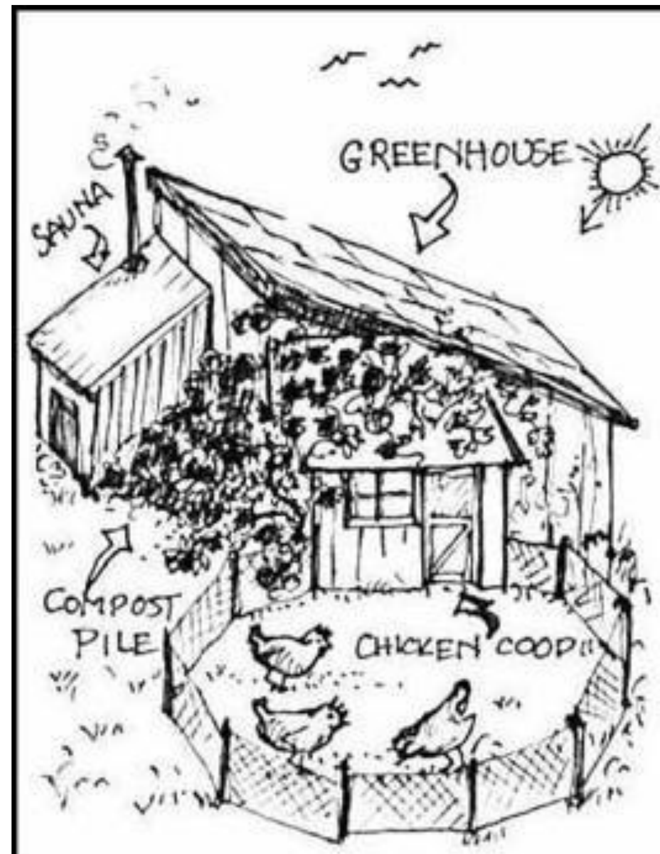
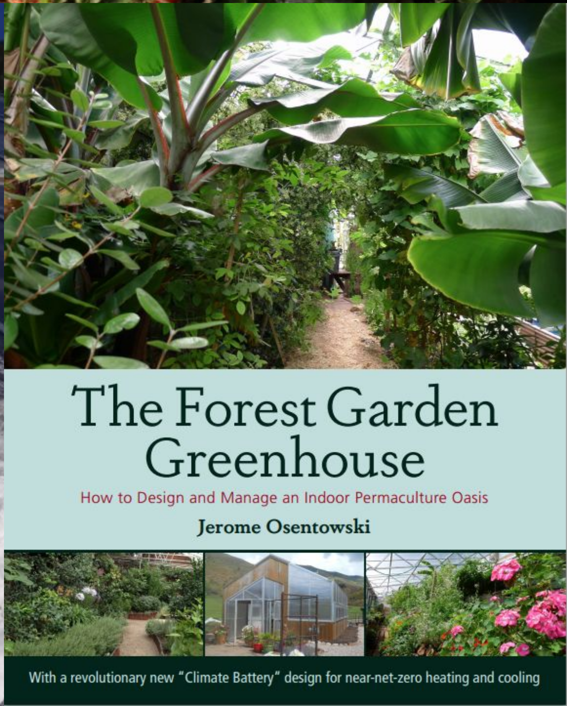
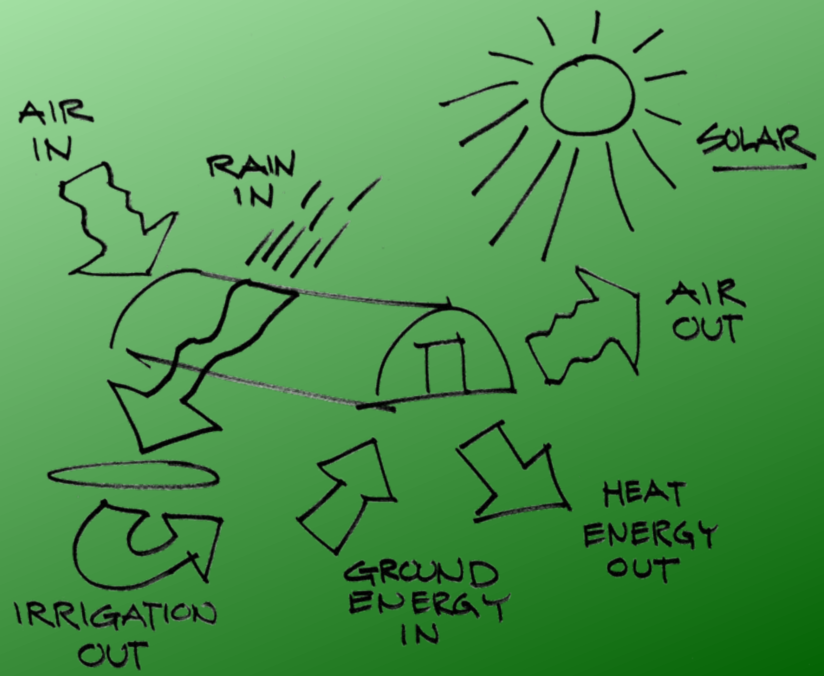
Winter Greenhouses

Justin Tilson
Director at NOPRI
September 2021




CRMPI.org


The Forest Garden Greenhouse
How to Design and Manage an Indoor Permaculture Oasis
Jerome Osentowski
With a revolutionary new "Climate Battery" design for near-net-zero heating and cooling



Why Greenhouses?

local production

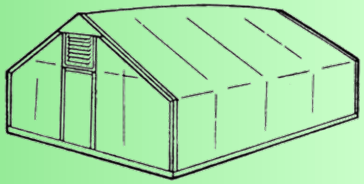
fresh produce through winter

food **security**

strengthen communities

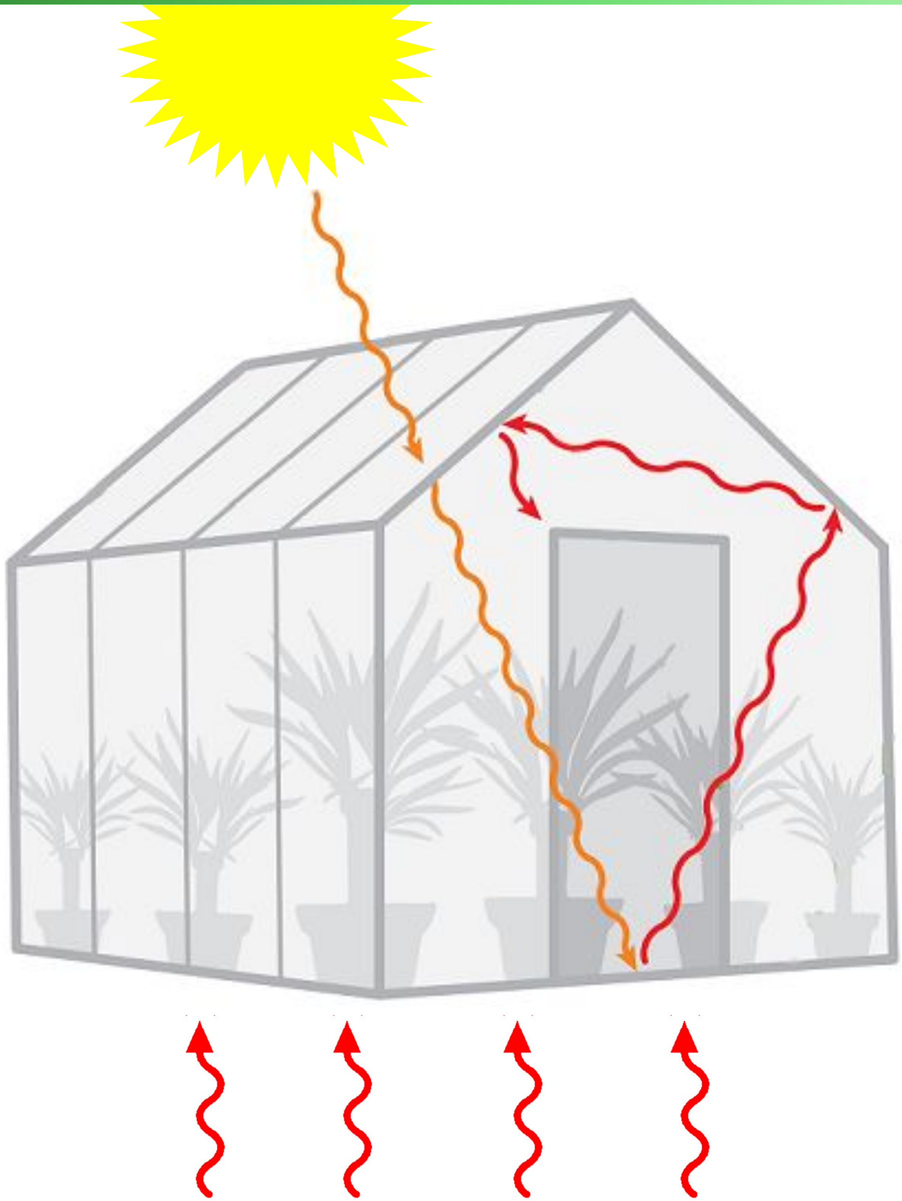
education & research

How does a greenhouse work?

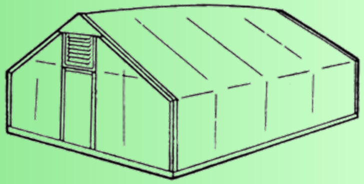


A controlled environment for optimal plant growth:

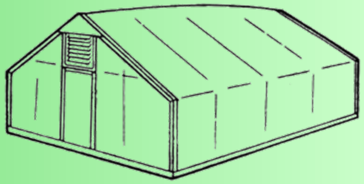
- temperature
- light
- humidity
- etc.



Traditional Greenhouse

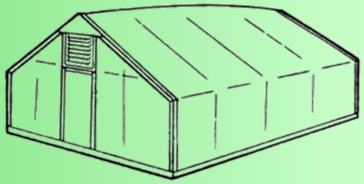


Greenhouse Concepts



- Insulation of glazing, walls, and ground
- Light transmission of glazing
- Direct vs diffuse transmission
- Light incidence angle to glazing
- Seasonal light incidence changes
- Glazing angle considerations (snow, cost)
- Greenhouse length, width, height, angles and orientation
- Thermal mass and temperature range
- Humidity control
- Pest control
- Supplemental light and heat

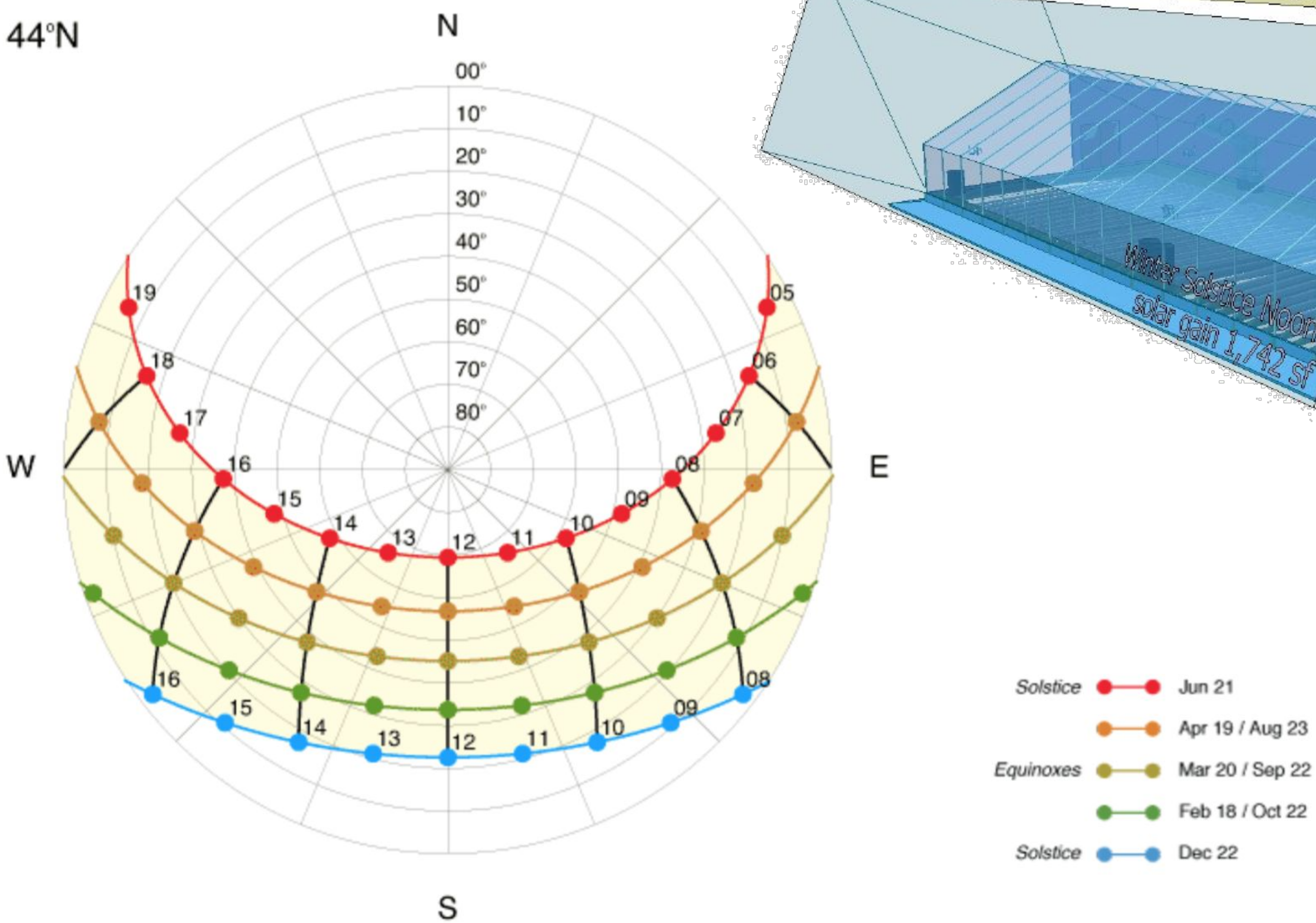
3 - 4 Season Greenhouses

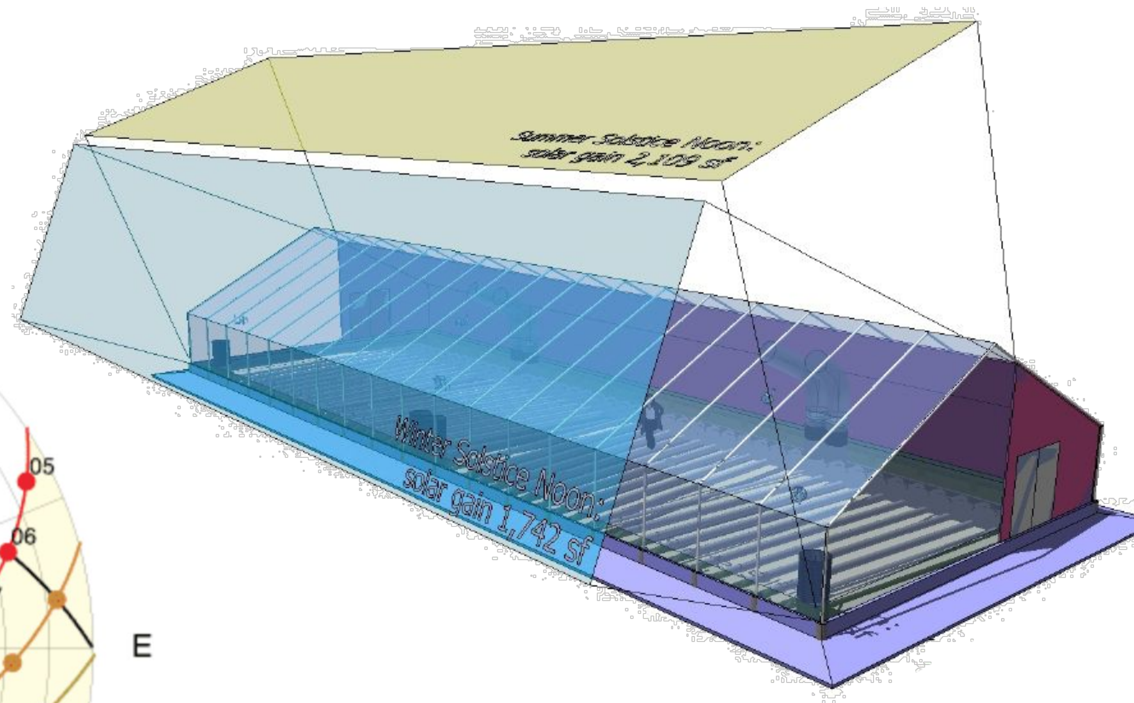


~$5,000

~$500,000

Seasonal Light Incidence Angles



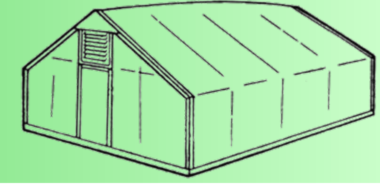


Sun Path Chart for 44ºN Latitude Image:University of British Columbia

Light incidence angle (to glazing)

Transmission through glazing drops off beyond 40°

Glazing Insulation

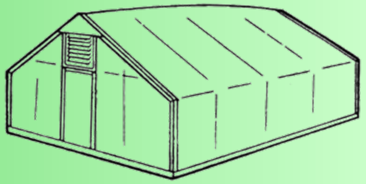


Material	R-value	% PAR light	Notes
Polyethylene Film (single layer)	0.83	80-90%	cheap, fragile 6-7 yr lifespan
Polyethylene Film (double layer)	1.5	70-80%	
Glass (single wall)	0.9	98%	expensive, fragile 50+ yr lifespan
Glass (double wall)	2	97%	
Polycarbonate (2-wall 8mm)	1.6	85%	yellows with time 15-20yr lifespan
Polycarbonate (3-wall 16mm)	3	75-79%	
ETFE film (inflated)	1.7	93%	expensive 30+ yr lifespan

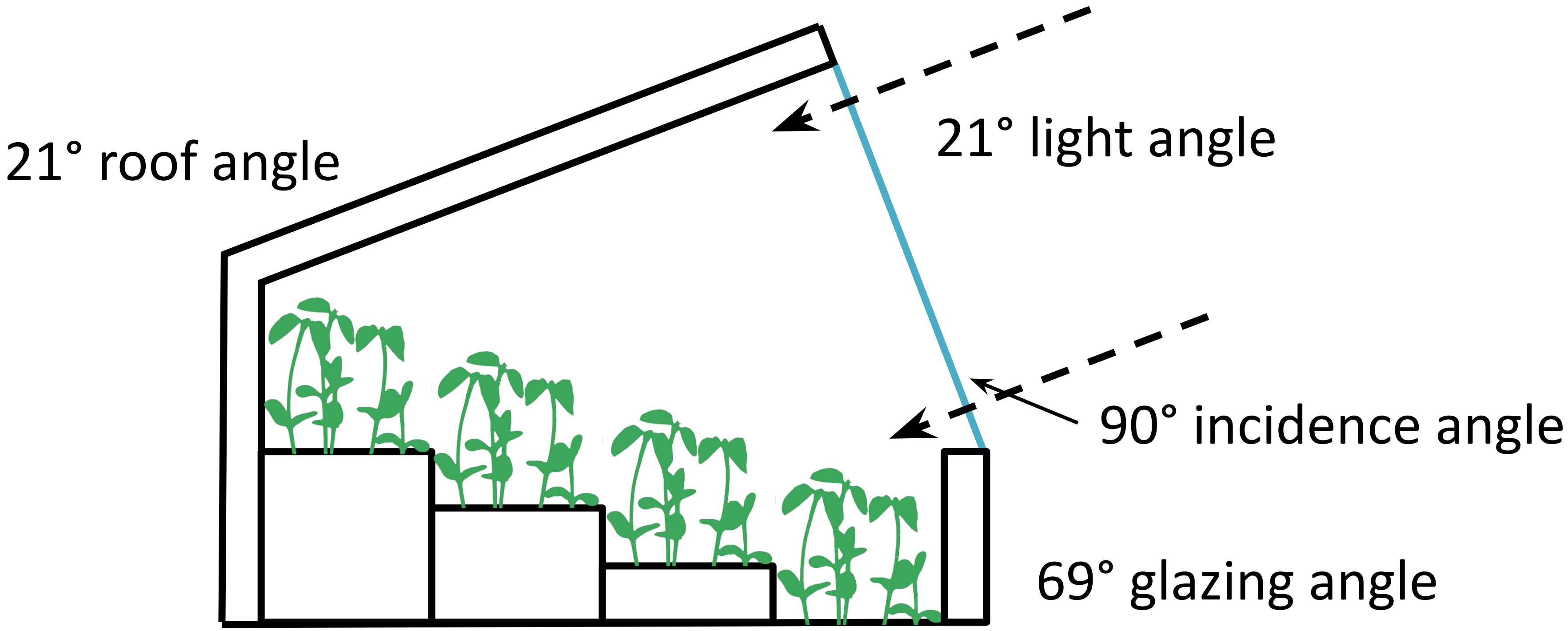
In modern insulated winter greenhouses most heat is lost through the glazing. Wall R-values are often 20 or higher, while the best glazing materials max out at 3.

For example, in a greenhouse with 50% R2 glazing and 50% R20 walls, the rate of heat loss through the glazing is 10X that of through the walls.

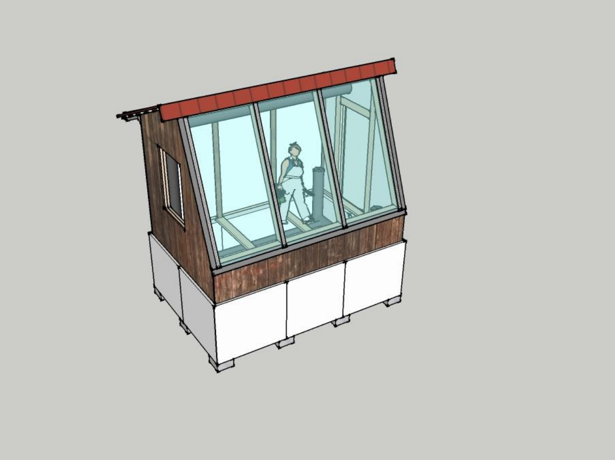
Greenhouse dimensions & orientation



Optimized design for winter solstice in cold climate:

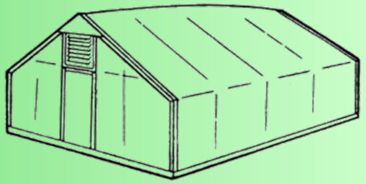


- Light incidence on glazing is 90° for maximum transmission
- Glazing area is minimized to reduce thermal losses
- Terraced interior reduces self-shading by plants
- Steep glazing won’t collect snow

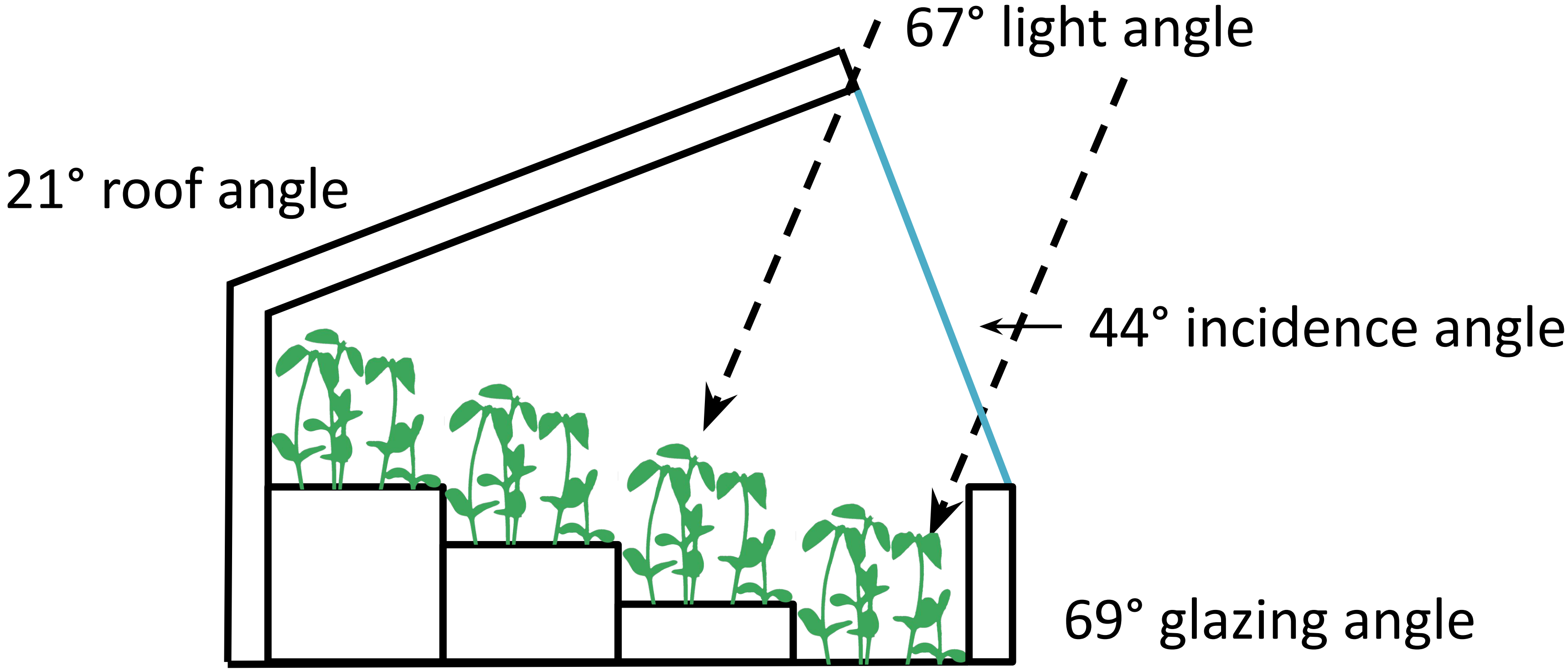





Glazing angle

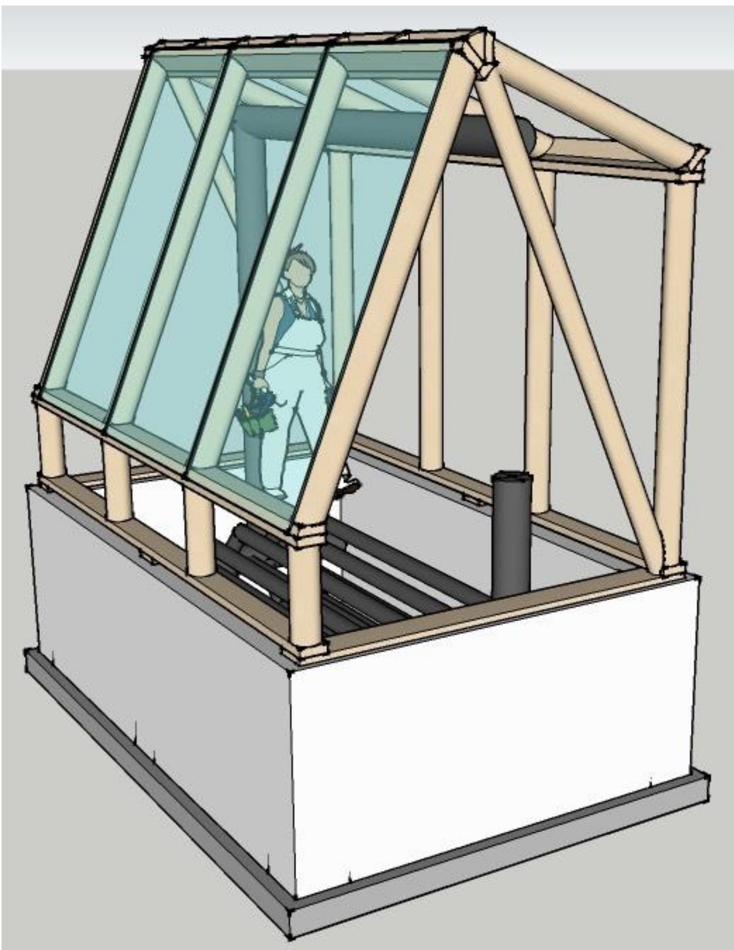


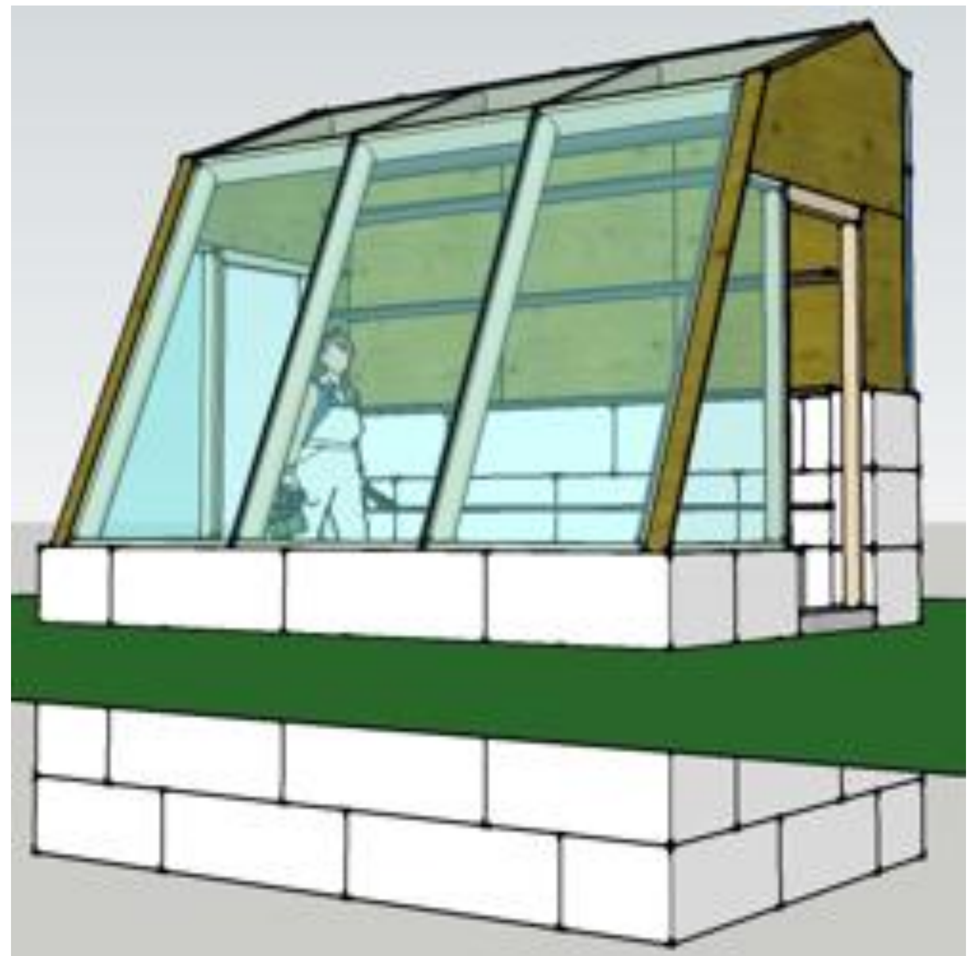
But what about summer?



- Only 50% of floor area is lit at summer solstice
- 44° incidence reduces light transmission further

Winter Optimized vs More Year Round

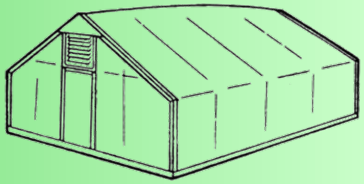




Micro - Lessons Learned

- For the scale of it, it is unrealistic (too expensive) to do completely off-grid - connect it to the grid.
- Primary function is starting seeds in the late winter/early spring. Little plants don’t need much space.
- Optimize glazing angle for March - May
- A few too many trade-offs to squeeze it all in under 100 sq/ft

Insulation (R-Value)



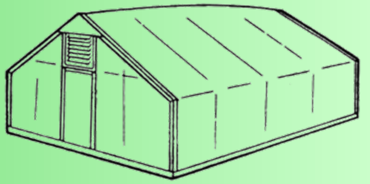
$$R = \Delta T/Q_A$$

R-value is a measure of thermal resistance. It is the ratio of temperature difference to heat flux across an insulator.

Higher R-value materials are better insulators.

R-values are often given in "per inch" and scale linearly with thickness – that is, doubling the thickness of a material doubles its R-value.

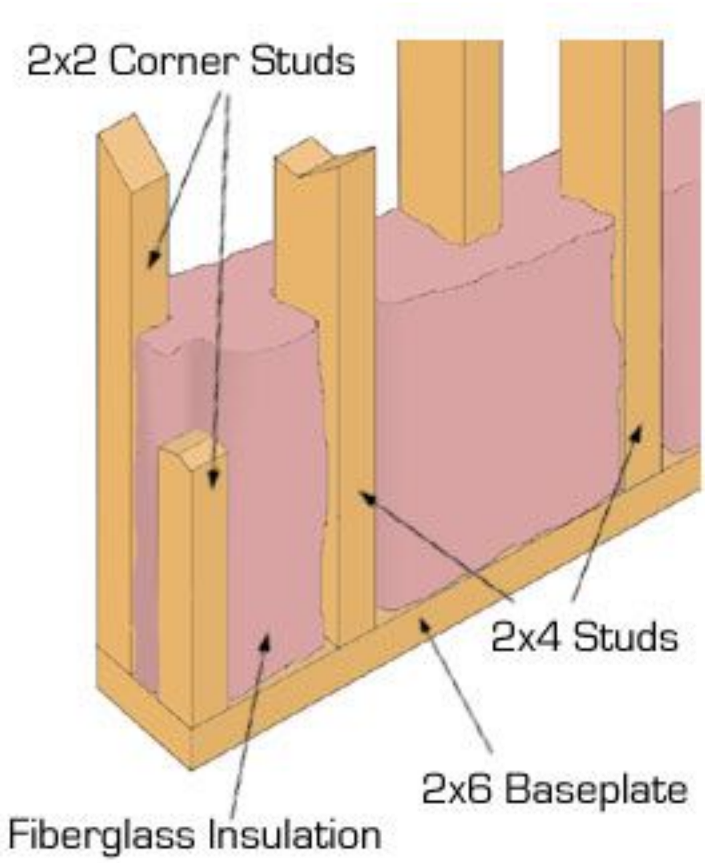
Glazing Light Transmission

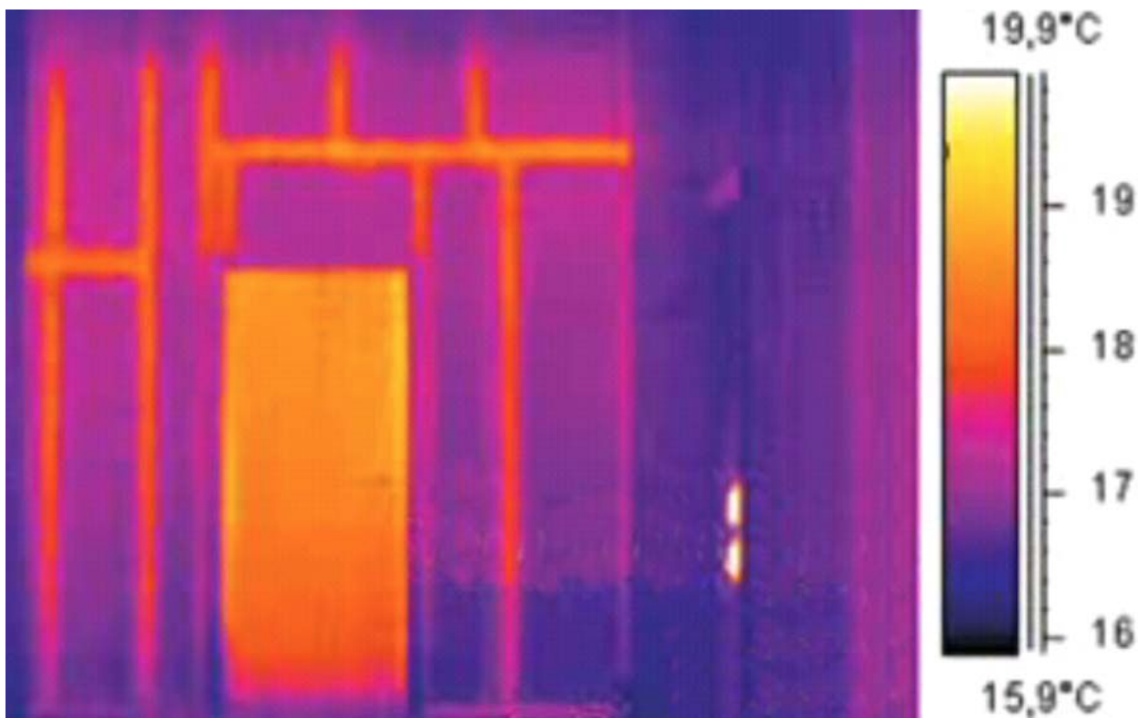


Material	R-value	% Transmission
Single wall glass	0.9	98%
Double wall glass	2	97%
Polycarbonate (2-wall 8mm)	1.6	85%
Polycarbonate (3-wall 16mm)	3	75-79%
Polystyrene insulation (per inch)	4	0%

- Light transmission below 70% will significantly reduce growth and health of most plants.
- Glass has high transmission but poor R-value, is expensive itself and requires a significantly more rigid and expensive structure, can be broken by hail.
- Multi-wall polycarbonate transmits sufficient light, is lower cost than glass, however it will gradually yellow over time (useful lifetime of ~15 years).

Insulation (Thermal Bridges)

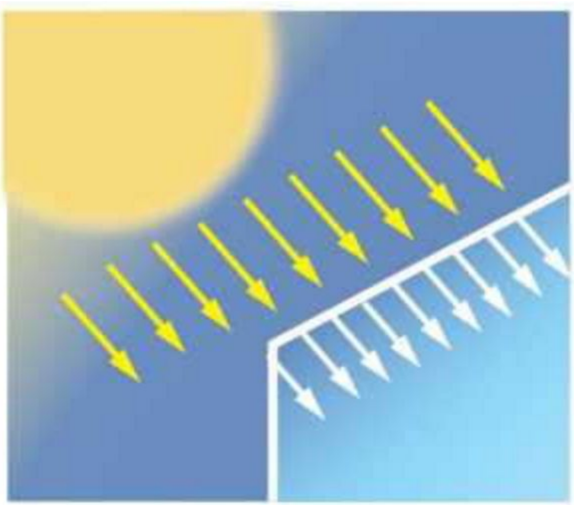




Your design is only as good as its weakest point

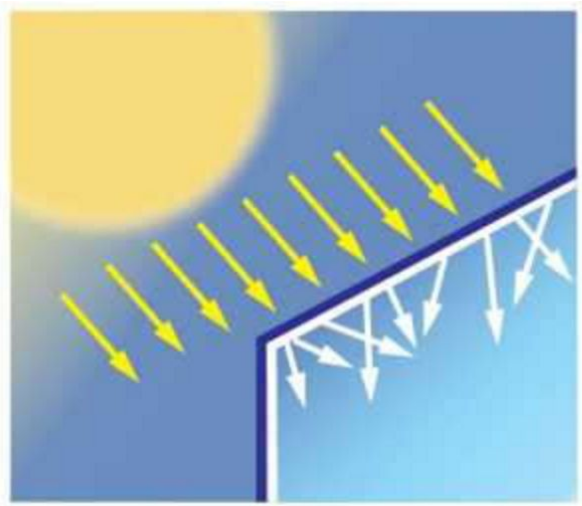
Diffuse vs Direct light

Glass

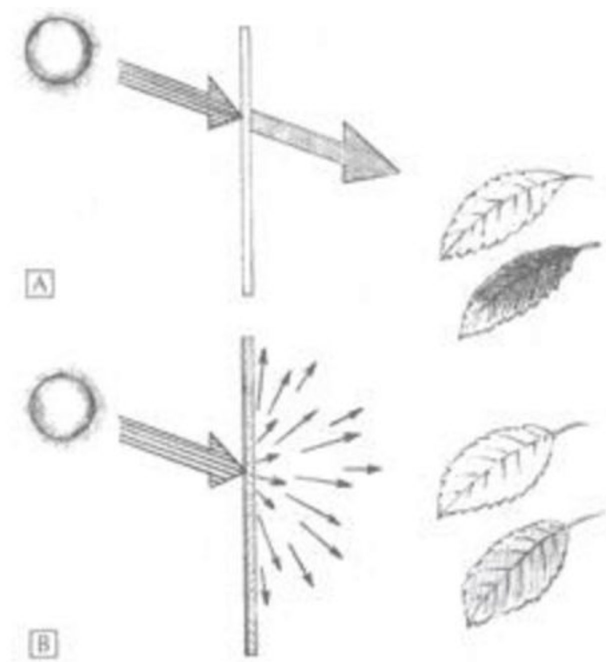


a) Direct light: no scattering takes place

Plastic

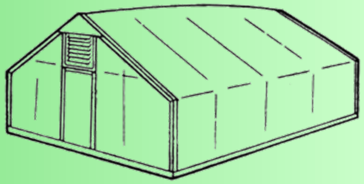


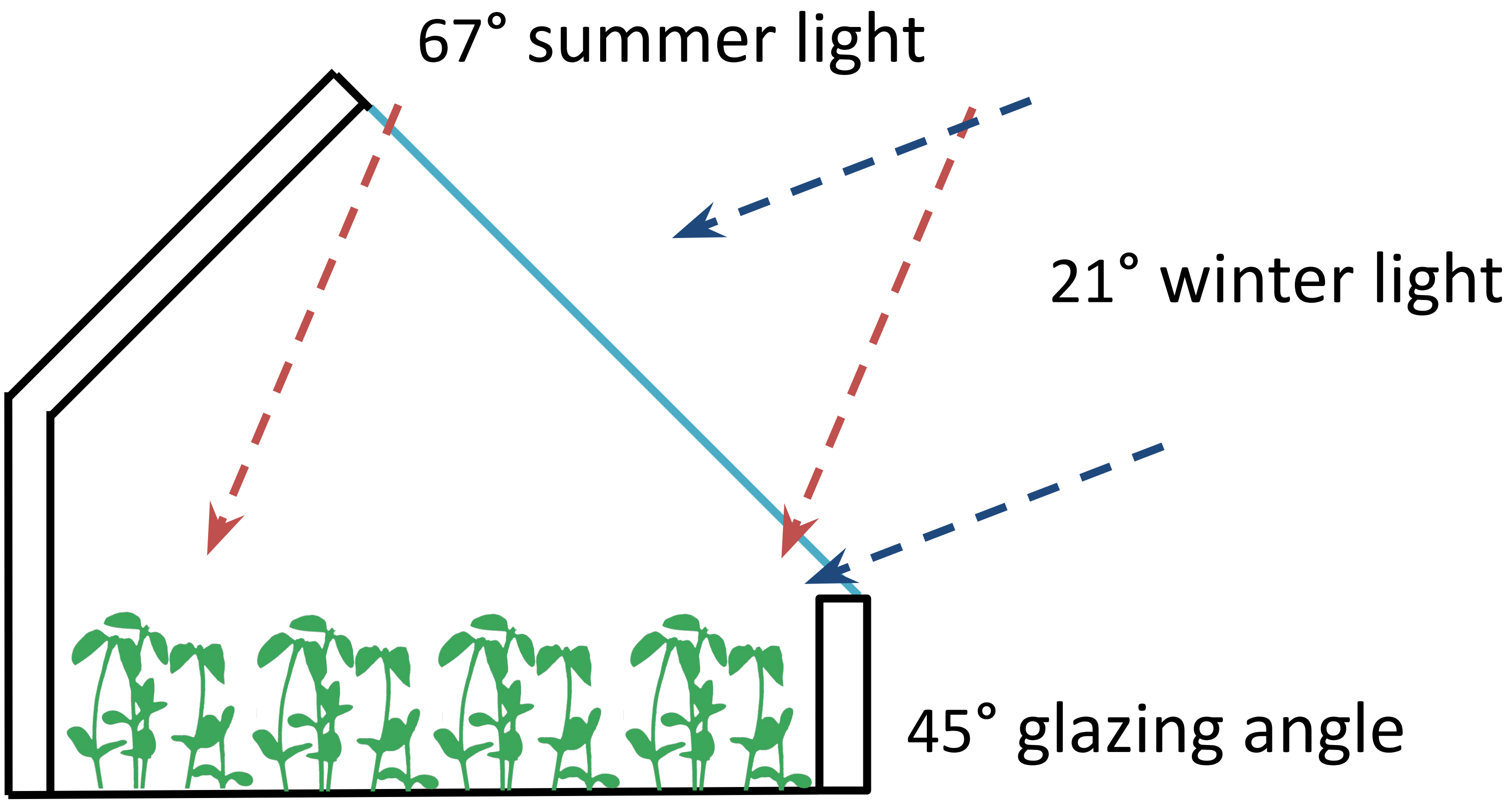
(b) Diffuse light: scattered by greenhouse roof materials



70% diffuse light is better than 100% direct light for photosynthesis

Glazing Angle

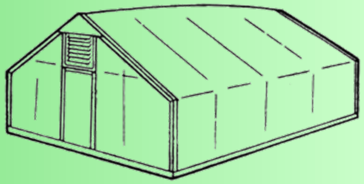


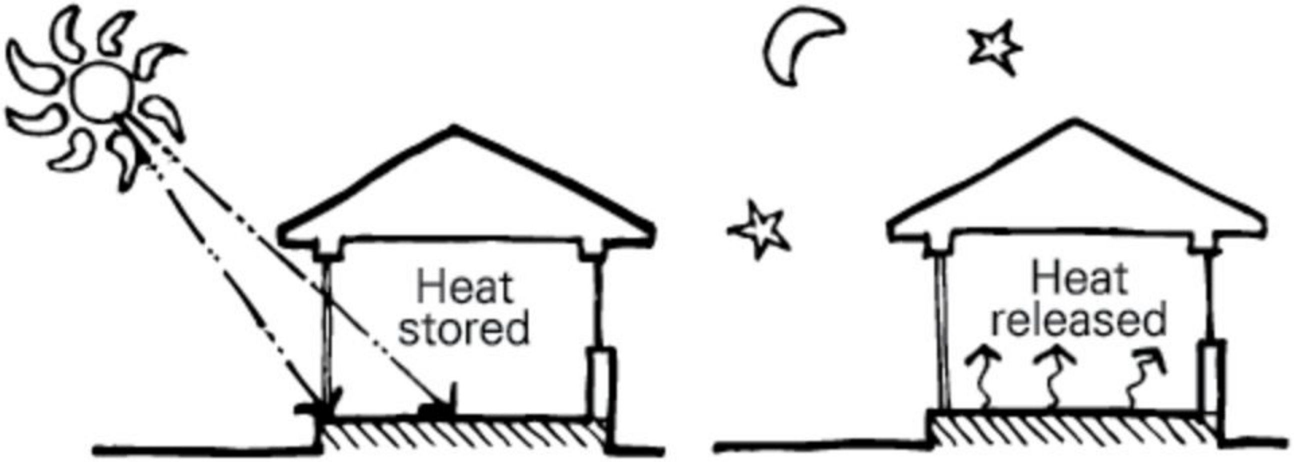


Optimized for all seasons:

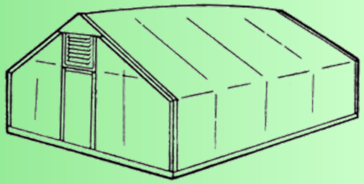
- +40% glazing area = +40% light but +30% heat loss rate

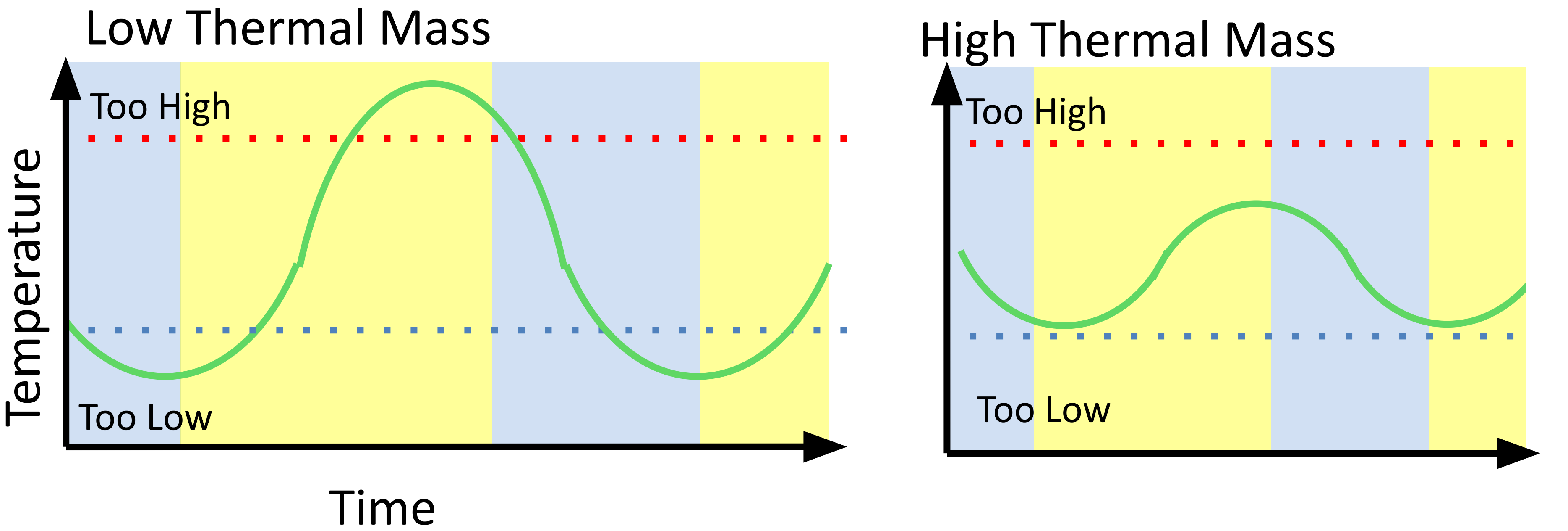
Thermal Mass / Temperature Control





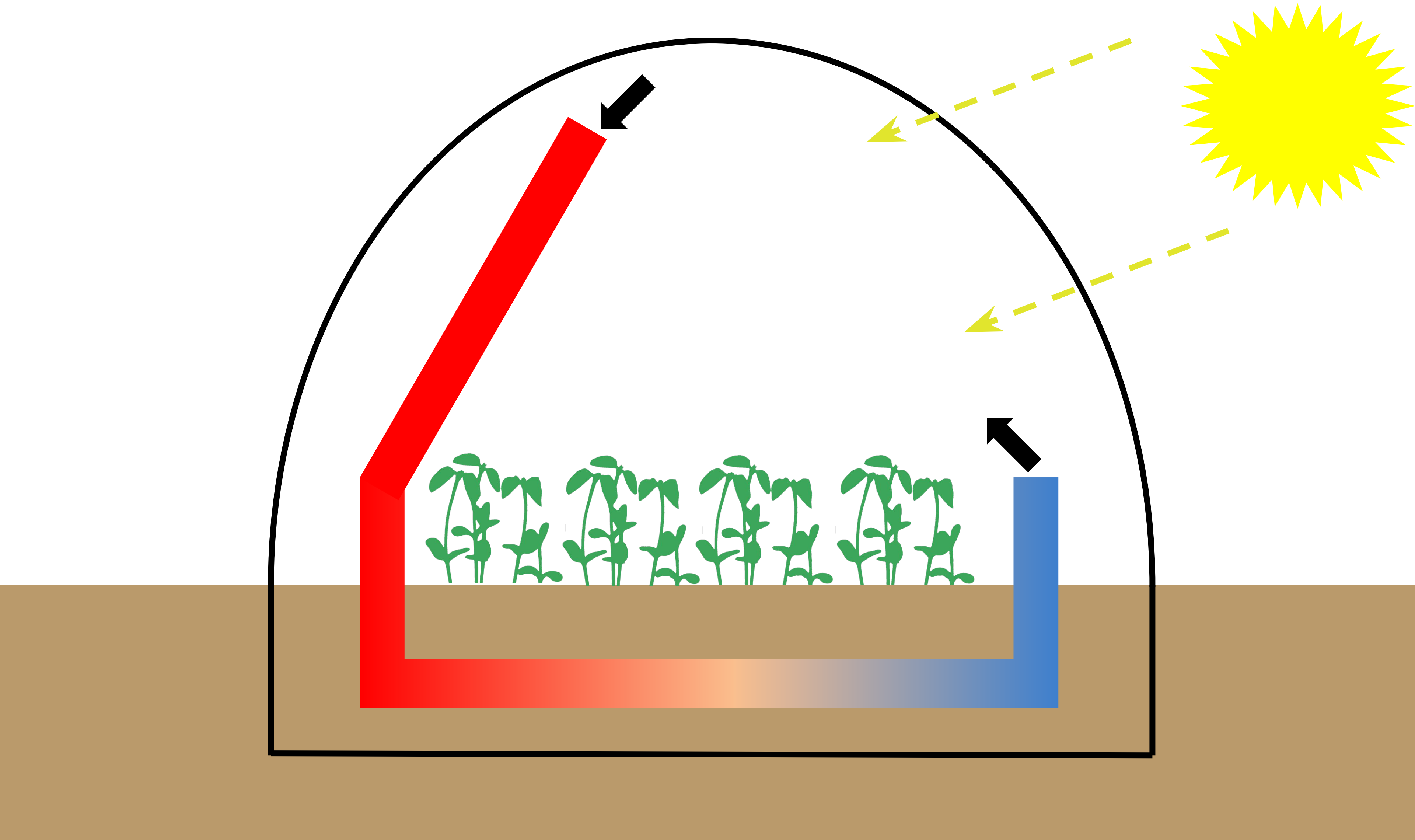
Thermal Mass / Temperature Control



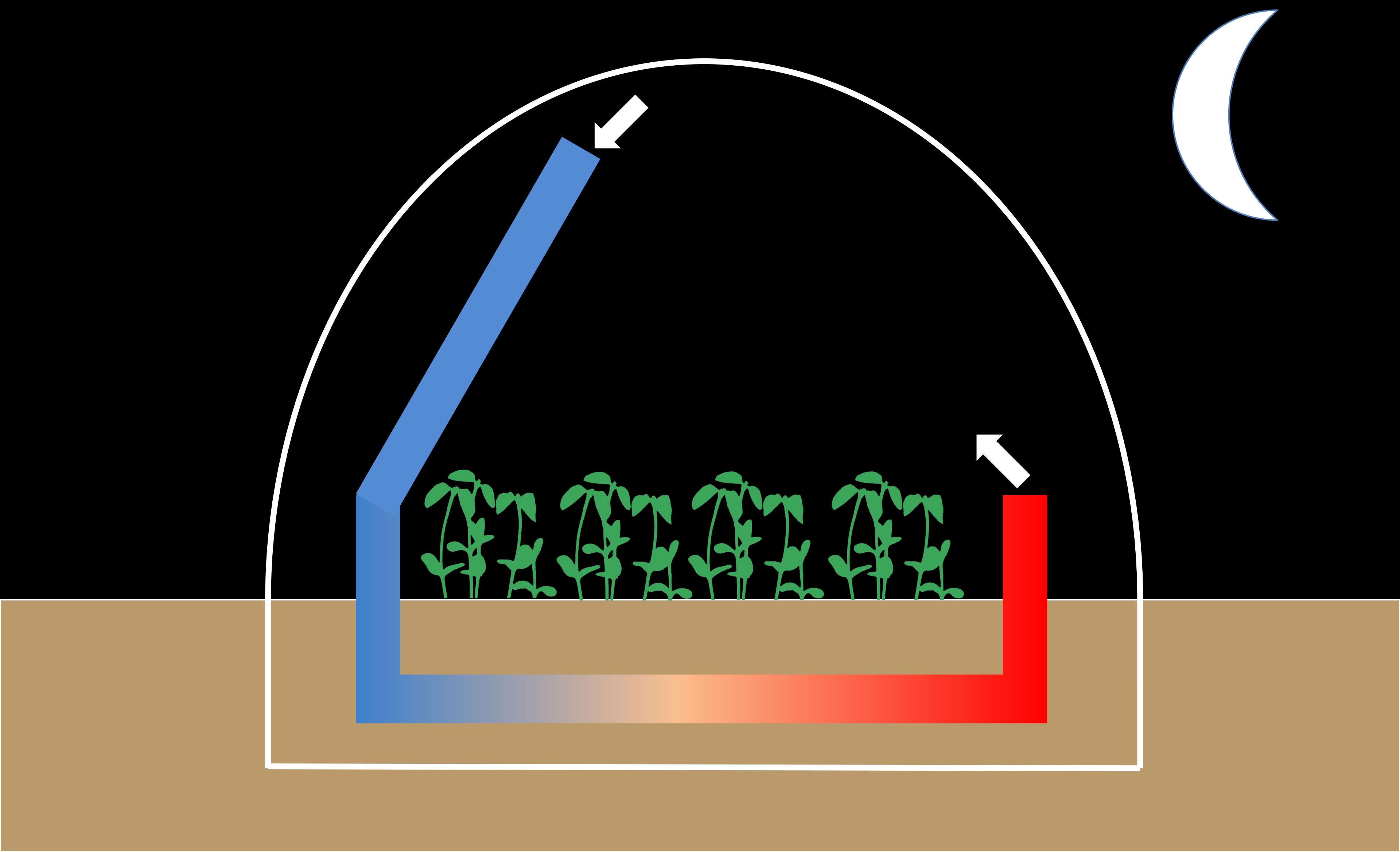


Thermal Mass / Climate Battery

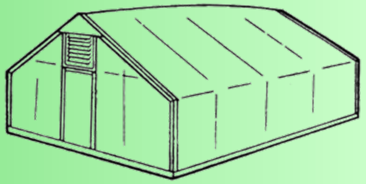
Climate Battery During the Day



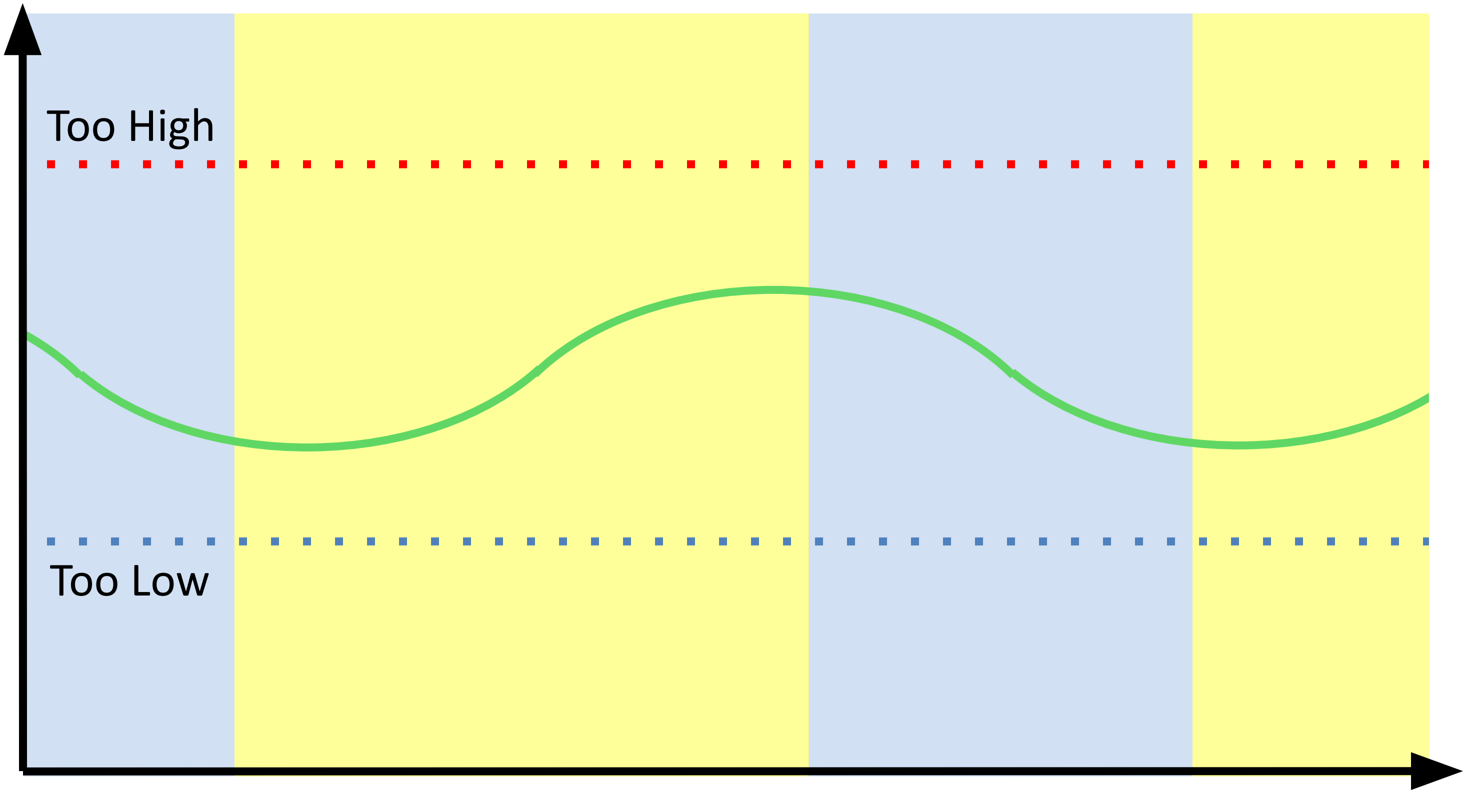
Climate Battery During the Night



Thermal Mass / Temperature Control



High Thermal Mass + climate battery



Current Generation




Current Generation

Current Generation
"Styrocrete"

Current Generation

Lessons Learned

- Crazy expensive ~ $100K (with lots of volunteer help)
- Vastly underestimated the complexity to build it - 5 years
- Trying to develop a novel building material at the same time slowed the process down considerably
- Triple wall polycarbonate can't flex - have to work in flat planes. You can curve double wall with only a minor decrease in R-Value
- Use off-the-shelf trusses that intersect perpendicular to the ground to simplify foundation requirements
- Get clear on what your goals and budget are up front.

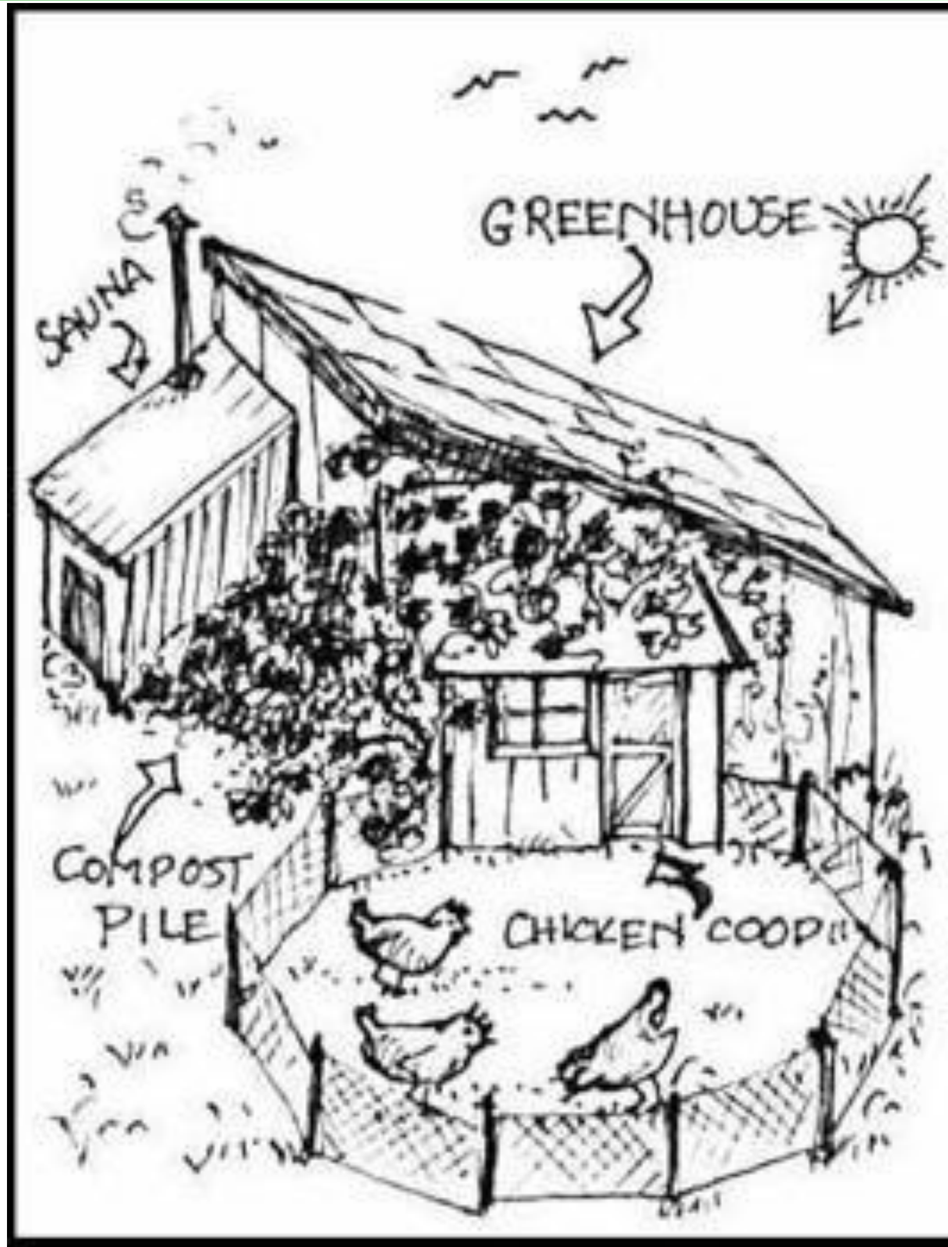
Supplemental heat

Anything you might use to heat a house/business:

- Natural Gas
- Wood
- Oil
- Geothermal

Stacking Functions

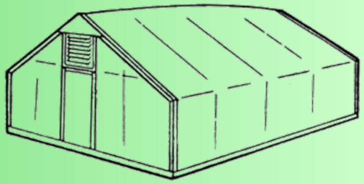
- Sauna
- Attached to a heated building
- Composting
- Animals (beware of ammonia)



Other Greenhouses


TYPAR

Greenhouse Resources



- http://CRMPI.org
- http://www.ecosystems-design.com/
- http://www.ceresgs.com/
- http://www.extension.umn.edu/rsdp/statewide/deep-winter-greenhouse/
- "Forest Garden Greenhouse" book
- http://www.suncalc.org/#/45.9805,-81.9278,13/2015.12.21/09:41/1

Are winter greenhouses economically feasible?

Can I make a living at it?

Maybe… some thoughts:

In Favor

reduced transportation cost

higher value (fresher) product

abundant government funding

community & education tie-ins

sell to restaurants

Against

high up front investment

more manual labor in harvesting

experimental