Part 1: Intro to Northern Year-Round Passive Greenhouses: SDMG/SDSPA Edition

Shannon Mutschelknaus February 2020

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Outline

Part 1:

1. About me, my farm and my research project
2. What are passive solar greenhouses?
3. Fully passive systems
4. Mostly passive systems

Part 2:

1. Details of my prototype & analysis
2. A review of 2020 performance data
3. Some resulting design guidelines
4. Some of the stuff we are/have grown

About me

Mechanical engineer with 20 years experience doing thermal design, research & testing of electronics mega-systems.

2021 Super Bowl Tampa, FL

Small farm owner/operator with a fruit obsession.

Wayward Springs Acres

Fruit trees & greenhouse tech.

Scottish Highland Beef

Jacob Sheep Fiber & Products

About my research project

Objective:

Produce data regarding design trade-offs of passive solar greenhouses features as well as demonstration of a selected design.

Motivation:

Cold northern climates prevent year-round crop production and make greenhouses too costly for tropical produce. This results in long distance shipping of fruits and vegetables from central America and prevents many types of delicate produce from being available in local markets.

FNC19-1185
High Efficiency Year-Round Tropical Greenhouse

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What are passive solar greenhouses?

What is a "passive solar greenhouse"

A good design can:

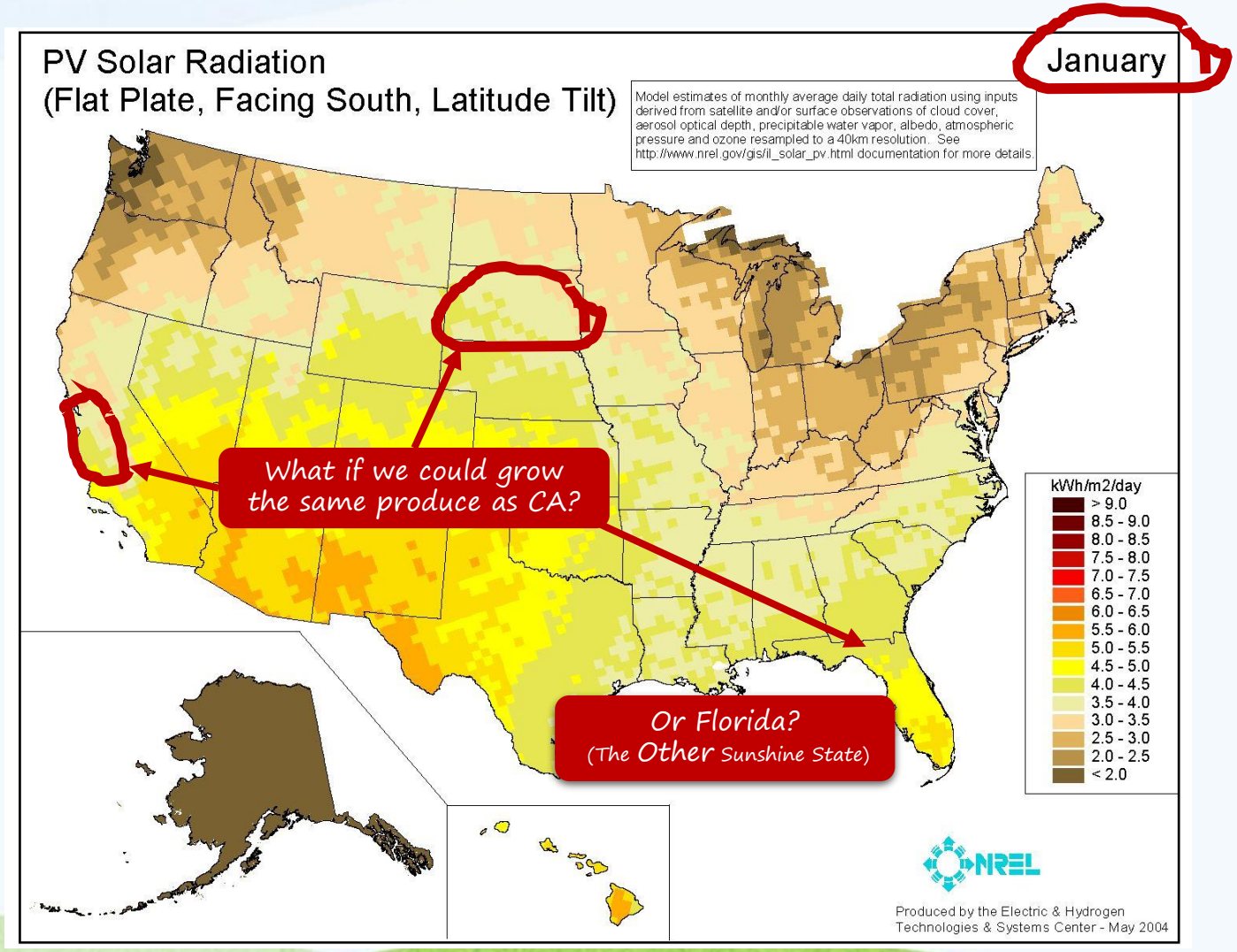
- Minimize total cost of ownership (construction & operation)
- Minimize or eliminate external energy sources for heat.

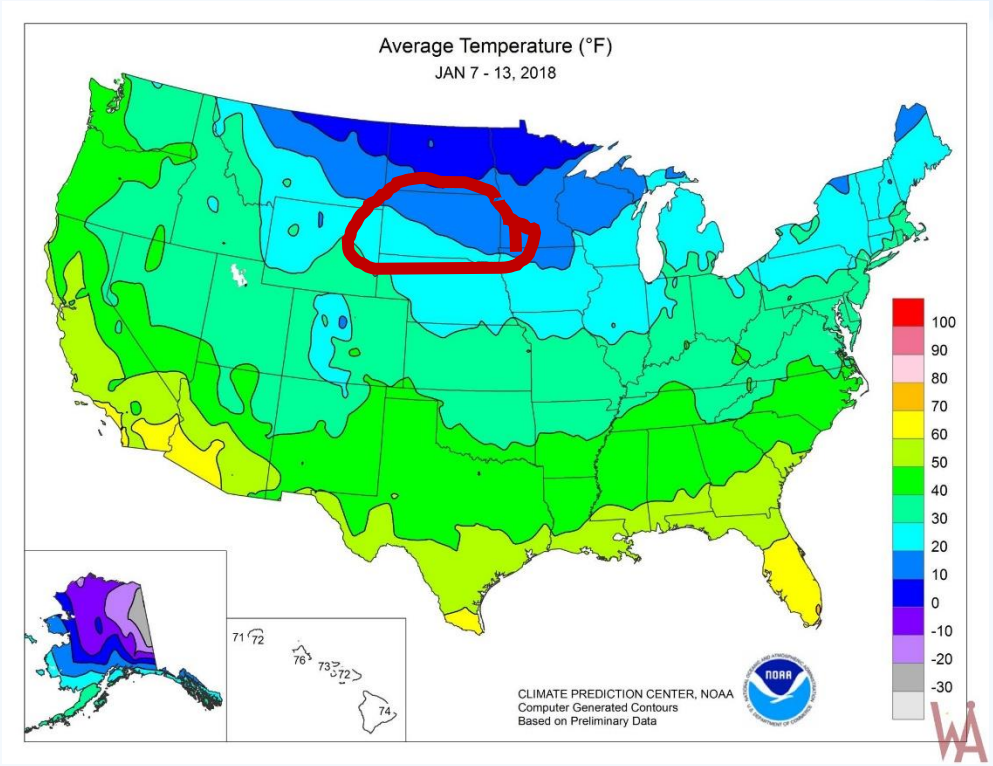
1909 State Flag Design

For our climate

Could it be possible to heat with only the sun?

South Dakota has a lot of winter sunlight!





All we need to do:

store it during the day to use for our long cold nights

For a reasonable price

Key elements of a "passive solar greenhouse"

The Key Feature

The south facing surfaces are a transparent glazing

The North facing surfaces are insulated

- Winter sunlight is predominantly from the south.
- North glazing would provide no lighting benefit.

- Glazing is a very poor insulator so minimize it.
- Summer sunlight is excessive, and some shading of the north side is beneficial.

Key elements of a "passive solar greenhouse"

Orientation

It is typically best practice to orientate greenhouses North-South

Typical Greenhouse

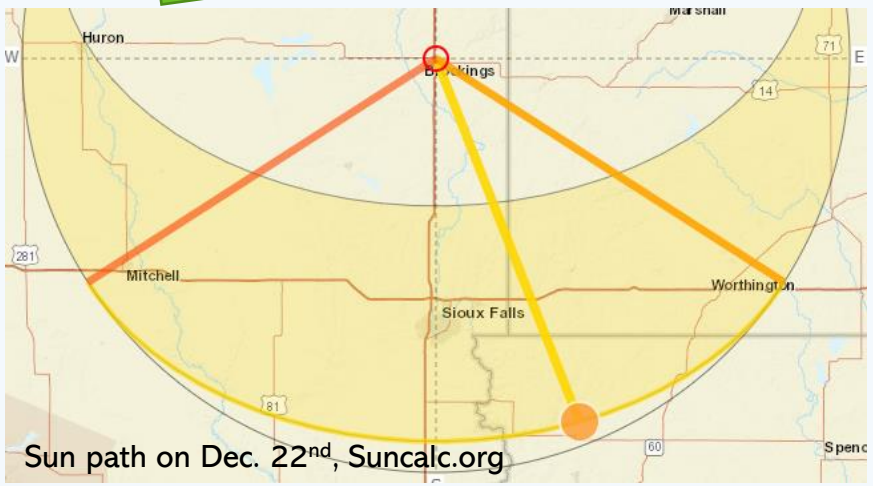
N

S

To get even lighting to all rows

East-West is best for capturing winter sunlight when it's needed the most.

Solar Greenhouse



Sun path on Dec. 22nd, Suncalc.org

WARNING: Sunlight will not be even throughout the structure

Key elements of a "passive solar greenhouse"

Location

Check for & remove sunlight obstructions

Sun Position App. (Free version only works for the current day, so download and scout your site on Dec. 22nd)

Also make sure ground water is >4ft. below grade

Key elements of a "passive solar greenhouse"

They can come in all kinds of shapes and sizes

Grandpa G's, Pillager, MN

REDCO, Mission, SD

Wenjing Guan, Beijing, China

Francie Popelka, Wisconsin

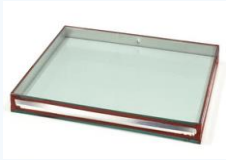
Char Graber

NPNRD Scottsbluff, NE 'Citrus in the Snow – Russ Finch'

Key elements of a "passive solar greenhouse"

Most Common Glazing types

R-15 to R-20 is typical for walls in new homes in our climate

		Light Transmittance	Insulation R-Value	
Glass		60%-93%	0.9 – 3.0	Heavy and can get expensive due to support structure. breakable
Polyethylene (PE)		74% - 87% Double Single	0.83 – 1.25 Single Double	Cheap! ~$0.01/sqft, max. 4yr life, poor thermal performance
Polycarbonate (PC)		70% - 85% Triple Wall Double Wall	1.5 - 2.3 Double Wall Triple Wall	~$5/sqft, 7+yr life, good thermal performance, durable


Fully passive solar greenhouses

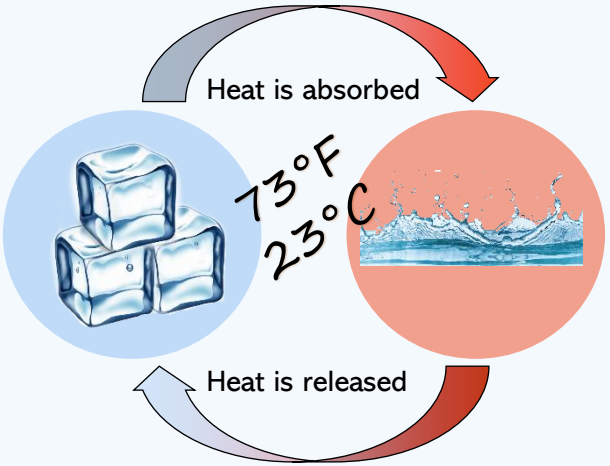
Fully Passive Heat Storage Systems

Water barrels

Pros: Water is cheap

Cons: The space is expensive, it's slow to absorb & emit heat

Phase change materials

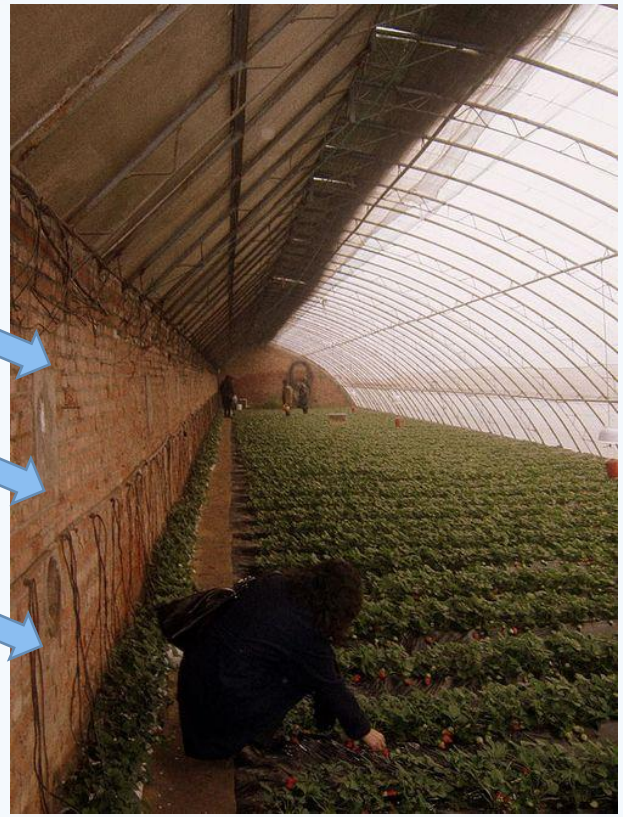


Pros: More heat, less space than water

Cons: More expensive than water

Fully Passive Heat Storage Systems

Concrete, Packed Earth, etc



Pros: Not that easy, cheap or durable

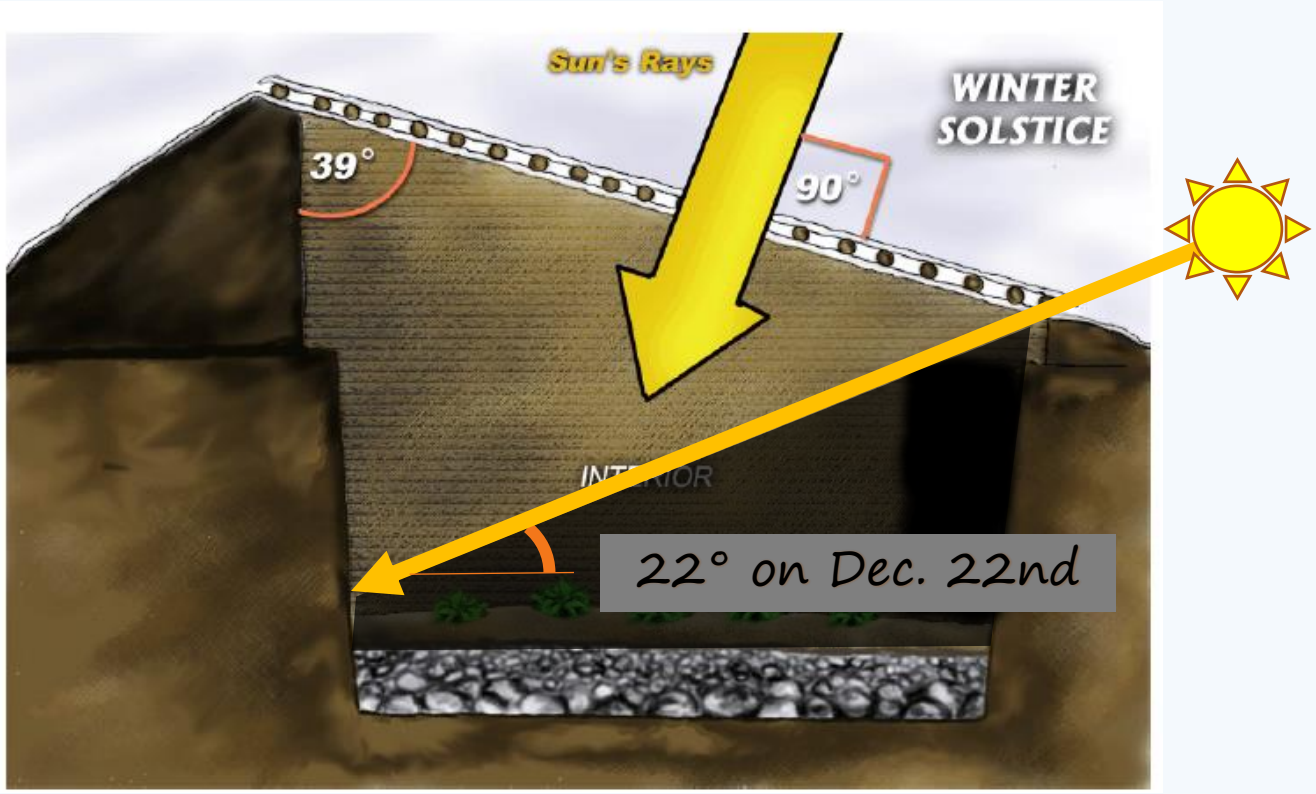
Cons: Doesn't store enough heat (1/3 of H_2O)

Underground, Walipini, Earth-Sheltered, Pit

Uses the ground on all sides as a "thermal mass" to reduce temperature swings.

Walipini Warnings

****Designed for LaPaz, Bolivia****



Bensen Agriculture and Food Institute, Brigham Young University, 2002

Pros: Thermal storage all around!

Cons:

- Stability, walls must be reinforced
- Water problems & drainage
- Winter sun shading!

Can Fully Passive Systems Work in SD Year-Round?

The Chinese Solar Greenhouse (CSG)

China has the highest greenhouse-based vegetable production in the world.

By 2010 china already had >1,970,000 acres under solar greenhouses! (17% of their total)

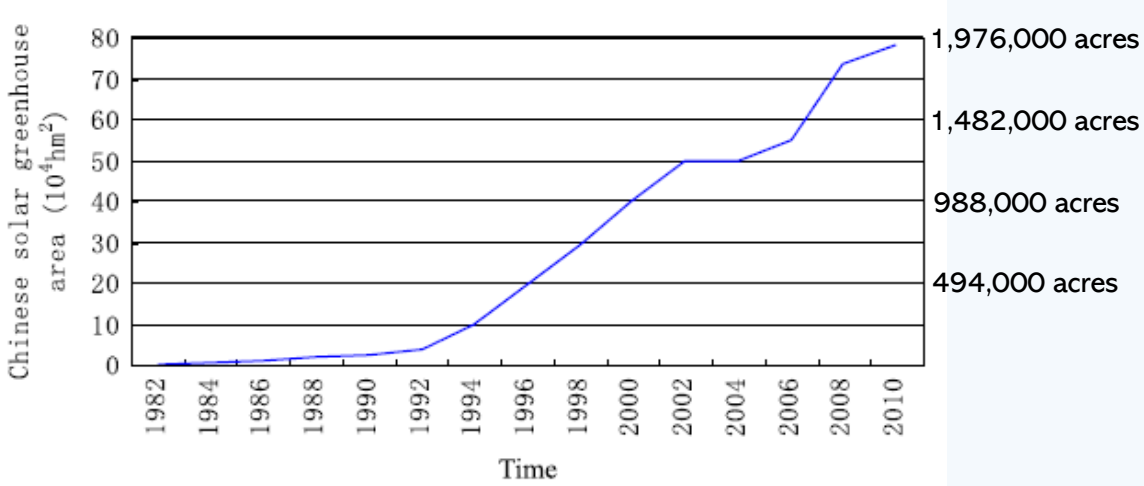


Fig. 2. Yearly total CSG areas.

HortiDaily.com 2017

Energy performance optimization of typical Chinese solar greenhouses by means of dynamic simulation (Alessandro Deiana et al., International conference of agricultural engineering, 2014, Zurich.

Passive solar energy utilization: A review of cross-section building parameter selection for Chinese solar greenhouses (Guohong Tong et al., 2013)

How the Chinese Solar Greenhouse Works

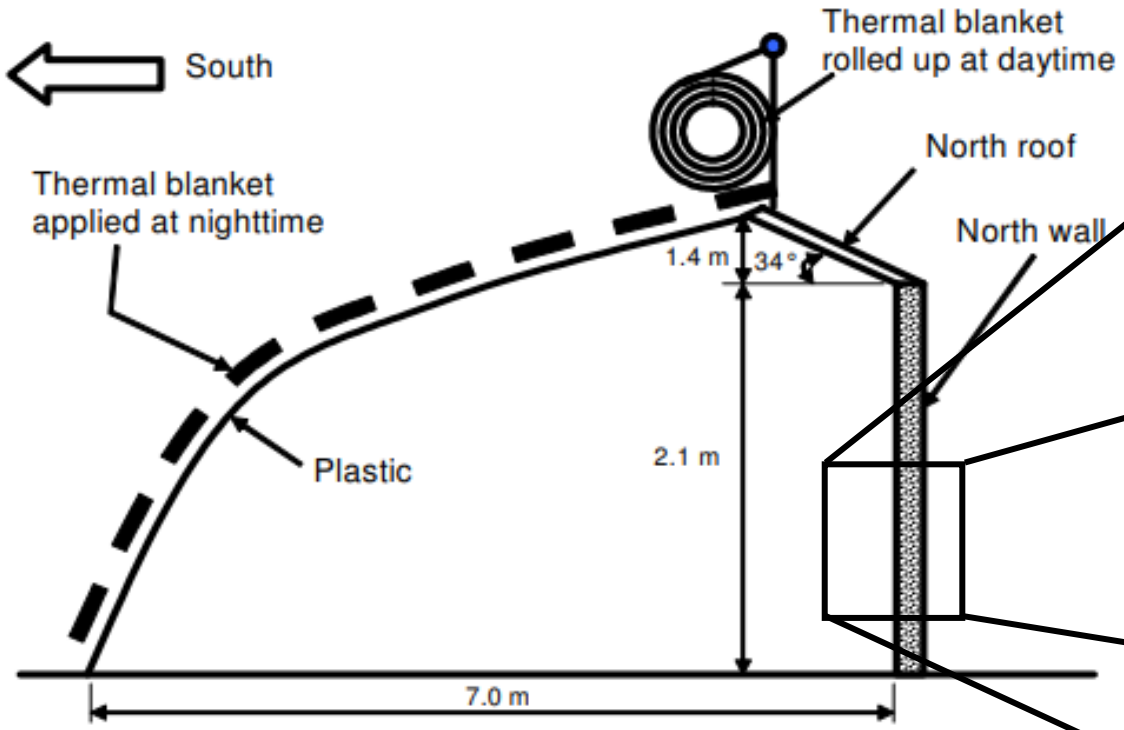


Fig. 1. Side view of the solar energy greenhouse. The greenhouse length was 30 m.

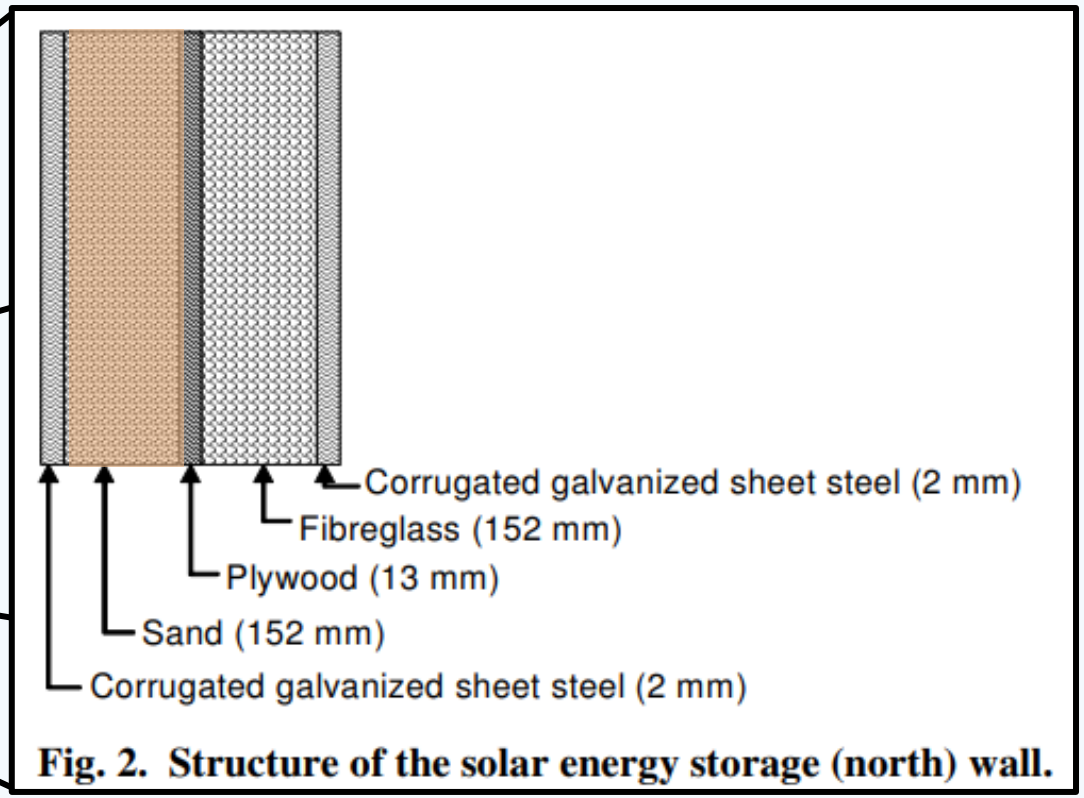


Fig. 2. Structure of the solar energy storage (north) wall.

An automatic thermal blanket is also a challenge with snow cover in northern climates.

Winter performance of a solar energy greenhouse in southern Manitoba (E. Beshada et al., Dept. of Biosystems Engineering, Univ. Manitoba, 2006

Fruit in the Chinese Solar Greenhouse

Figure 2: Cherry trees inside a Chinese half-greenhouse. (Photo: Greg Lang)

In 20yrs China has gone from a minor cherry producer to at least #3 in the world.

>2,500 acres of sweet cherries were being grown in solar greenhouses to fill the market gap between southern & northern hemisphere cherries.

Fruit in the Chinese Solar Greenhouse

V-trained peach trees after post harvest pruning.

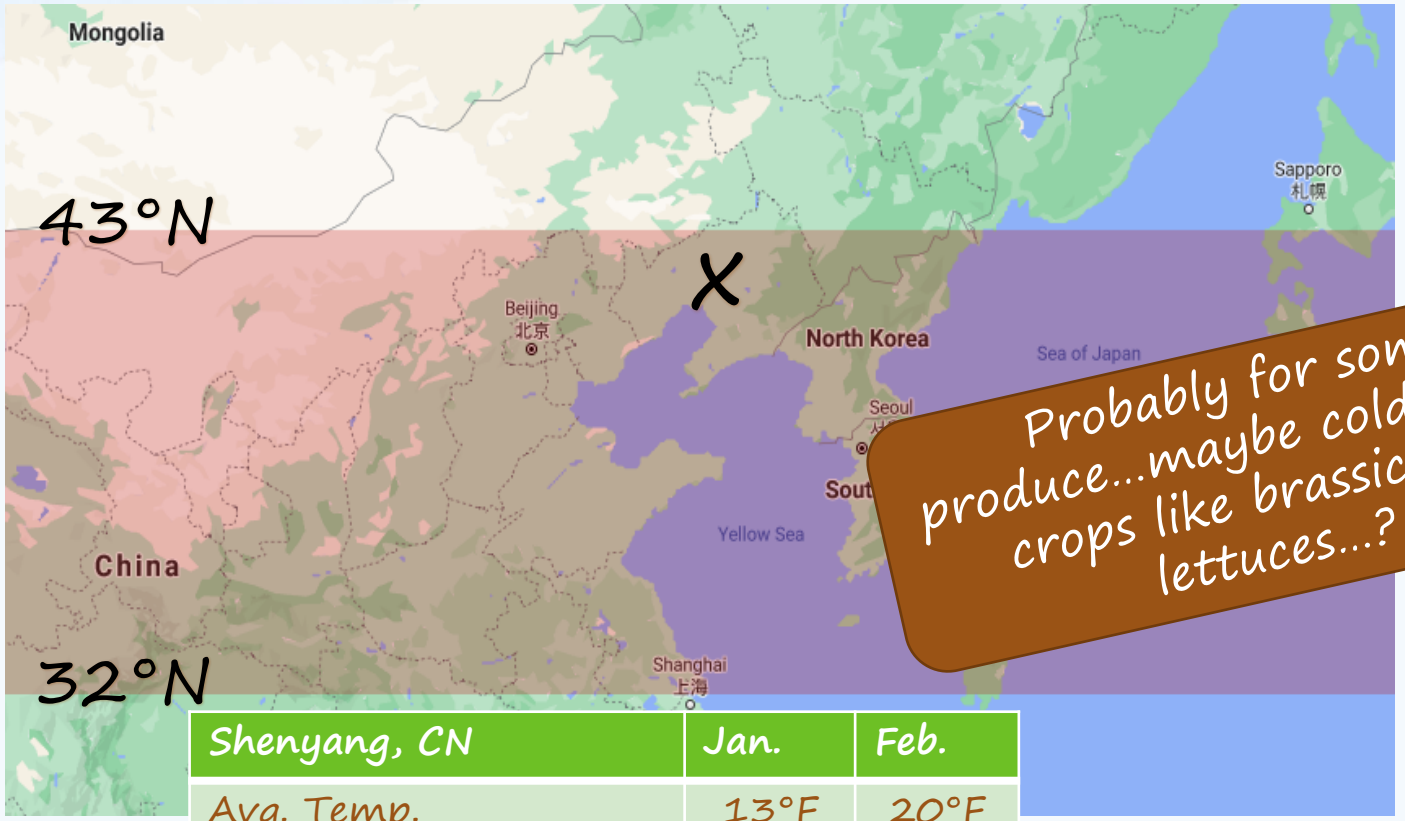
>40,00 acres of low-chill greenhouse peaches & nectarines.

A typical, south-facing solar lean-to greenhouse with sunken floor. The side and back walls are made of earth. Note the nontransparent insulation rolled up at the top of the house. **(Courtesy Desmond R. Layne, Ph.D./Washington State University)**

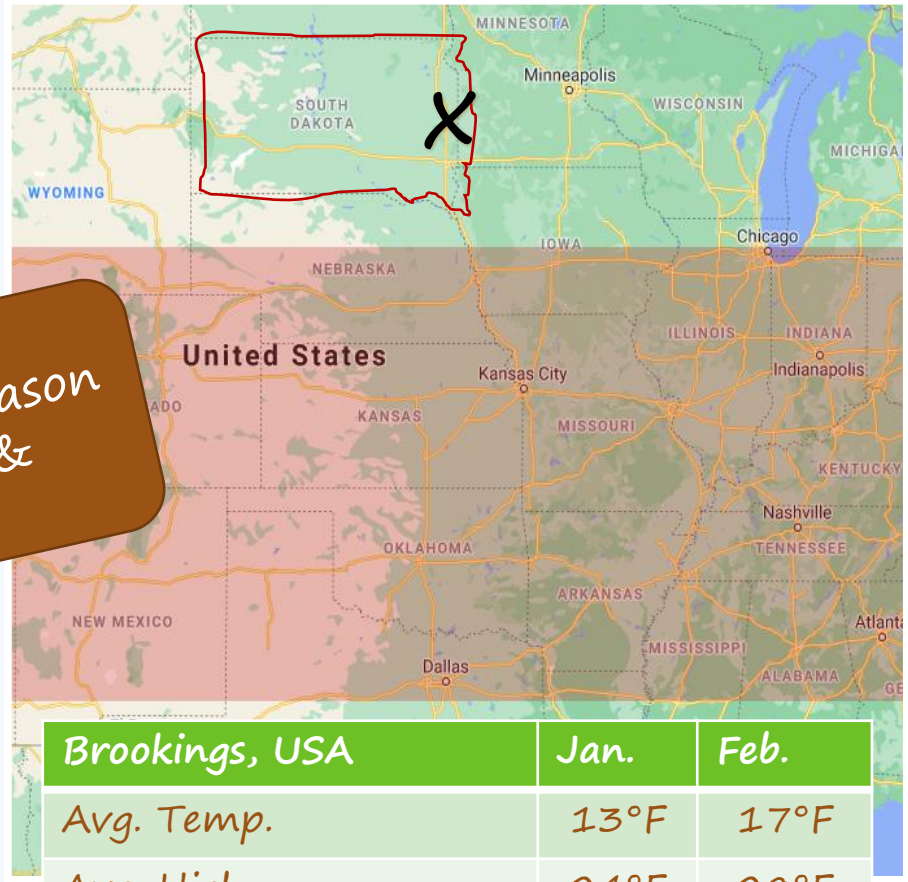
Undercover production in China – GoodFruitGrower – www.goodfruit.com (July 1, 2013)

Can Fully Passive Systems Work in SD Year-Round?

Could they work in SD?



Probably for some produce...maybe cold season crops like brassicas & lettuces...?



Shenyang, CN	Jan.	Feb.
Avg. Temp.	13°F	20°F
Avg. High	22°F	28°F
Avg. Low	4°F	11°F
Highest Recorded	46°F	57°F
Lowest Recorded	-19°F	-14°F

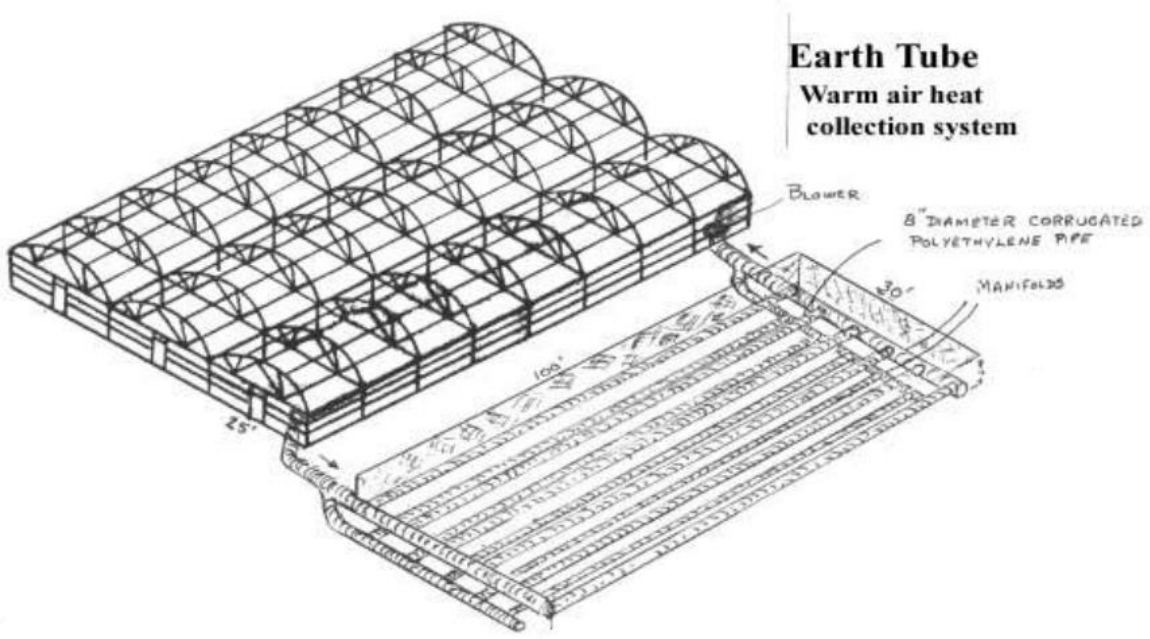
Brookings, USA	Jan.	Feb.
Avg. Temp.	13°F	17°F
Avg. High	24°F	28°F
Avg. Low	3°F	6°F
Highest Recorded	61°F	69°F
Lowest Recorded	-41°F	-41°F

What are mostly passive solar greenhouses?

Mostly Passive Systems (uses fans)

1. Direct Use Low-Grade Geothermal (LGG)

(aka. Earth Tubes)



John Bartok, Jr., University of Connecticut

2. Ground based Heat Storage Systems

(Climate battery, GAHT™, GETS, SHCS, earth tubes etc.)

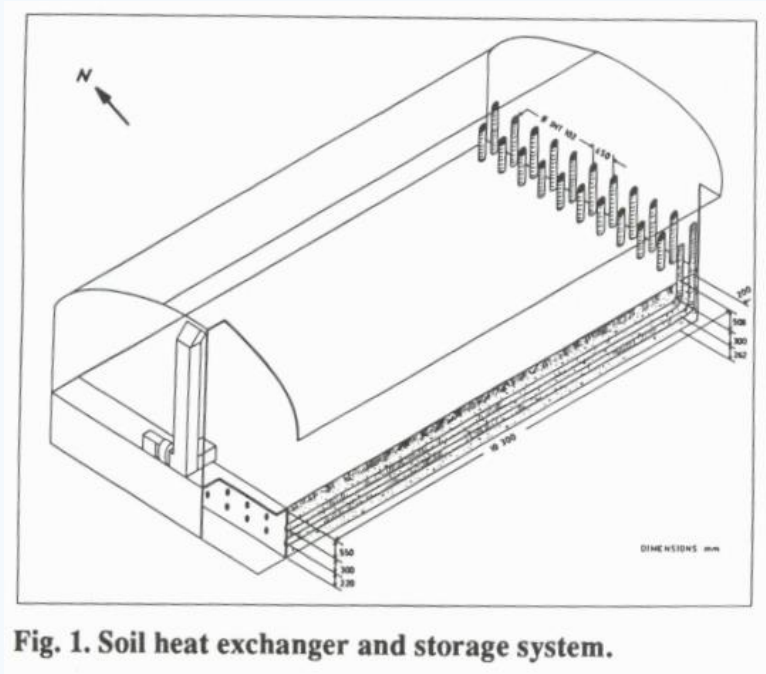


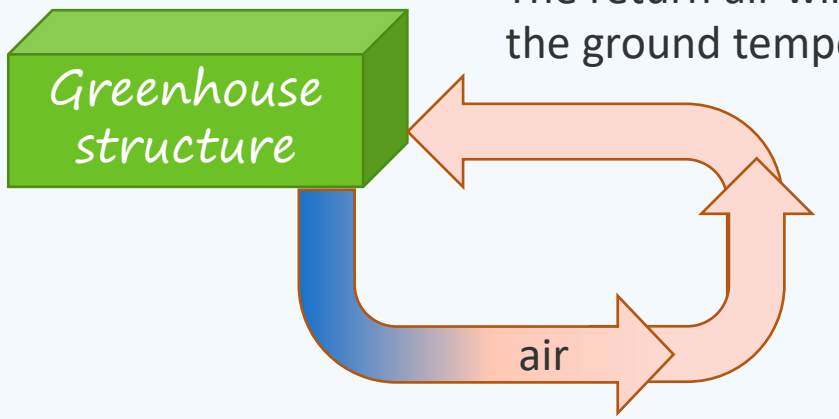
Fig. 1. Soil heat exchanger and storage system.

Evaluation of soil heat exchanger-storage system for a greenhouse.
H. Bernier, 1991 Canadian Ag. Engineering

Mostly Passive Systems

Direct Use Low-Grade Geothermal (LGG)

Extracts the natural heat accumulated in the ground to provide heat to the greenhouse.



The return air will be heated to the ground temperature.

Typically air is blown through a series of perforated drain tile tubes.

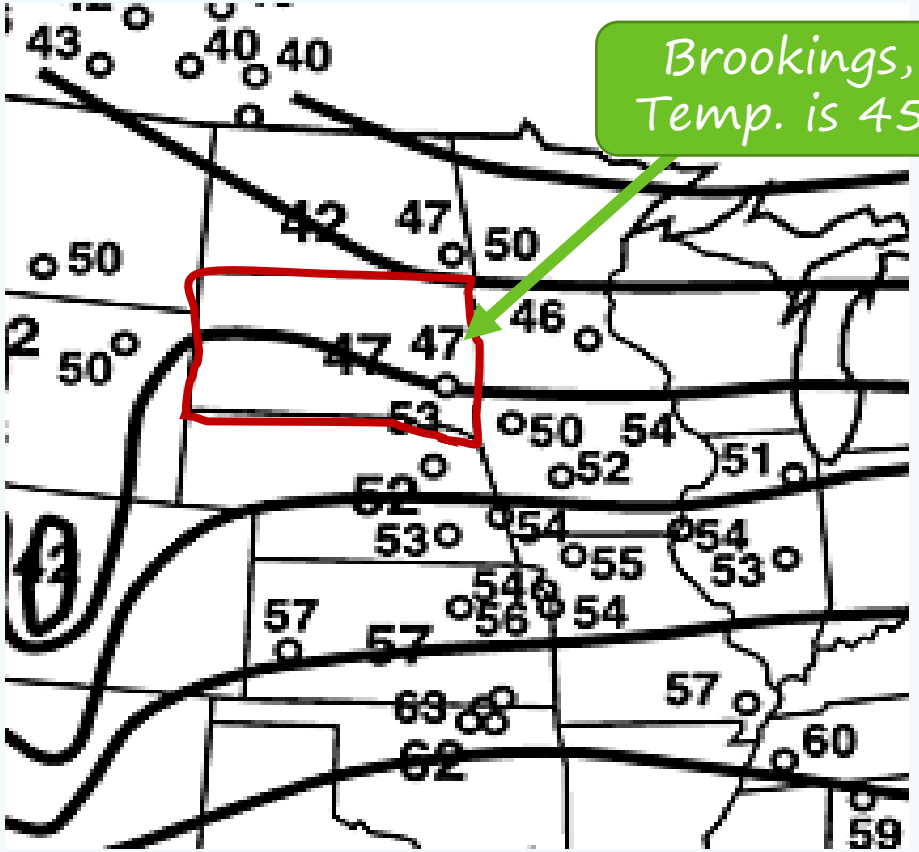
John Bartok, Jr., University of Connecticut

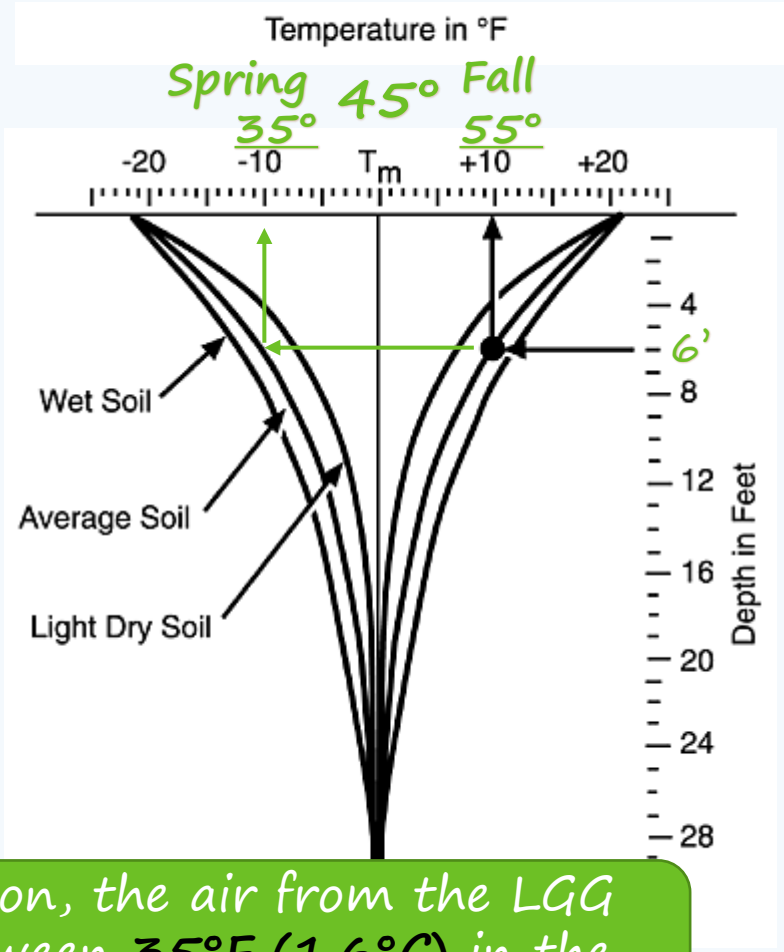
NPNRD Scottsbluff, NE “Citrus In the Snow” system

Mostly Passive Systems

Direct Use Low-Grade Geothermal (LGG) Limitations

Mean earth temperature (30ft down)





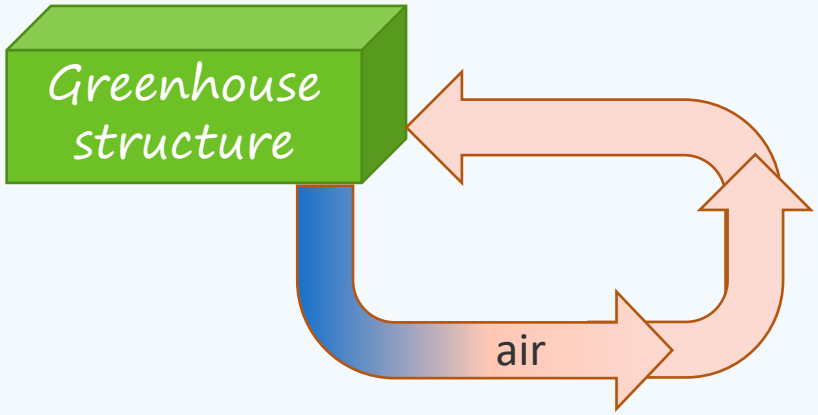
For my location, the air from the LGG would be between **35°F (1.6°C)** in the early spring to **55°F** (12.7°C) in late fall.

*Other variations are possible:

- water-air (adds heat exchanger, $$)
- Indirect use LGG (adds heat pump, $$$)

Mostly Passive Systems

Direct Use Low-Grade Geothermal (LGG)



Pros:

- Very simple components (Fans, tubes, thermostats)
- Low energy input

Cons:

- Must be able to dig down over 6ft (2m)
- Water table must be below tube depth (6ft)
- Limited heating based on your ground temperature
- Requires proper tube & fan sizing to be effective

*Other variations are possible:

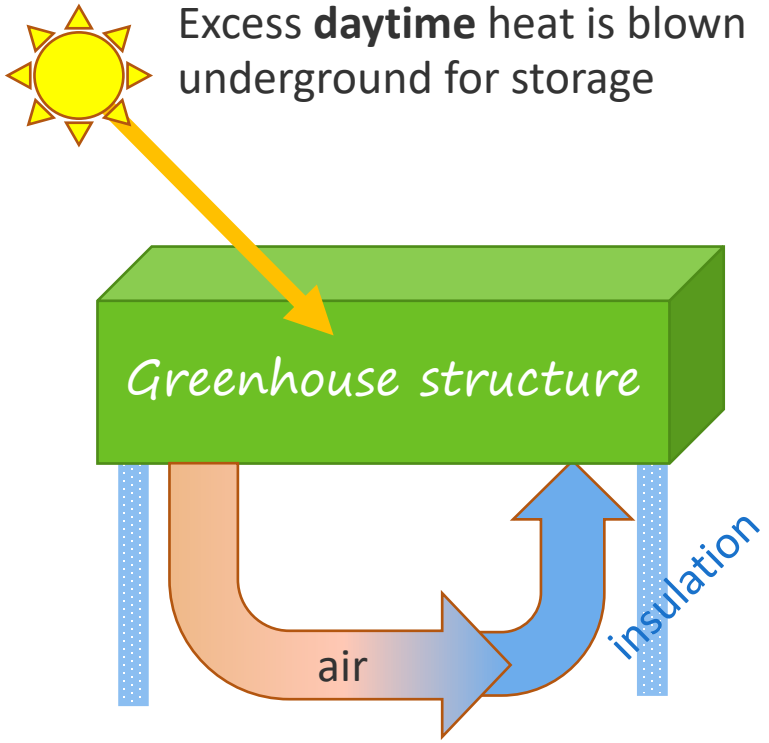
- water-air (adds heat exchanger, $$)
- Indirect use LGG (adds heat pump, $$$)

Mostly Passive Systems

Ground/Soil Based Heat Storage Systems

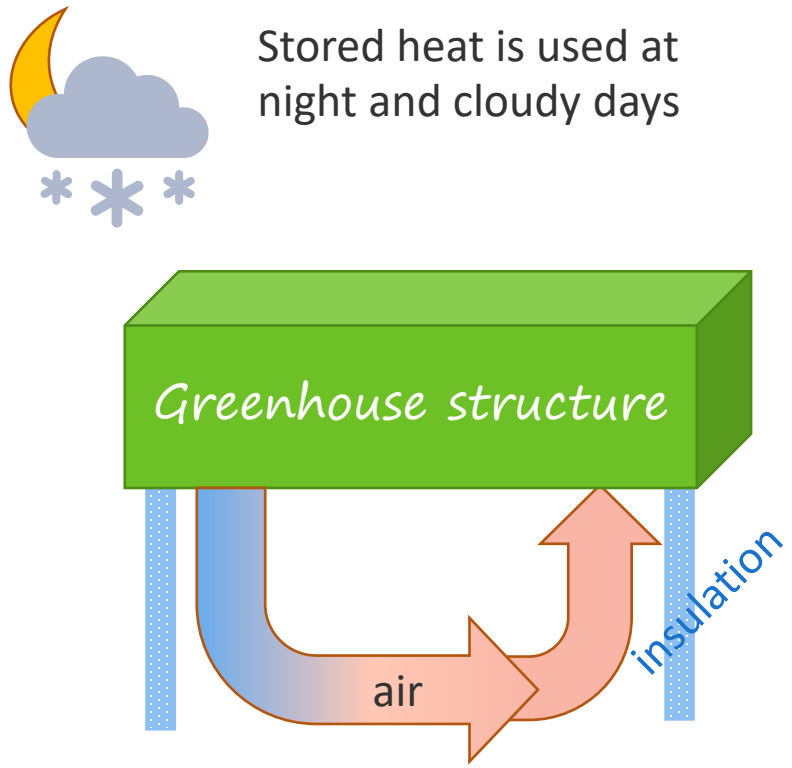
(**Climate/Earth battery**, GAHT™, GETS, SHCS, earth tubes etc.)

1.

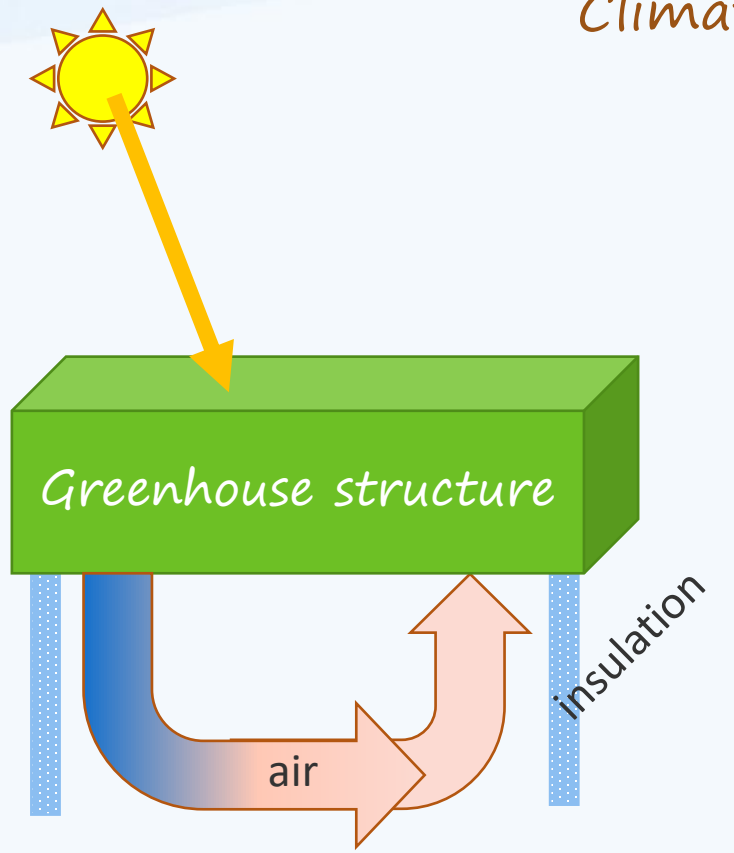


*climate batteries also provides a significant amount of cooling.

2.



Mostly Passive Systems



Climate/Earth Battery Heat Storage

Pros:

- Very simple components (Fans, tubes, thermostats)
- Low energy input
- More heating capacity, if in high sunlight regions
- Also provides some cooling
- Doesn't require excavation outside the structure

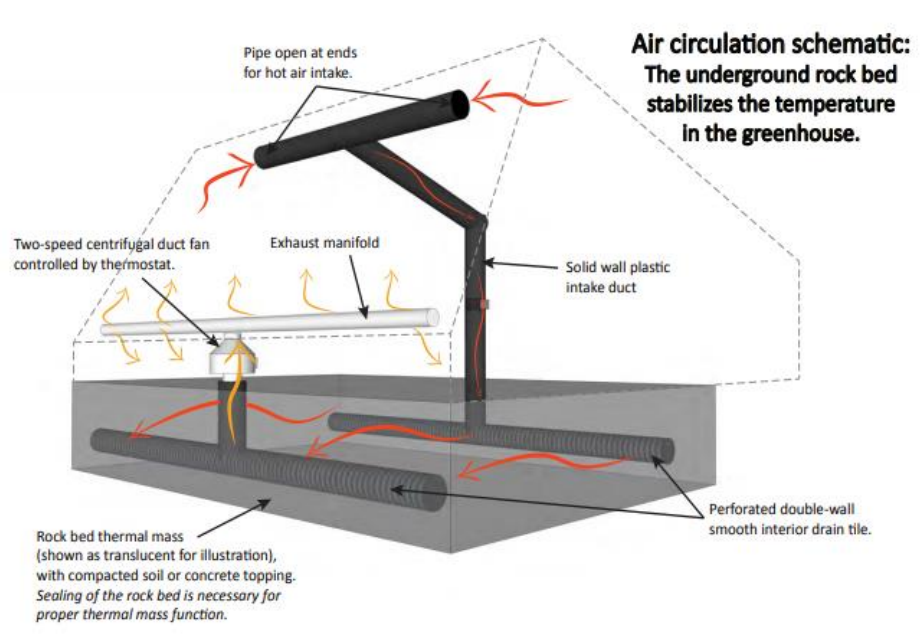
Cons:

- Must be able to dig down 4ft (1.3m)
- Water table must be below tube depth
- Requires proper tube & fan sizing to be effective

Mostly Passive Systems

Climate Battery Heat Storage Types

Rock Bed Storage Systems



Deep Winter Greenhouse v2.2, UMN

Pros:
- Rock bed can store more heat

Cons:
- Cost/availability of clean rock
- Cannot grow plants in the ground

Soil/Earth Based Storage Systems

Wayward Springs Acres, Aurora SD

Pros:
- Lower cost, dirt/soil is easily available
- Can plant in the ground or pots!

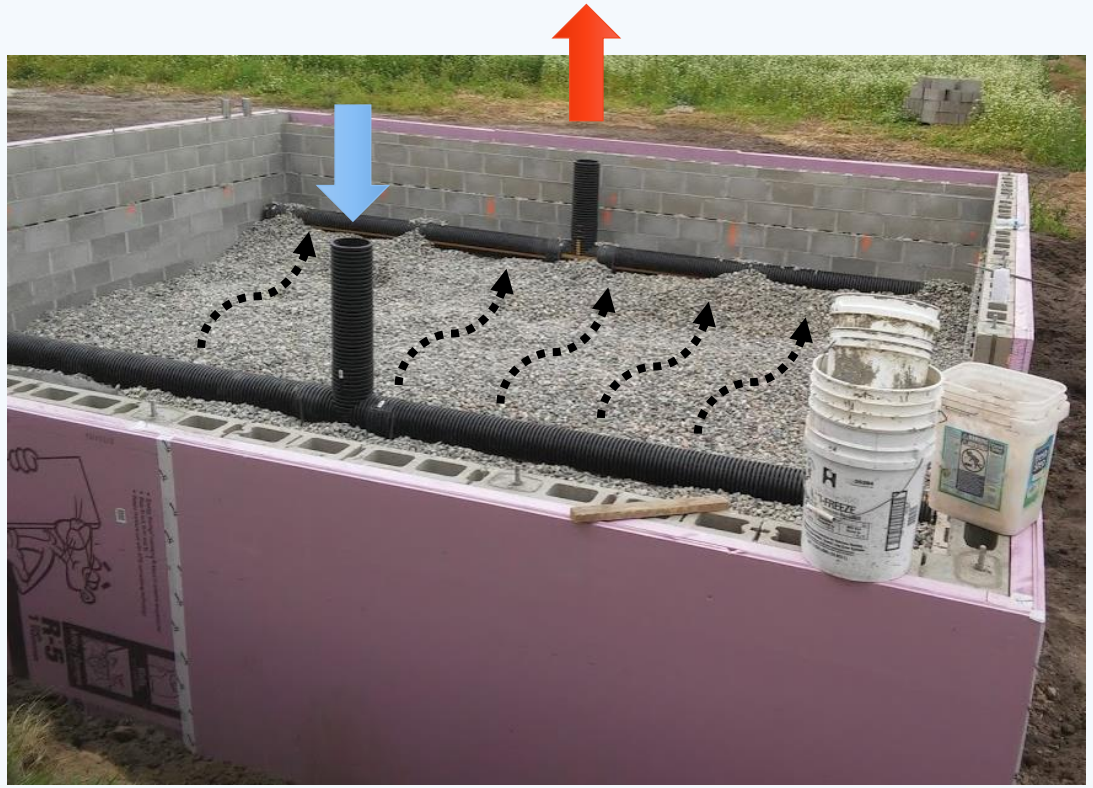
Cons:
- Slightly less heat storage than rock

Mostly Passive Systems

Grandpa G's, Pillager, MN

Deep Winter Greenhouse (DWG 2.2)

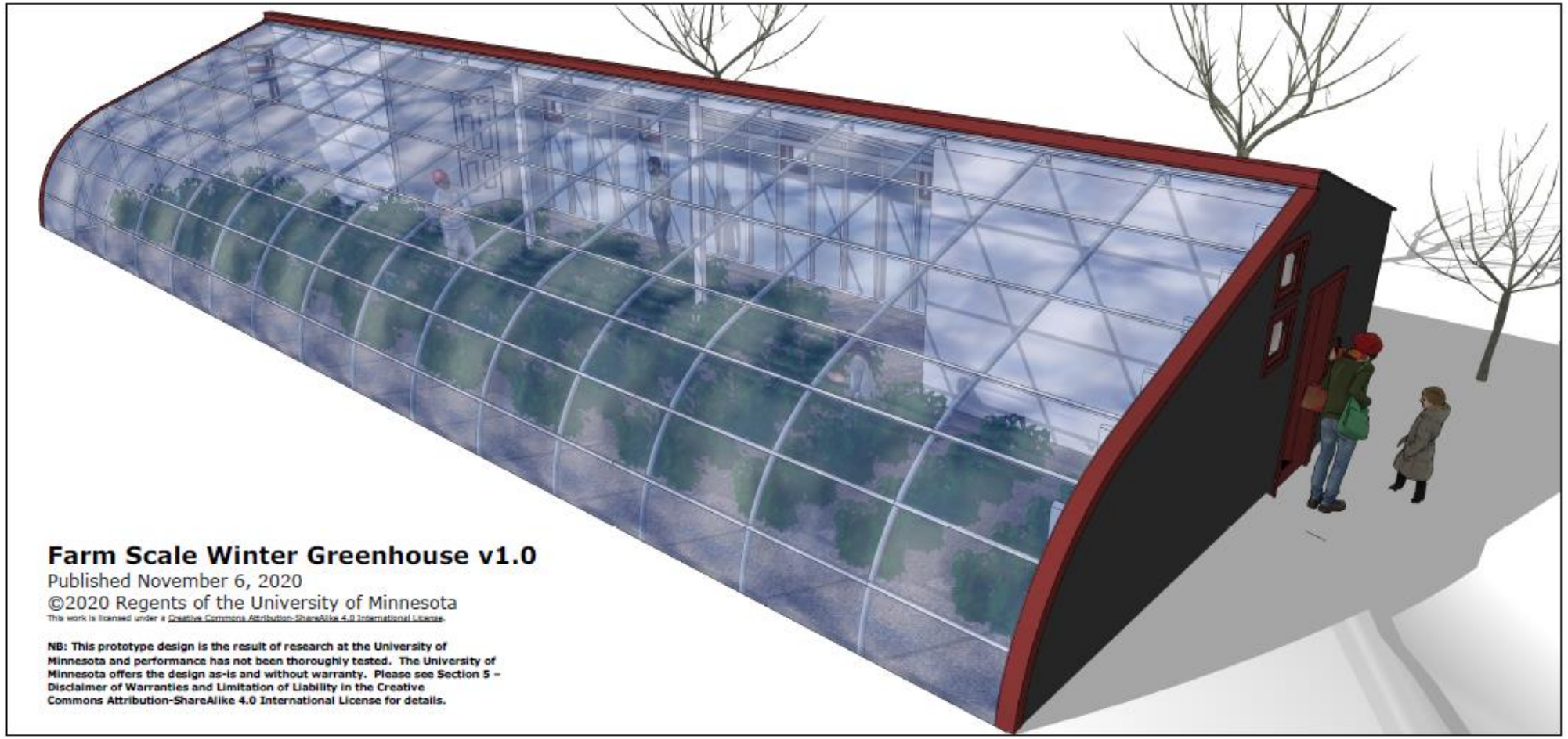
Optimized for winter growing



https://extension.umn.edu/growing-systems/deep-winter-greenhouses

Mostly Passive Systems

UNIVERSITY OF MINNESOTA | EXTENSION



Regional Sustainable Development Partnerships
UNIVERSITY OF MINNESOTA EXTENSION

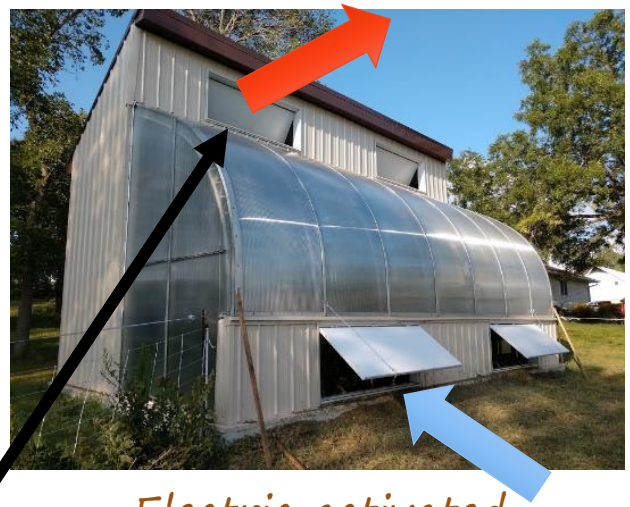
CSBR
Center for Sustainable Building Research

https://extension.umn.edu/growing-systems/deep-winter-greenhouses

Passive Cooling! (often overlooked)

Roof vents

Fully Passive



Electric activated

Rack & Pinion (large scale commercial)

Shade cloth

Thermal mass/storage
(climate battery, water barrels, phase-change, etc)

Questions?

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www.facebook.com/waywardsprings/

Next Time:

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2. A review of 2020 performance data
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Shannon.mutschelknaus@gmail.com

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