High Tunnel Heating Alternatives

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A Huge Thank You!

- Bob Schultheis, retired agricultural engineer with MU Extension

What We'll Discuss

- Site selection and energy considerations
- Structural approaches for saving energy
- **Technological approaches for saving energy**

Technological Approaches for Saving Energy

Which Fuel Source is the Best?

Fuel Type	Selling Unit	Avg. Efficiency, %
Electricity	KwH	100-280
Natural gas	CCF (therm)	65
LP (propane) gas	Gallon	65-80
Wood	Cord	15-60
Wood pellets	Ton	80
Corn (shelled)	Bushel	80
Fuel oil	Gallon	60
Kerosene	Gallon	85
Coal	Ton	60
Biomass	Ton	40

Standard Heating Unit (SHU)

- One SHU = 100,000 BTUs
- Cost per SHU

$$= \text{Fuel cost} \times \frac{100{,}000}{(\text{Heat Content} \times \text{Avg.Sys. Eff.})}$$

- LP (propane) gas = $1.56/gal x $\frac{100{,}000}{(91{,}000 \text{ BTUs} \times 0.65)}$

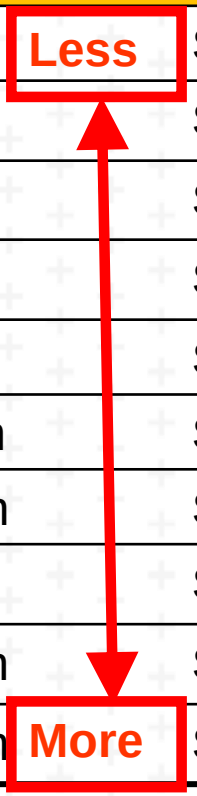
= $2.64 per SHU

- Electricity = $0.09/KwH x $\frac{100{,}000}{(3413 \text{ BTUs} \times 1.00)}$

= $2.64 per SHU

How They Rank (as of 11/2/2014)

Heating System	Fuel Cost	Cost per SHU
Air-tight stove - dry red oak	$ 140 / cord	$ 0.92
Ground-source heat pump	$ 0.09 / KwH	$ 0.94
Pellet stove - shelled corn	$ 3.74 / bu.	$ 1.19
Pellet stove - wood pellets	$ 200 / ton	$ 1.52
Air-to-air electric heat pump	$ 0.09 / KwH	$ 1.60
Natural gas forced-air furnace	$ 1.33 / therm	$ 1.66
LP gas H.E. forced-air furnace	$ 1.83 / gallon	$ 2.51
Electric resistance heat	$ 0.09 / KwH	$ 2.64
LP gas older forced-air furnace	$ 1.70 / gallon	$ 3.09
Forced-air furnace - #2 fuel oil	$ 3.33 / gallon	$ 4.01



Keeping a Good High Tunnel Environment

- Some ventilation is needed for moisture control
- Air circulation within the high tunnel is important
- Ideally, natural ventilation has openings high in the roof
- ALL combustion gases must be vented outside

Photo credit: Tim Baker

Warning on Contaminant Gasses

- Combustion gasses from burning wood, propane, heating oil, natural gas, kerosene, or coal
  - Ethylene, sulfur dioxide, nitrogen oxides, and CO are the most common problems
  - Affects tomatoes, cucumbers, lettuce, melons, peppers, tobacco, some flowers, and bedding plants
- Plant sensitivity depends on:
  - Variety, species, age of plants
  - Light intensity and time of day
  - Humidity, watering and nutrient status
    - High humidity, well-watered plants most at risk

Ethylene Problems

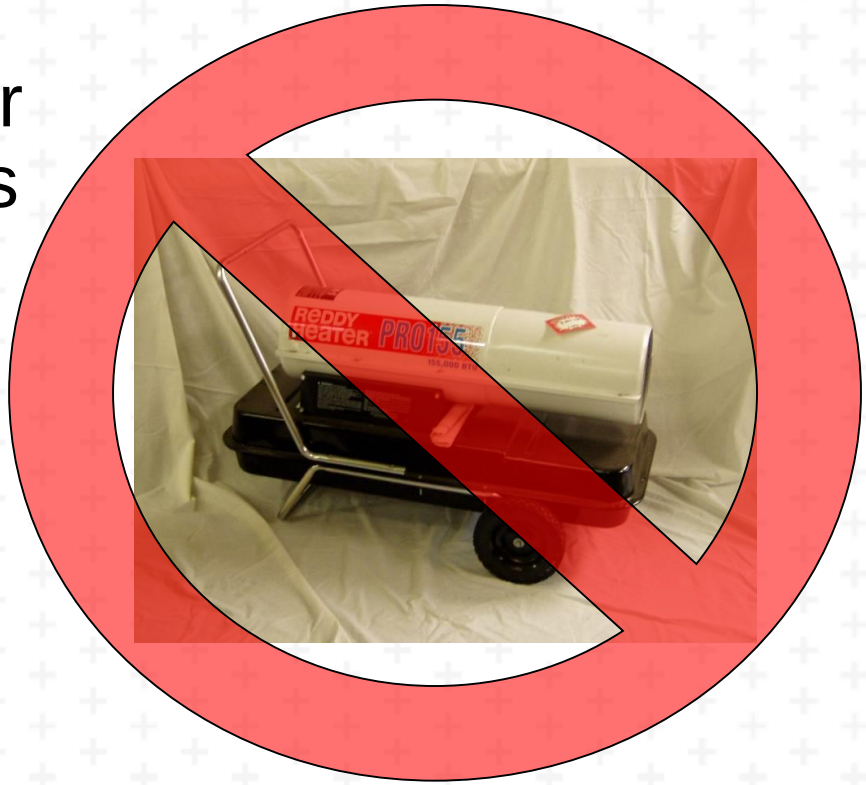
- Ethylene (C_2H_4) is produced from incomplete combustion of fuels
- Incomplete combustion occurs with low oxygen supply to fire and wet wood
- Ethylene causes “2,4-D”-like symptoms


Photo credit: Penn State University


Photo credit: Tim Baker

Warning on Contaminant Gasses

- Never use kerosene or fuel oil heaters indoors
- Venting is required!
- Keep wood boilers outdoors
- Inspect furnace and chimney for cracks, leaks & obstructions



- Use dry wood for fuel; avoid large loads of wood with low air supply (dampers closed down)

Supplemental Heating High Tunnels

- In-ground heating
  - Installed before planting, buried 2” deep
    - Electric heating cables
    - Pumped hot water through hoses or pipes
  - Heats soil to set temperature to hopefully extend season
- Above-ground heating
  - Heats air around plants
  - Typically used to protect against cold nights
  - More costly than in-ground


Photo credit: Utah State University


Photo credit: Utah State University

Hot Water Under Plants


Photo credit: James Quinn


Photo credit: James Quinn

- Plastic tents over plant beds on benches

Hot Water Under Plants

Photo credit:

Photo credit: James Quinn

- Rigid foam insulation board under pipes

Active Water Heating


Photo credit: Tim Baker

- Assure no leaks in boiler door
- Vent flue to outdoors
- Plants close to boiler may suffer


Photo credit: Tim Baker

Active Water Heating


Photo credit: Tim Baker

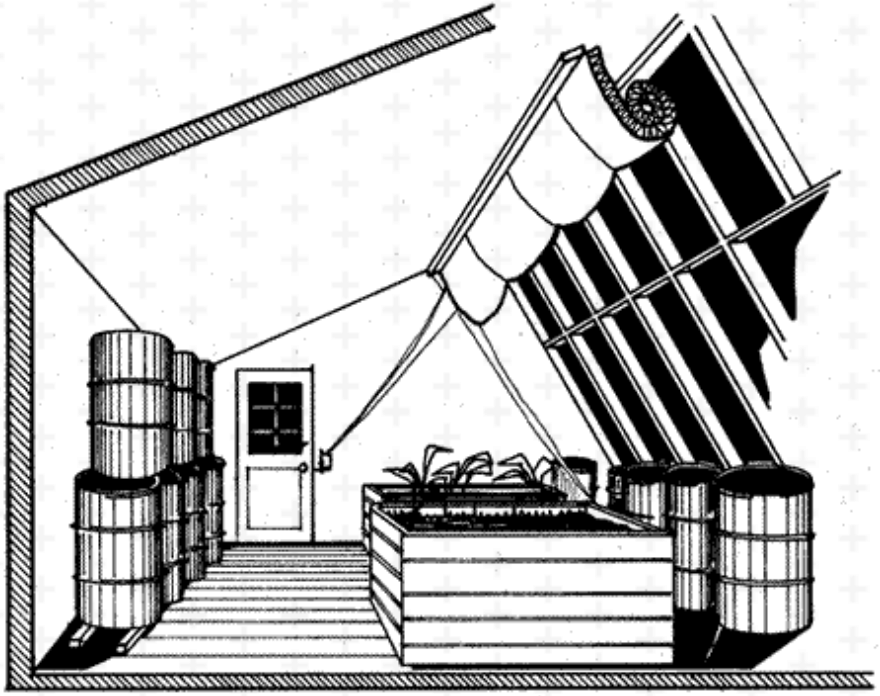

Photo credit: Tim Baker

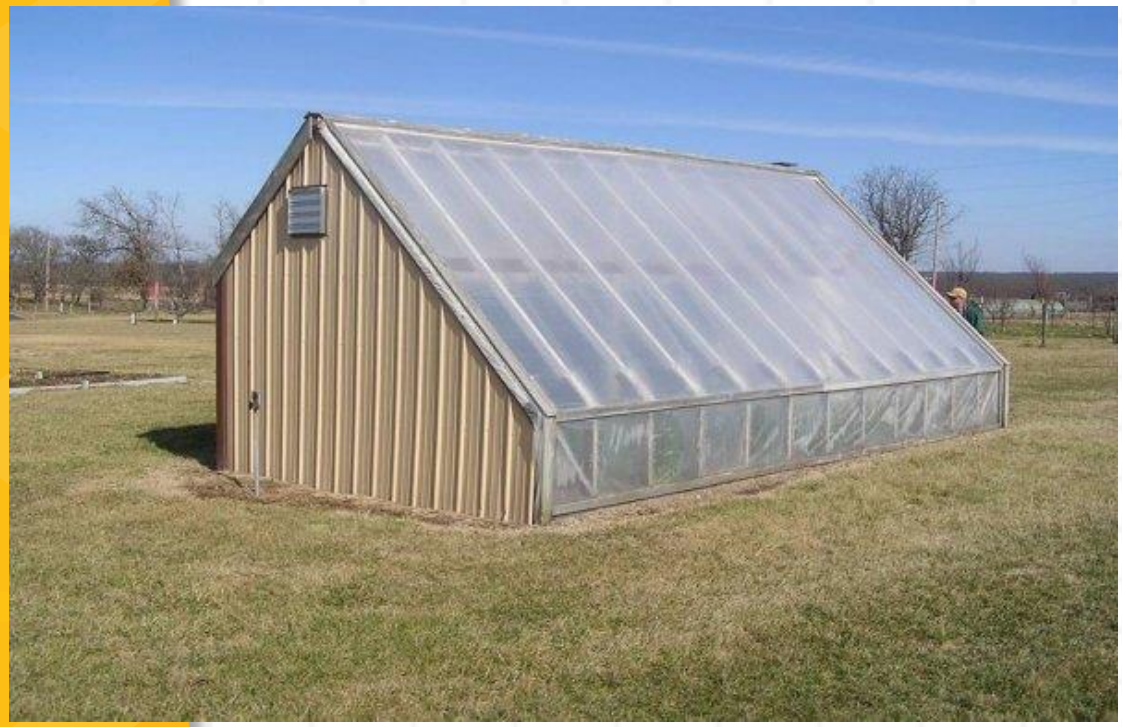

Photo credit: Tim Baker

Water for Storing Heat

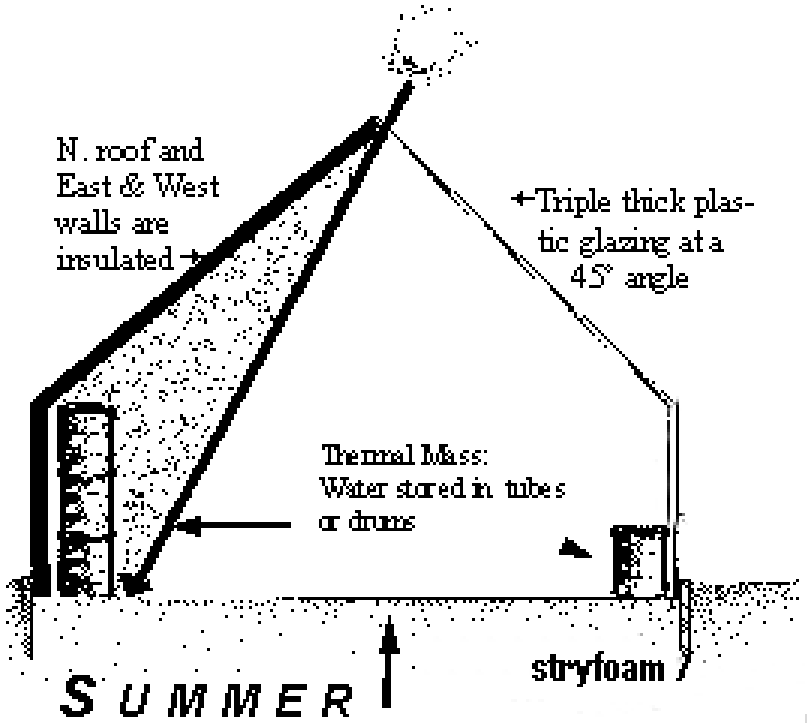
- Water is one of the best naturally-occurring materials for storing heat
- Thermal mass moderates temperature swings
- Metal or plastic barrels
  - No temperature difference
  - Metal rusts; plastic deforms
  - Plastic may hold more
- Soil will steal heat away if pad not insulated

Passive Solar Greenhouse

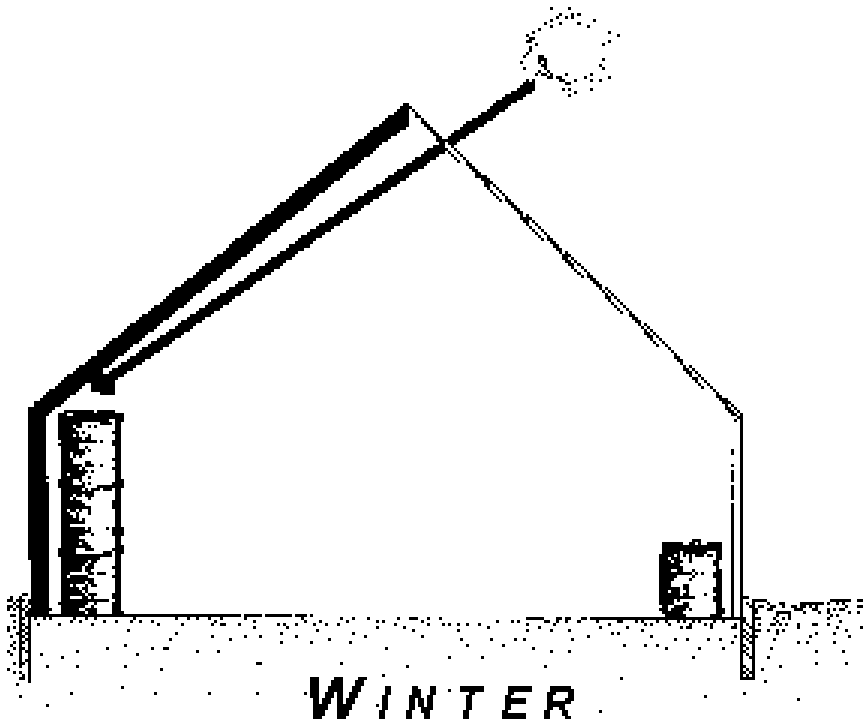




Passive Solar Greenhouse



Sun is higher in the sky and casts a shadow over the water-filled tubes and drums of the Botanic Gardens greenhouse helping to keep the green-house cool.



Sun is lower in the sky shining directly into the Botanic Gardens greenhouse directly illuminating and warming the water-filled tubes and drums. This helps keep the greenhouse warm.

Volunteer watering Plants. Water barrels are part of our passive solar system

Water-to-Air Heat Exchanger


Photo credit: Tim Baker


Photo credit: Tim Baker

Photo credit: Bob Schultheis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Water-to-Air Heat Exchanger

Photo credit: Scott Sanford, University of Wisconsin

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Water-to-Air Heat Exchanger


Photo credit: Tim Baker


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Wood Pellet & Corn Furnace


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Infrafred Heaters

- Heats objects (plants, soil, benches) in the high tunnel (not the air)
- Generally low intensity heaters in high tunnels

Circulation fans

- Mix air to prevent stratification of air
- Reduces heating
- Dries wet leaves faster – prevents disease

Paddle fans

Jet blowers

Basket fans

Good Air Circulation is Critical

Source: Greg Brenneman – Iowa State University

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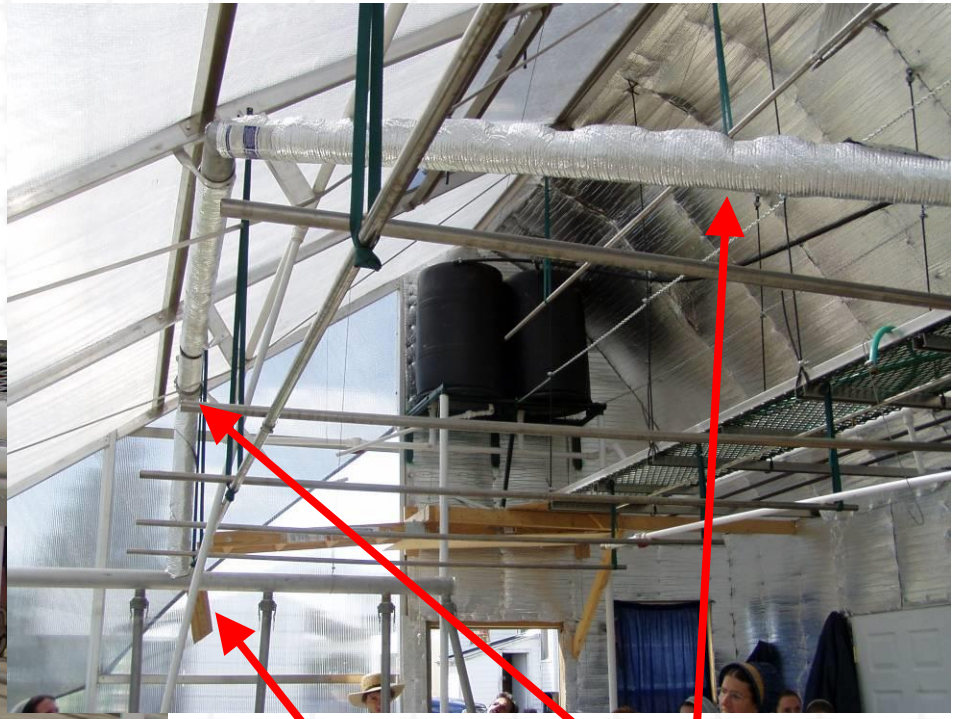
Under-Bench Forced Air

- Lowers heating costs 20-25%
- Same as a 5-10°F reduction in greenhouse temperature
- Study of bottom heated tomatoes = 7% increased yields

Under-Bench Hydronic heating

Under-Bench Hydronic Heating

- Natural Convection / Thermal buoyancy
- No pumps



Supply from boiler

Distribution to pipes running under benches

Return piping to boiler

Geothermal Cooling and Heating

- 8”-24” diameter tubes run underground; buried 6’-12’ deep
- Air drawn through tubes by blower
- Ground is cool in summer, therefore cool air comes out
- Hot air drawn in during summer also warms up ground
- In winter, the air is warmed by the soil

Geothermal Cooling and Heating

High Tunnel Resources – Page 1

- High Tunnels.org
  www.hightunnels.org
- Missouri Alternatives Center (click on “H” for high tunnels)
  agebb.missouri.edu/mac/links/index.htm
- Siting High Tunnels (eXtension)
  www.extension.org/pages/18365/siting-high-tunnels
- High Tunnel Construction Considerations (Iowa State)
  www.iowaproduce.org/pages/production/files/high_tunnel/high_tunnel_construction.pdf
- High Tunnel Hoop House Construction Guide (Noble Foundation)
  www.noble.org/Global/ag/horticulture/hoop-house-construction-guide/nf-ho-14-01.pdf
- High Tunnel Fruit and Vegetable Production Manual (Iowa State)
  https://store.extension.iastate.edu/Product/pm2098-pdf

High Tunnel Resources – Page 2

- Passive Solar Greenhouse (University of Missouri)
  aes.missouri.edu/swcenter/research/Solar-heated%20greenhouse.pdf
  bradford.cafnr.org/passive-solar-greenhouse/
  bradford.cafnr.org/greenhouse-materials/
- Plasticulture (Penn State)
  extension.psu.edu/plants/plasticulture
- Horticultural Engineering (Rutgers University)
  aesop.rutgers.edu/~horteng/
- High Tunnel Tomato Production
  extension.missouri.edu/p/m170
- High Tunnel Melon and Watermelon Production
  extension.missouri.edu/p/m173
- Watering and Fertilizing Tomatoes in a High Tunnel
  http://extension.missouri.edu/p/G6462

High Tunnel Resources – Page 3

- AgEnergy Resource website (Univ. of Wisconsin) www.uwex.edu/energy/greenhouses.html
- NRAES137 Greenhouses for Homeowners and Gardeners extension.missouri.edu/p/nraes137
- Energy Self-Assessment website (NRCS) www.ruralenergy.wisc.edu/default.aspx
- National Greenhouse Manufacturers Association www.ngma.com

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