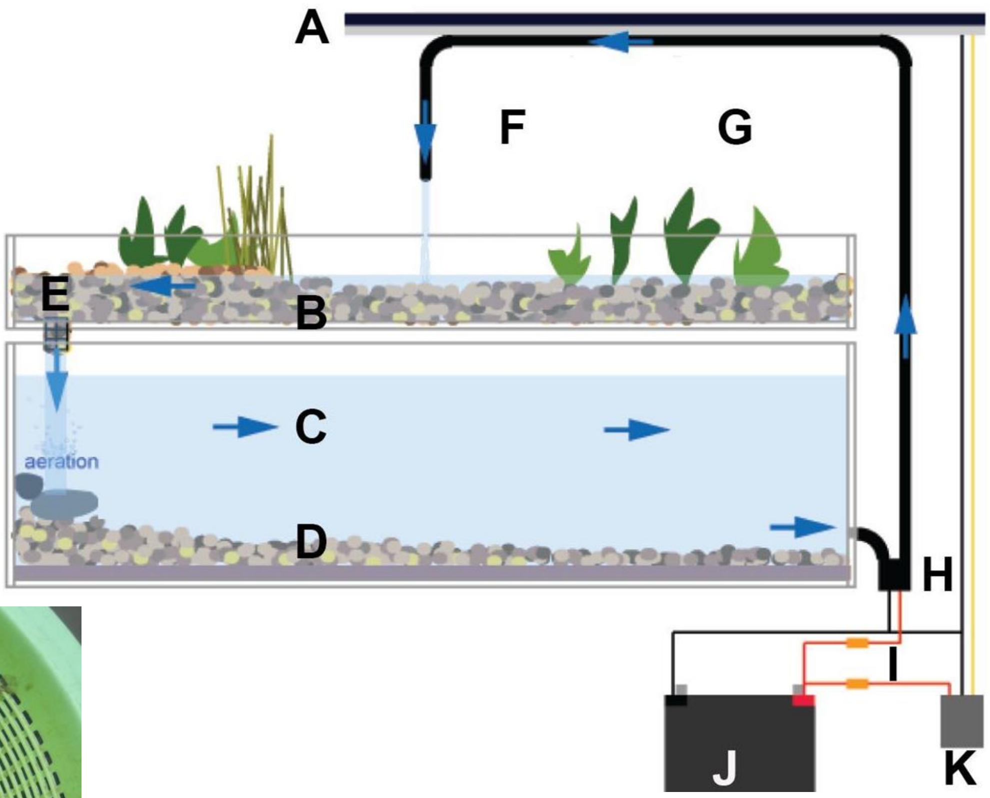
A head lettuce can be grown in about 35 days with a hydroponic system

Floating Plants

Rafts of hydroponic plants in an aquaculture greenhouse. The containers are placed in foam panels and float on the surface of the water. This is a very efficient production method.

Aquaponic Production

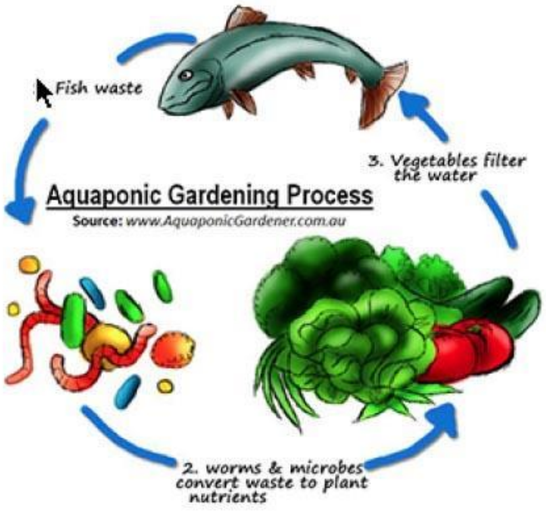
A - Photovoltaic panel
B - Growing Media
C - Fish tank
D - Aeration pump to increase dissolved oxygen
E - Filter
F - Recirculated water
G - ⅜" tubing
H - Pump
I - Coarse stone
J - 12 volt battery
K - Charge controller



About six months is required to raise Tilapia for harvest

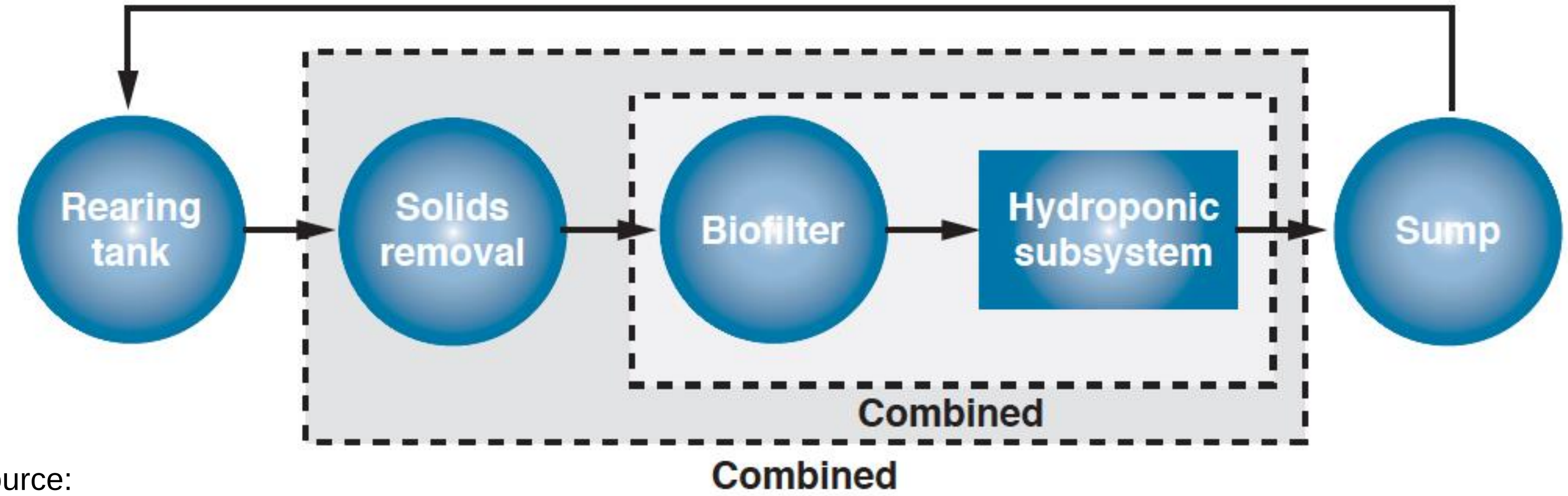
Aquaponics

Growing fish in concert with plant production provides a two types of products fish and plants. This system makes efficient use of space, water, nutrients and energy. However, the system is more complex and requires greater skill and system management.



Fish waste creates nitrate rich water that supports the hydroponic plants. The plants and growing media remove contaminants from the fish tank water so that it can be recycled for fish production.

The image below shows the basic system and opportunities to combine functions.



Source:

Aquaponic Production

The ratio of pounds of fish to gallons of water and the ratio of pounds of fish to square feet of plant growing area must be carefully managed for successful production. About six gallons of water in the fish tank can support one pound of fish if the water is aerated. Also six gallons of water in the system should be matched with one square foot of 12” deep media grow bed.

L

In this image the plants are in containers with media rather than being planted in the bed of media.

L

- In this system there are two plant growing beds and a fish tank directly below.
- When the plants are grown in media such as stone pebbles or vitrified clay pebbles, the media depth is generally 12” deep.
- Generally one gallon of growing bed volume is necessary for each gallon of fish tank volume.

Ryan Griffis (Growing Power Milwaukee).

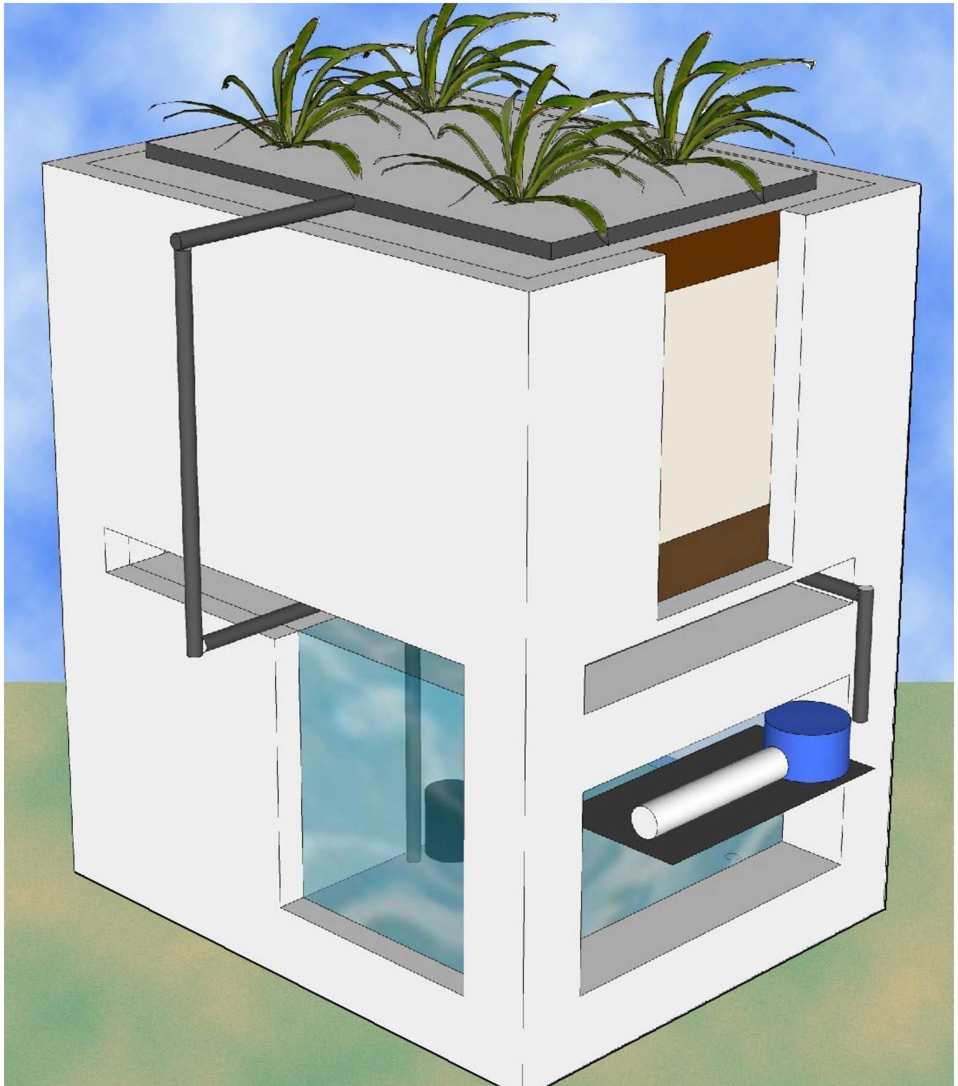
Cold Climate Aquaponics

This aquaponic project is located within a pit greenhouse to compensate for a cold climate.

The rough walls could be stabilized with a plaster coating.

In this case the plants are planted in deep beds of gravel.

Greywater Treatment



Source: M.Y. Sklarz, A. Gross, A. Yakirevich, M.I.M. Soares, 2009

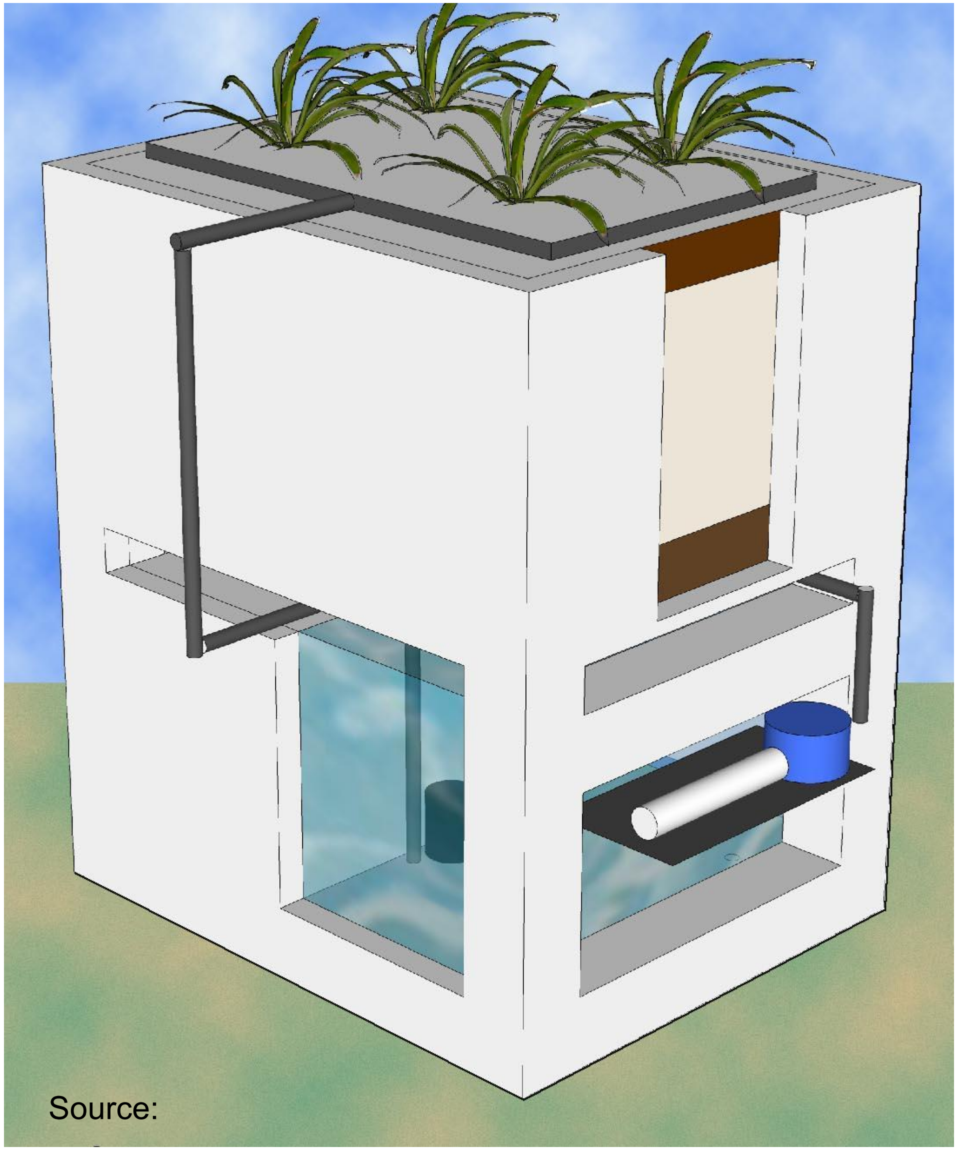
This perspective image of the proposed greywater treatment system for MOSS shows portions of the container cut away to illustrate the interior elements. A water reservoir is below the treatment section.

Each person generates about 30 gallons of greywater per day, so for a population of 125 the treatment requirement is 3,750 gallons per day).

If the green house is 900 square feet it would require 560 gallons to provide 1” of irrigation water over the entire surface.

Contaminated water is circulated from the reservoir to the top of the treatment chamber for six hours and then discharged to the storage tank in the greenhouse.

Greywater Treatment



Source:

The treatment area (top tray) is composed of four layers. A layer of peat (8 cm) above a layer of plastic beads (40 cm) above a layer of lime chips (5 cm).

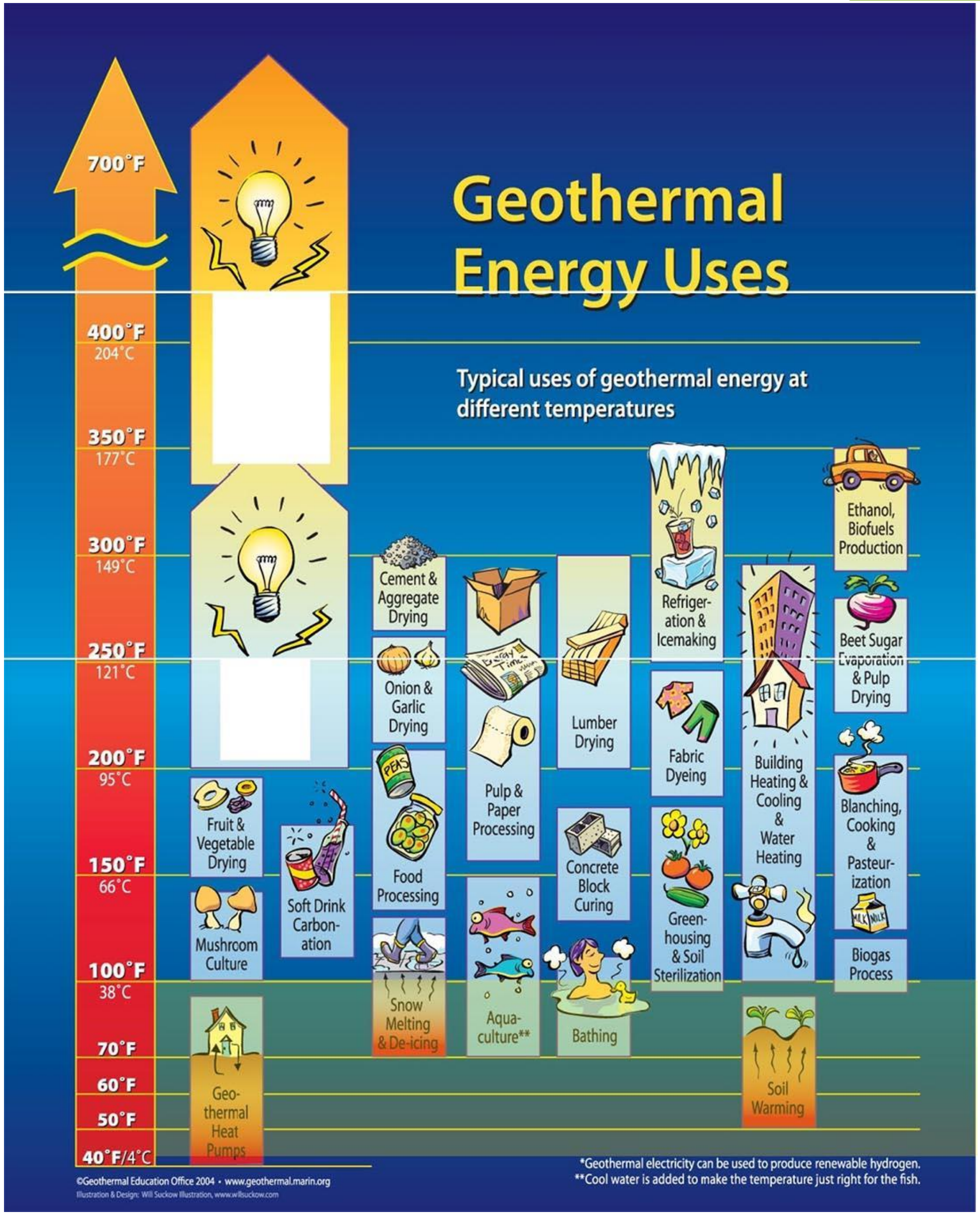
Greywater treatment using this system requires a 3' x 3.6' (10.8 square feet) space to treat 79 gallons of greywater in each 6 hour period (316 gallons per day). So for 125 people we need 128 square feet of treatment area. During the 6 hour treatment period the water is recirculated through the planted bed at the rate of 2.5 cubic meters per hour (660 gallons per hour), or 4.5 cubic meters per hour for an unplanted treatment bed.

The organic loading rate should be 120 g BOD_5 per square meters per day or less.

Treating the effluent with a 11 W UV irradiation unit reduces bacteria to 10 cfu per 100ml.

Nitrate in the effluent is high (good for plant nutrition).

Geothermal Energy



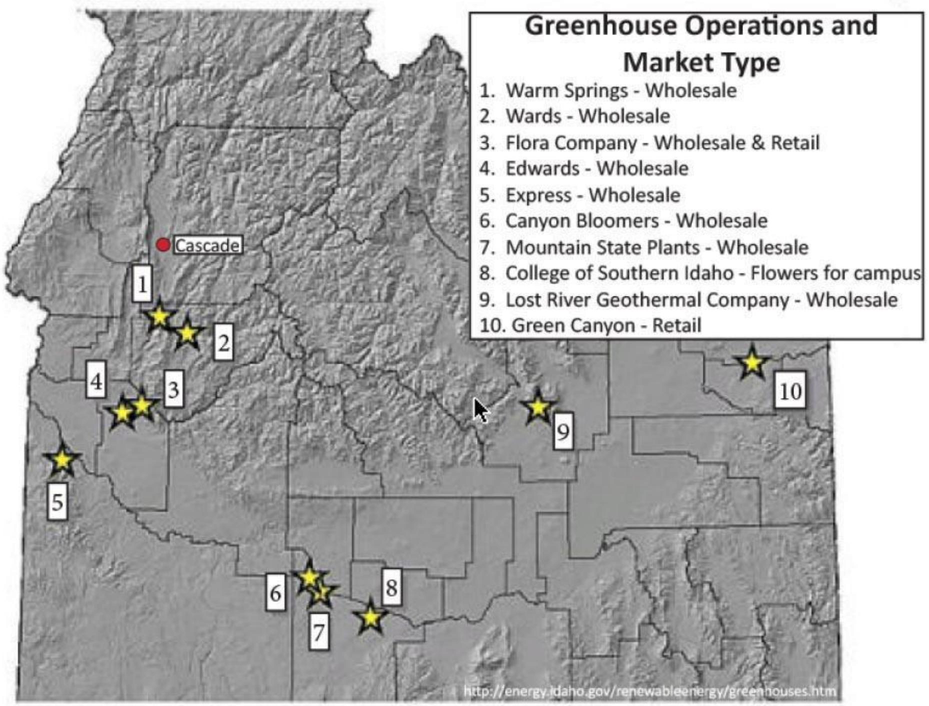
- The demonstration greenhouse proposed adjacent to the Cascade Recreation Center has access to geothermal water.
- The graphic at left illustrates that the use of geothermal water varies with the temperature and flow rate of the water from the well.
- Since the temperature of the water from the well at the recreation center is about 100 degrees, it is suitable for warming soil, aquaculture and in a heat pump to heat air.
- Aquaponics is most feasible at the recreation center site.
- Geothermal energy provides growers with a competitive advantage compared to those using fossil fuel heat. However, labor is by far the greatest cost for any greenhouse operation.

Geothermal Energy Used for Greenhouse Production in Idaho

There are several examples of successful ventures of using geothermal water in Idaho. With temperature ranging from 90°F to 175°F, entrepreneurs have delved into district heating, plant propagation, aquaculture and aquaponics.

Geothermal greenhouses in Idaho raise ornamental plants, flowers, and vegetables for market year-round. Although water temperatures are usually range from 115°F to 120°F, lower temperatures have been successfully used. Low temperature systems sometimes require supplemented heating in the coldest months.

Aquaculture took root in Idaho in 1973 and has ranged from catfish to tilapia, ornamental fish to coral, aquatic plants and even alligators.



Idaho Geothermal

Idaho experience with greenhouse production using geothermal energy

Name	Town	County	Crop	Business
Edwards Greenhouses	Boise	Ada	Flowers, Vegetables	Wholesale/ Retail
Flora Company	Boise	Ada	Flowers, bedding plants	Wholesale/ Retail
Wards Greenhouses	Garden Valley	Boise	Flowers, bedding plants	Wholesale
Warm Springs Greenhouses	Crouch	Boise	Flowers	Wholesale
Green Canyon Hot Springs	Newdale	Fremont	Vegetables	Retail
Express Farms	Givens Hot Springs	Owyhee	Vegetables, bedding plants	Wholesale
Mountain States Plants	Hagerman/ Buhl	Twin Falls	Flowers, bedding plants	Wholesale
Canyon Bloomers	Buhl	Twin Falls	Flower, vegetables	Wholesale
College of Southern Idaho	Twin Falls	Twin Falls	Flowers, other decorative plants	Flowers are used for academic studies and to beautify the campus

Source: Boyd, Tonya. March 2008. Geothermal Greenhouse Information Package.

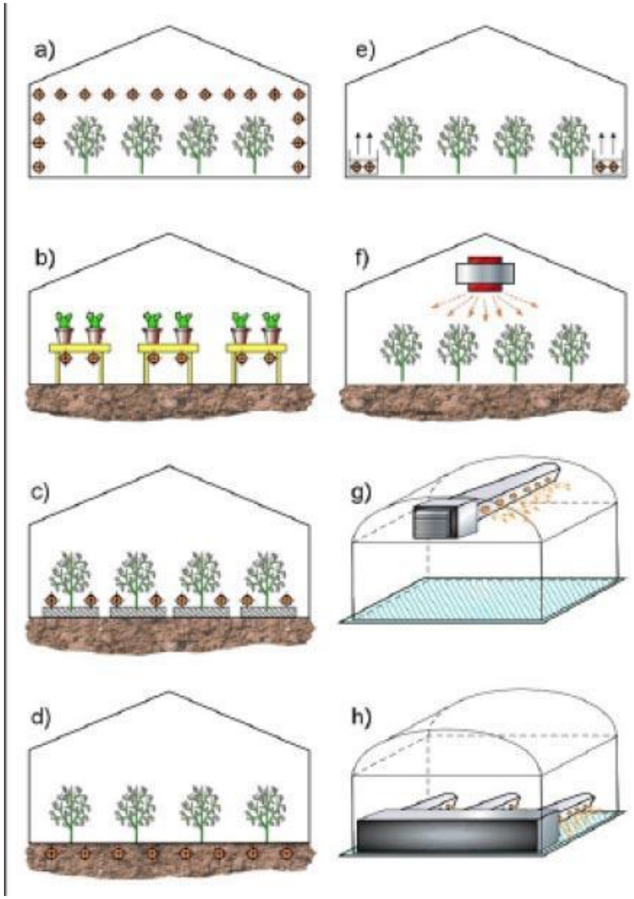
Geothermal Heating Systems

There are six basic types of geothermal heating systems:

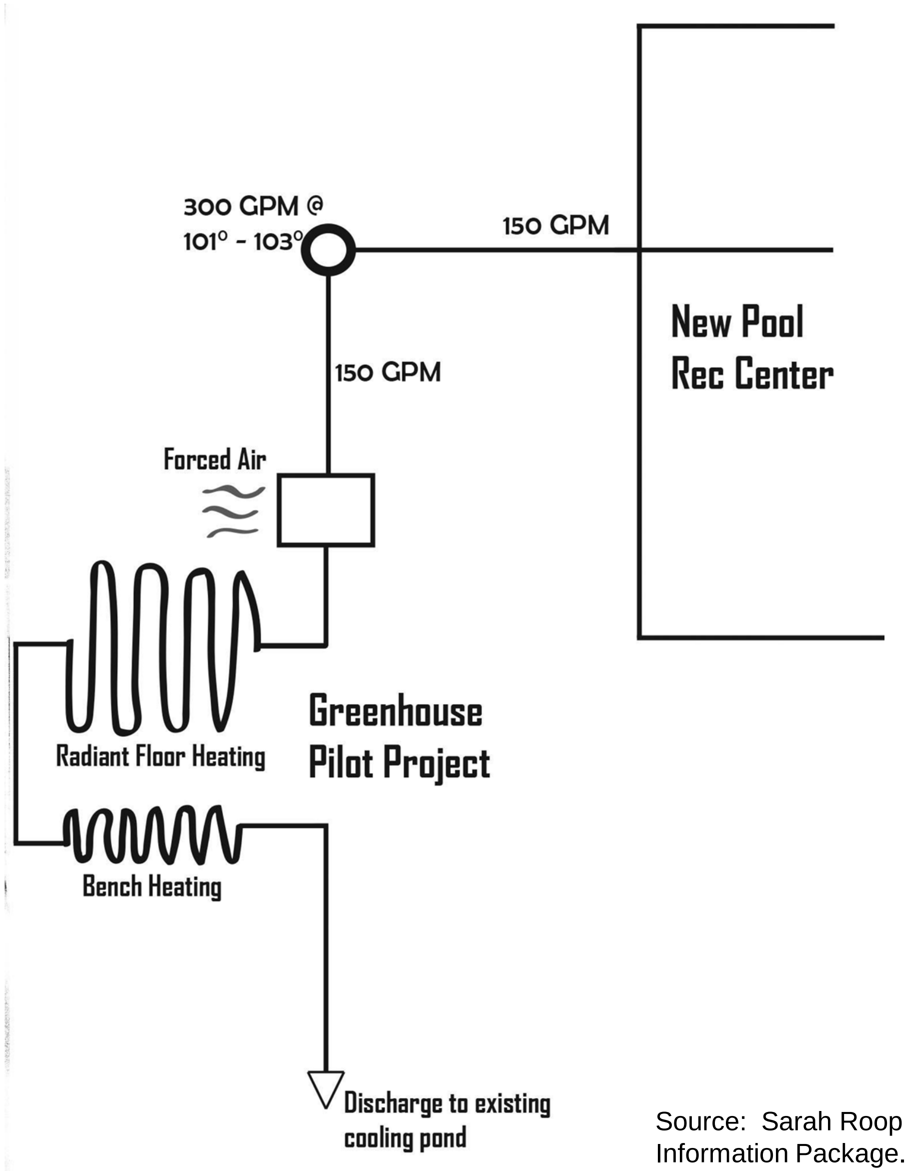
1. Finned pipe
2. Standard unit heaters
3. Low-temp unit heaters
4. Fan coil units
5. Soil heating
6. Bare tube

Of the heating alternatives, low temperature unit heaters and soil heating are good options for the Cascade greenhouse pilot project because of the relatively low temperature geothermal energy in the area.

The following are examples of geothermal heat installations for greenhouses.



Heating Diagram



- At the Cascade site 150-250 gpm is available
- Secondary use of water from the recreation center is probably not viable
- The geothermal water could be used directly (aquaculture or hydroponics)
- Before use in the fish tank or planted areas the geothermal water will required filtration (charcoal) to remove any contaminants
- Warm water can be used for air, bench or floor heating

Source: Sarah Roop after Boyd, Tonya. March 2008. Geothermal Greenhouse Information Package.

- Geothermal energy provides growers with a competitive advantage compared to those using fossil fuel heating. However, labor is by far the greatest cost for any greenhouse operation. combining fish and plant production maximizes the advantage of geothermal resources.
- In this aquaculture facility plants are not rooted in media beds, therefore a separate filter or clarifier is necessary to remove particulates.

References

Boyd, Tonya. March 2008. Geothermal Greenhouse Information Package. http://www.oit.edu/docs/default-source/geoheat-center-documents/publications/greenhouses/green.pdf?sfvrsn=2

Çakır, Uğur, and Erol Şahin. "Using Solar Greenhouses in Cold Climates and Evaluating Optimum Type according to Sizing, Position and Location: A Case Study." *Computers and Electronics in Agriculture* 117 (September 2015): 245–57. doi:10.1016/j.compag.2015.08.005.

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http://www.aquaponicsusa.com/ap-info/aquaponics-grow-beds.html

Thank You.

Questions?