Site Planning and Building Considerations

COLORADO AQUAPONICS

THE Aquaponic SOURCE™
Growing Fish and Plants Together

Presentation Topics

- Site Selection
- Greenhouse structures
  - Traditional greenhouses
  - Covering materials, orientation and loading
  - Passive solar, energy efficient designs
- Space planning and location
  - Interior, exterior
  - Aquaponics considerations

Area and Location Considerations

- Regulations, zoning, land use, business development
- Transportation and accessibility
- Security and safety
- Market visibility, proximity to customers, retail presence
- Relative cost of land and building
- Personal residence or business location
- Temperature and seasonal factors impacting structure

Does the location fulfill the business mission?

Site Selection Criteria

- Zoning – Is commercial greenhouse allowed?
- City or county entitlement process
- Utility availability, water quality
- Distance to customer base, distribution methods
- Size, setbacks, right of ways, sight lines
- Space designated for greenhouse or building
- Orientation, solar access, slope, drainage, soil quality
- Roads and physical access for trucks and equipment
- Security of site, surrounding areas

Outdoor Growing

- Works best in tropical climates or long-seasonal growing
- Cover structures used to block rain and as sun shade
- Fish need to be protected from sun, predators
- Controls similar to field crop production
- Challenges with reptiles, birds and animals which can result in pathogen issues

Green Acre Aquaponics, FL

University of the Virgin Islands

What is Controlled Environment Agriculture?

- CEA is defined as an integrated science and engineering based approach to establish the most favorable environmental conditions for plant productivity while optimizing resources including water, energy, space, capital and labor, and thereby to provide the desired plant product or biological processes under controlled conditions

**University of Arizona, Controlled Environment Agriculture Center*

Indoor Growing

Greenhouse structures or Hard lid buildings

- Bio-security controls
- Extended growing seasons, year round
- Protection from elements and outside climate
- Controlled resources usage; water, energy
- Ability to heat or cool
- Pest control and management
- Uses on unproductive land, rooftops or buildings

Choosing a Greenhouse

- Production goals, market size
- Climate and environmental conditions
- Plant requirements
- Capital investment
- Cost of operations and resources
- Expected lifetime, depreciation, durability
- Technology, automation, labor requirements
- Supplier confidence, availability and support

High Tunnel/Hoop House

- Plastic-covered structures that provide some environmental protection
- May have rollup sides and ends for venting
- Extend season or grow year round if temp controlled
- May or may not require building permit if considered temporary structure
- Works best in temperate climates
- $2-3/sq ft
- Don’t Use PVC for Support pipe!

Greenhouse Styles

Quonset greenhouse

Arch greenhouse

"A" frame greenhouse

Retractable roof greenhouse

Styles cont…

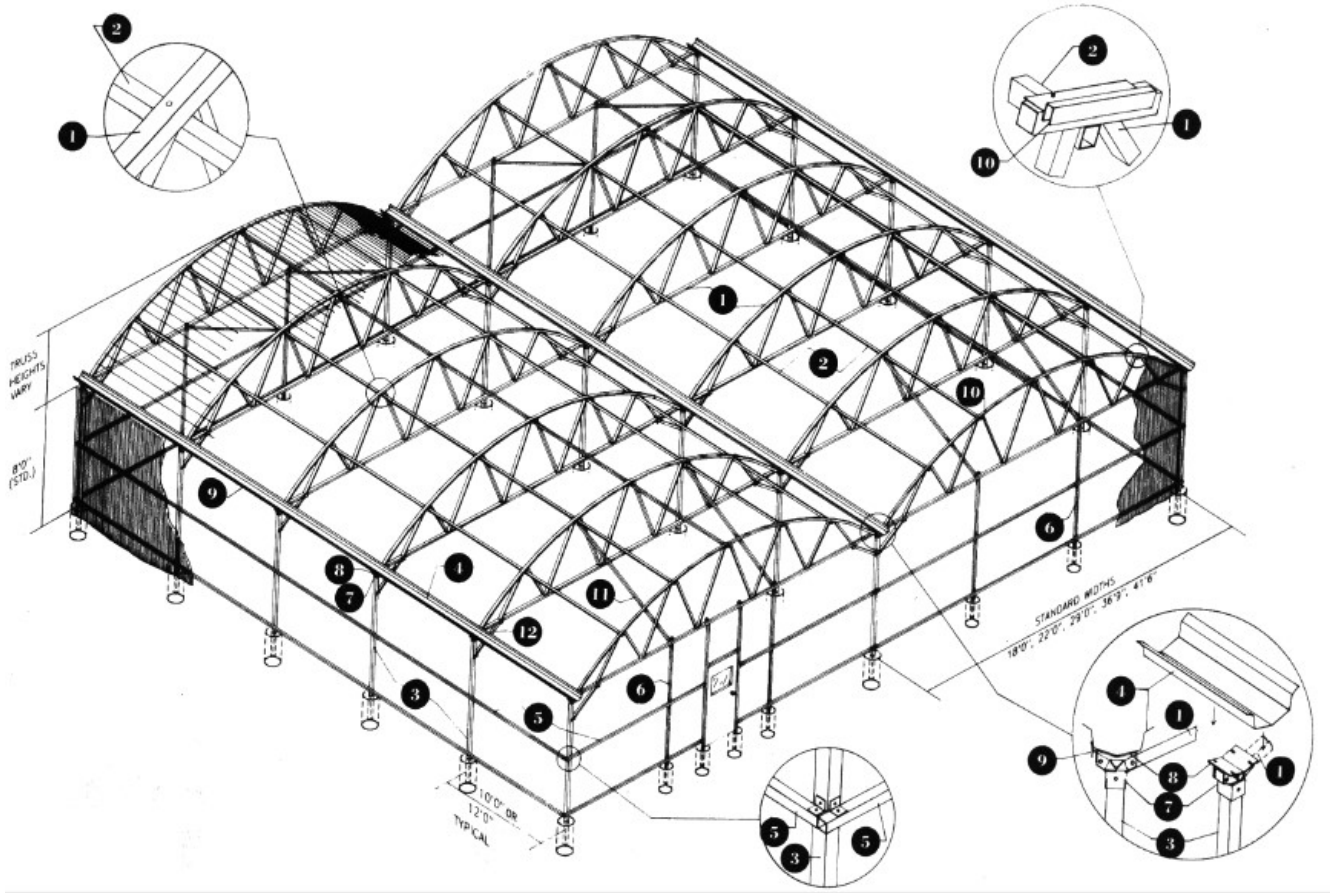
Wide single span greenhouse

Venlo (Dutch) greenhouse

Open roof (Cabrio) greenhouse

Multi bay (span) greenhouse

Gutter Connect Greenhouse



Nexus Teton Quonset Style

Traditional Greenhouses

Combined use of High and Low Technology

- Active and/passive cooling systems
- With/without heaters
- Simple environmental monitors and controls
- Substrate (soil/soilless)
- Aluminum Frame, concrete footings, rigid plastic
- Cost ($20.00-$30.00 per sq ft)

Pardossi et al. 2004

High Tech Greenhouses

- Plant-response-based environmental control to optimize plant growth, maximize productivity and fruit quality.
- Computerized climate control of greenhouse (temperature, irrigation, shading based on integrated light, CO 2 enrichment.)
- Aluminum Frame, concrete footings, double layered poly panels
- Engineered to meet local wind, snow loads
- Cost ($40.00-$50.00 per sq ft)

Energy Efficient Greenhouses

- Uses the most current standards in energy efficiency
- Thermal mass, phase change materials, ground to air heat transfer, building orientation, roof angle, venting systems and much more to reduce the demand for heating and cooling
- Higher initial building costs offset by lower energy consumption
- Cost $35+ per sq ft

Estimated Greenhouse Costs

$3 – $4 Metal Pipe Frame includes steel pipe, wooden-framed end walls, with plastic film cover

$4 - $5 Wooden Frame of construction-grade lumber, and plastic film cover

$6 - $7 Wooden Frame of construction-grade lumber, and single-layer, rigid plastic cover

$9 - $10 Wooden Frame of construction-grade lumber, and structured sheet rigid plastic cover

$25 - $30 Aluminum frame, concrete footings, structured sheet rigid plastic or single-layer glass cover from a kit.

$40 - $50 Aluminum frame, concrete footings, double-layer tempered glass cover from a kit.

Covering Materials & Considerations

- Light transmission, diffusion, quality
- Heat loss and thermal resistance
- Condensation
- Durability, lifespan, replacements
- Size
- Availability
- Cost

Polyethylene Plastic Film

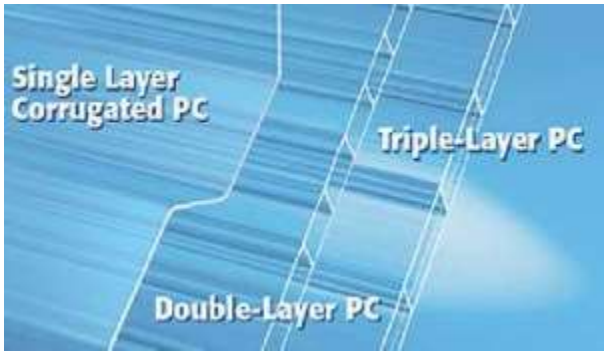
- Short life span, 3-4 years
- Covering materials are 4 to 6 mil thick
- Infrared (IR) blockers = less heat loss
- Anti-condensate AC materials
- Cost around $0.16/sq ft
- Double poly layers with air pocket in between to increase r-value and reduce light transmission
- Use outside air to inflate

Solexx Greenhouse Wraps

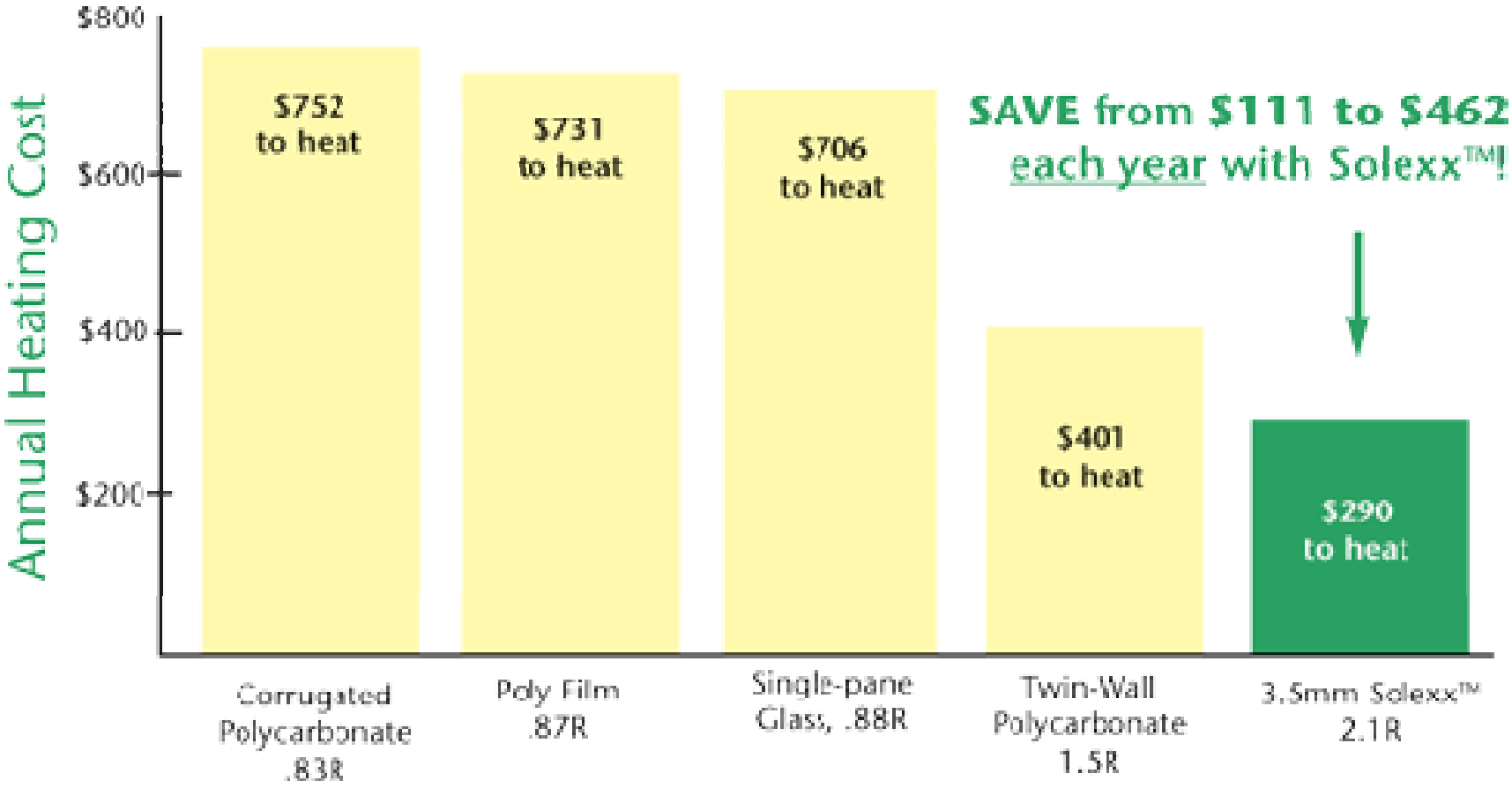
- Light weight
- Structured air pocket
- Good defused light
- Easy to install
- 10 year warranty
- 2.1 R value
- Comes in rolls or panels

Polycarbonate

- Easy to install
- Longer life span 10+ years
- Stronger and lighter than glass
- Flame retardant
- Widely used and readily available
- Double and triple walls provide better r-value
- Used on end walls and roof
- Cost $1.5/sq ft



Glazing Comparison



Comparison of annual heating costs with various Greenhouse Coverings using Denver, Colorado as the greenhouse location. The 8' x 12' greenhouse is kept at a minimum temperature of 45 degrees all year using natural gas at $2 per therm as the heat source. Data was compiled from the USDA Virtual Grower software.

Greenhouse Loads

- Work with your local greenhouse company, extension agents or look at NGMA standards for greenhouse loads
- Dead loads – The weight of all permanent construction and building materials, rooftop, equipment
- Live loads – Temporary loading such as snow, debris, equipment – max 15lb ft2
- Wind – 70-80mph common design

Greenhouse Orientation

Below 40° latitude:

- Ridges running North-South direction
- Provides better light distribution (moving shadows), more important than light transmission optimization

Above 40° latitude:

- Ridges of single-span houses running East-West to maximize light intensity in the greenhouse
- Run ridges of multi-span houses North-South for light distribution

**Kacira, 2012 UA CEAC*

Sun Exposure

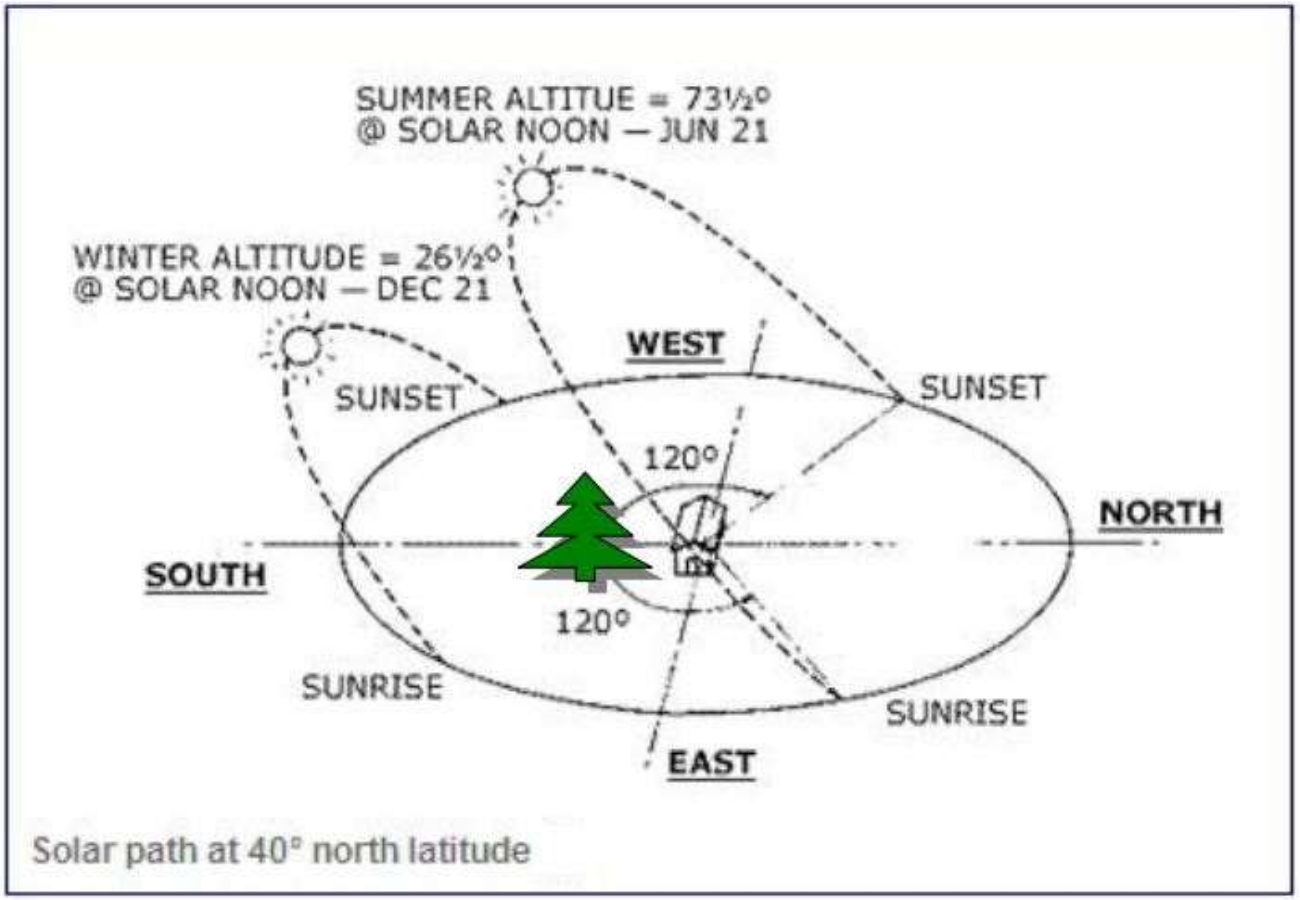


Figure: Alward, Ron, and Andy Shapiro. 1981. Low-Cost Passive Solar Greenhouses. National Center for Appropriate Technology, Butte, MT. 173 p.

Passive Solar Greenhouses

- Roof angle and building oriented to seasonal sun
- Reflect/deflect sun in summer, draw in sun during low angle winter months
- Solid north wall and roof
- Reduced heating/cooling
- Thermal mass – water, rock, concrete
- Geothermal elements
- Built like a house, requires permit

Insulation below ground

- Installing insulation around the perimeter of a building between wall insulation and four feet below grade effectively ***couples the structure to deep earth beneath the footprint of the*** structure.
- Equally important, it ***decouples the structure from the surface of the earth immediately*** surrounding the structure, thereby isolating the building from soil whose temperatures vary substantially from season to season.
- In the winter and spring, the temperature at 4 feet under the soil of the research greenhouse averaged 60° F, by August it was over 65° F. The soil outside of the greenhouse at a depth of 4 feet averages 51° F.

Key Elements

1) Faces South
Windows mostly on South, but also East and West. Roof can be polycarbonate plastic or partially or fully insulated.

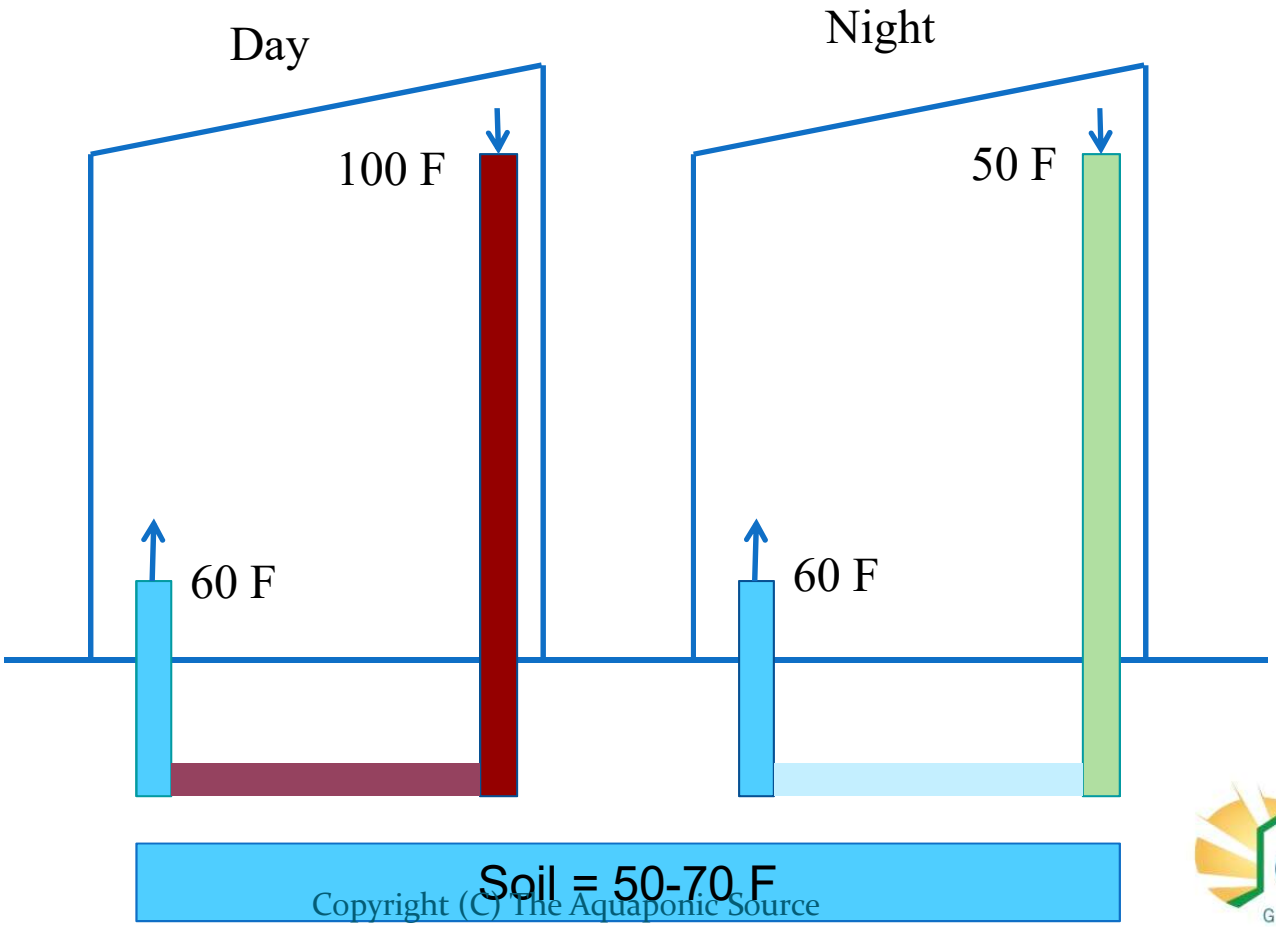
2) Super Insulated
Highly, highly insulated walls (made out of Structurally Insulated Panels) prevent too much heat loss / heat gain

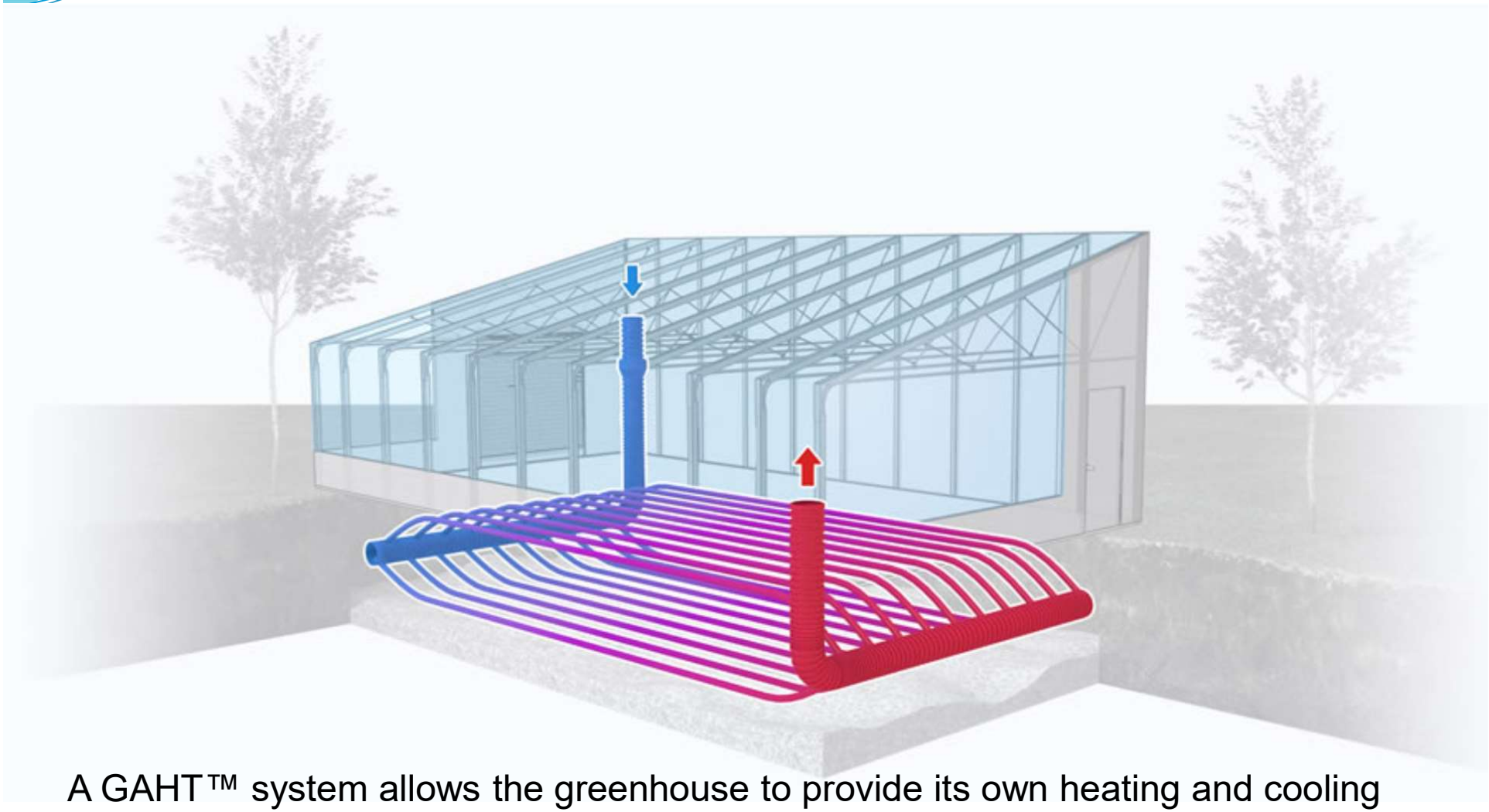
3) Lots of Thermal Mass
The soil underneath the greenhouse is used as thermal mass, evening out temperature

4) Self-Heating
Ground to Air Heat exchanger (aka climate battery) makes the greenhouse self-heating and cooling

Ground to Air Heat Exchanger

Aka….Earth Tubes; Climate Battery; Ground to Air Heat Transfer (GAHT) System





A GAHT™ system allows the greenhouse to provide its own heating and cooling using the energy of the sun, and the soil underground. The result is a renewable climate control system that both heats and cools the greenhouse at a fraction of the cost of traditional HVAC.

The problem with conventional greenhouses…

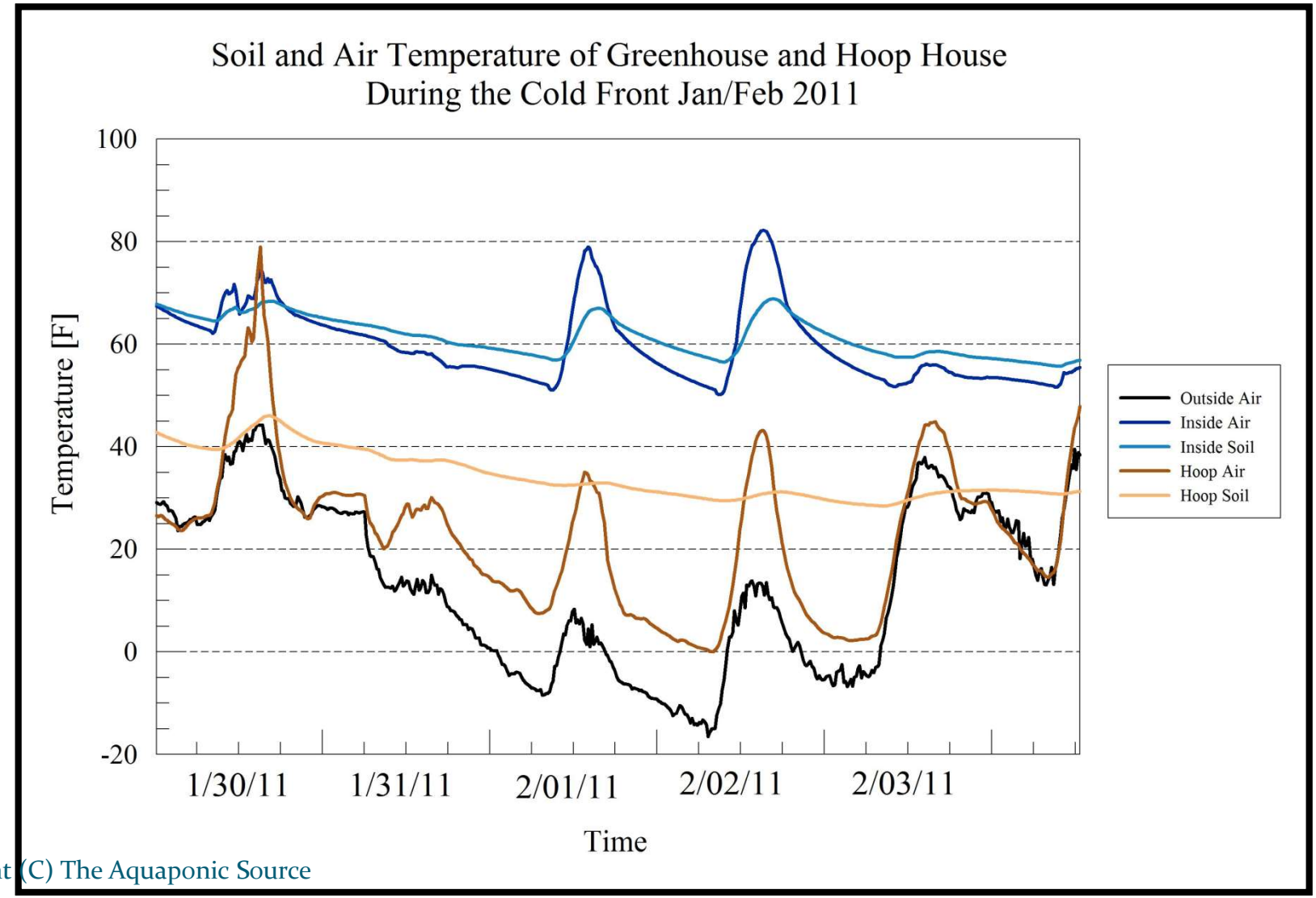
Heat Loss

Energy cost ball park: $3-4/SF/ year for heating, cooling and ventilation in typical greenhouse in Colorado.

CERES GREENHOUSE SOLUTIONS

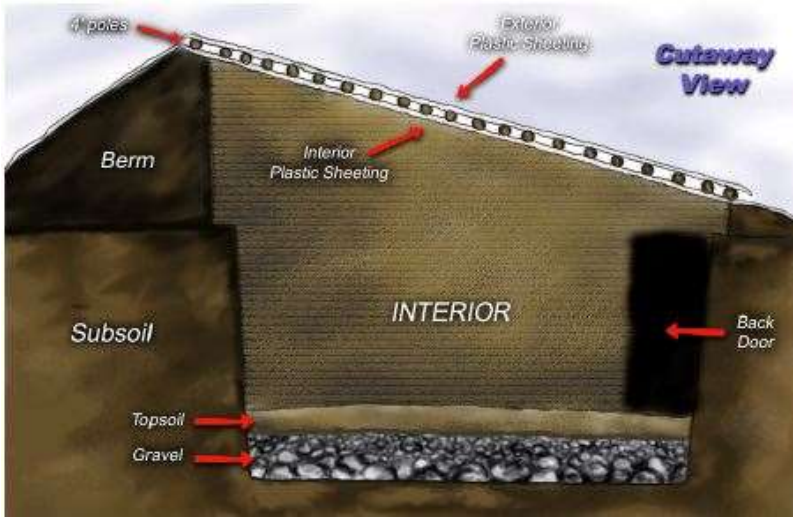
The difference…

Super-insulated, passive solar greenhouse compared to a hoop house
(Neither are conventionally heated. Greenhouse has a GAHT system)



Walipini (the underground greenhouse)

- "Walipini" comes from the Aymara Indian language and means "place of warmth"
- Locating the growing area 6'- 8' underground and capturing and storing daytime solar radiation are the most important principles in building a successful Walipini



Photos: Benson Agriculture and Food Institute
Brigham Young University, 2002

Walipini cont…

- When the temperature above ground is cold, say 10º F with a cold wind, the soil temperature at 4’ deep in the earth will be at least fifty degrees in most places.
- Example: An underground temperature of 50º requires heating the Walipini’s interior only 30º to reach an ambient temperature of 80º.
- An above ground temperature of 10º requires heating a greenhouse 70º for an ambient temperature of 80º

Insulation Considerations

- Insulate the north wall and roof if possible
- Seal up around vents, holes, cracks, doors, etc
- Add another layer of clear poly with air pocket
- Avoid heat loss in tanks, rafts, sump, etc.
- Insulate system components to maintain temp
- Retractable insulation blankets, night curtain
- Thermal mass/geothermal inside and out
- Insulate the foundation (if there is one)

Floor Considerations

- Dirt, rock, sand – not ideal, can't be sanitized
  - Mud, pathogens, weeds, debris, plant matter
  - Concerns for stability for system weight
- Landscape fabric – better, can be swept, hard to sanitize
- Hardscape – concrete, brick, slate
  - Can be swept and sanitized
  - Harder to do below grade plumbing or sumps

Interior Space Planning

- Circulation space
- Physical and bio-secure entrance
- Customer front end – market, meeting space
- Loading/unloading area
- Seed starting, germination, nursery space
- Cutting, transplanting and harvesting space
- Storage, refrigeration, food prep, etc
- Rest room, hand washing facility
- Water access, electrical outlets
- Lab area for testing, recording data, laptop

Exterior space planning

- Street access, gates, security
- Parking and loading dock areas, fish delivery
- Weed control outside of greenhouse
- Site slope, soils, sun and trees
- Pest, predator and other contaminant prevention
- Physical barriers and proximity to others
- Backup generator
- Site drainage from greenhouse
- Composting site, outdoor garden

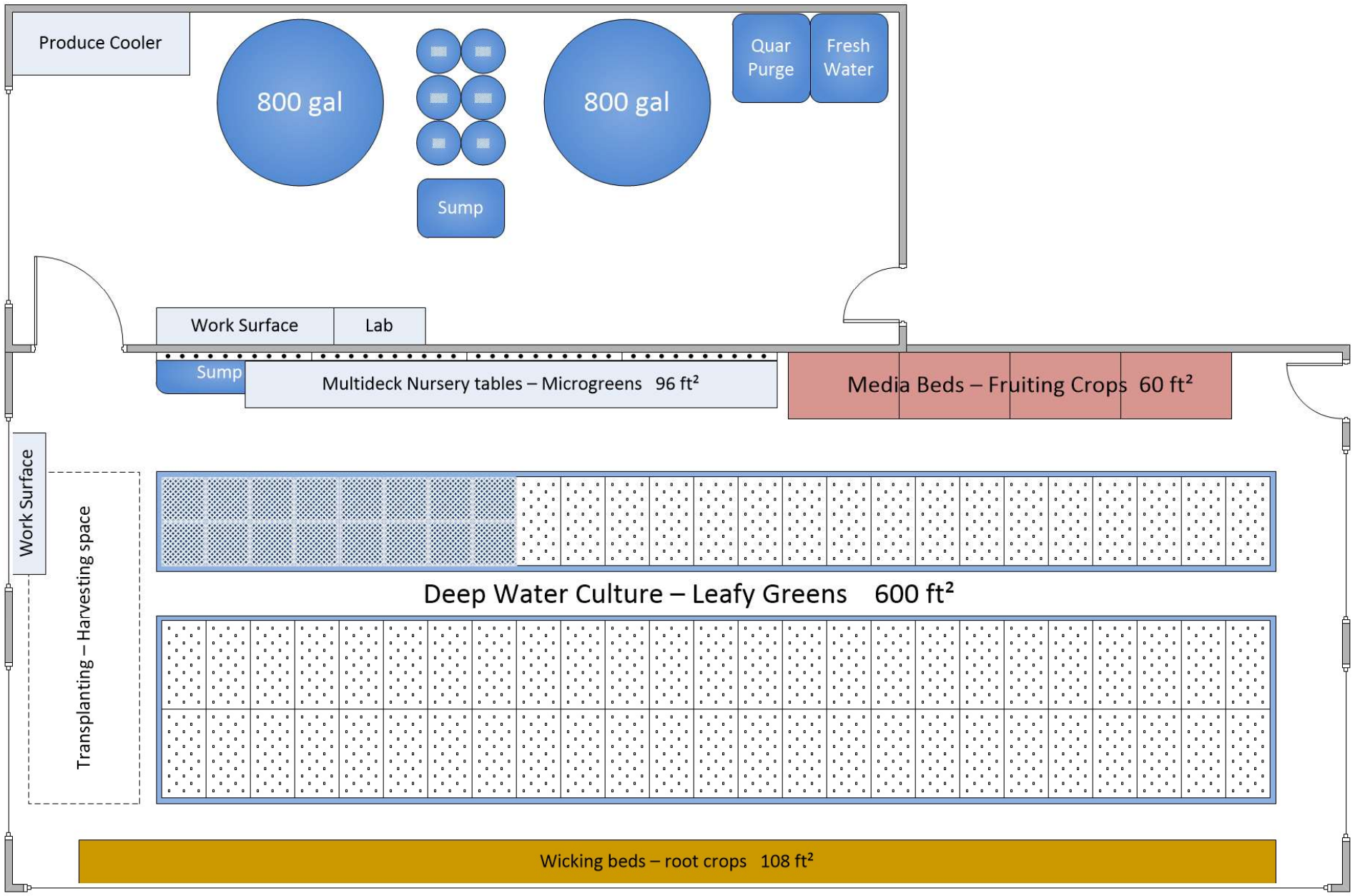
Water pooling outside greenhouse can seep in and also be a vector for pests

Aquaponics Considerations

- Understand your tank footprints, circulation and plumbing requirements
- Keep fish tanks in the warmest part of the greenhouse, insulate in winter
- Don’t place tanks where they will restrict airflow or cooling walls
- Filtration tanks, pump(s) and aeration
- Nursery and purge tanks
- Water storage and filtration systems
- Water discharge, floor drains
- Ensure access for fish deliveries
- Tanks and deep water culture provide additional thermal mass

Head House for Fish

- Consider separating fish and plants
- Fish don't need intense greenhouse sunlight
- Maintain better temperature controls
- O2 & CO2 exchange, degas tank in greenhouse, venting system, fans
- Greenhouse space is premium for growing plants
- Lose some thermal mass
- Repurpose barn, shed, etc



On-Site Cooler

- Necessary to keep harvested plants food safe until delivery
- Sized according to the volume of harvest and storage
- Used to store fish feed and seeds outside of growing area
- Can be a tow-behind trailer unit, a refrigerator, a container cooler or walk in unit
- Plans for making a cooler unit are available on the internet using an insulated space, an air conditioner and a “coolbot” controller to maintain refrigeration temps

Indoor Building Growing

Barn, warehouse, shed, mall, office building, basement, garage

- Lighting is the biggest expense
- Heating and cooling may be reduced or increased by building
- Ventilation and air circulation critical
- Biosecurity and pest management similar to greenhouse
- Zoning and building use permits may be challenging
- Vertical growing suggested to maximize footprint
- Potentially higher rent/mortgage rate and insurance costs
- Good to repurpose unused buildings
- So far not a great track record with indoor food production

Building Security

- Way to lock the building
- Double entry vestibule ideal to help with biosecurity
  - Keep animals, birds and reptiles out
  - Double doors helps block dust and flying insects
  - Location for footbath, personal belongings storage, hand washing or sanitizing, record keeping, storage space
- Security alarm helpful to discourage intruders
- Security service can call emergency contacts for power outage, intruder detection, or other issues
- Security service can also dispatch emergency personnel