Solar Heating & Cooling for High Tunnels – Technical and Economic Considerations

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Wyoming Famers Market Conference

April 9, 2010

University of Wyoming
Cooperative Extension Service

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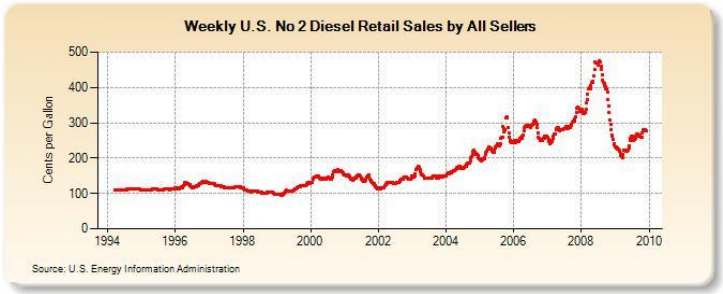
Outline

- Why renewable energy
- High tunnel vs. greenhouse
  - At what cost?
- Evaluating energy sources
- Design ideas
- Making it pay
  - Assessing returns
  - Incentives
  - Characteristics of profit
- Discussion and brainstorming

Why do you want to own a small renewable energy system?

- Energy Independence
  - Limited assistance to national independence
  - Important component of individual independence
- Environmental concerns
  - Air pollution
  - Climate change
  - Sustainability
- Education/Community
  - Teaching and technology
- **Save money**
  - Know the cost of your energy into the future



Why not small renewables?

- Maintenance
  - Responsible for energy production, not simply delivered as a service
- Intermittent resource
  - Sun and wind cannot economically be stored
- **Cost**
  - Can be more expensive than existing energy from grid or fossil fuel heating resources

What are the typical small RE systems?

- Wind
- Solar
  - Thermal
  - Photovoltaic (PV)
- Small hydroelectric
- Geothermal
  - Direct use and heat pumps
- Biomass
  - Heat, power, and transportation fuels

Thermal vs. Electric

- Heat and cooling living/working space and industrial processes
  - Solar thermal
    - Active or passive
  - Geothermal heat pump
  - Biomass

- Producing electricity
  - Photovoltaic
  - Wind turbine
  - Hydroelectric

High tunnel vs. Greenhouse

High Tunnel vs. Greenhouse

- High tunnel
  - Low cost
  - Temporary structure
  - Season extension
  - Typically without large-scale heating and cooling systems
- Greenhouse
  - Capital-intensive
  - Permanent structure
  - Year round production
  - Includes large-scale climate control systems

High Tunnel vs. Greenhouse – What are your goals?

If you want robust year-round production with significant renewable energy inputs…

Build a greenhouse!

(We can still talk about renewable energy for it…)

Evaluating energy sources – Heating and cooling

- Cooling
  - Solar electric driven fans
- Heating
  - Passive solar thermal
    - Building on the basic principle of high tunnels
  - Active solar thermal
    - Air tubes
    - Water tubes
  - Geothermal (aka ground source)
    - Heat pumps
  - Biomass
    - Composting

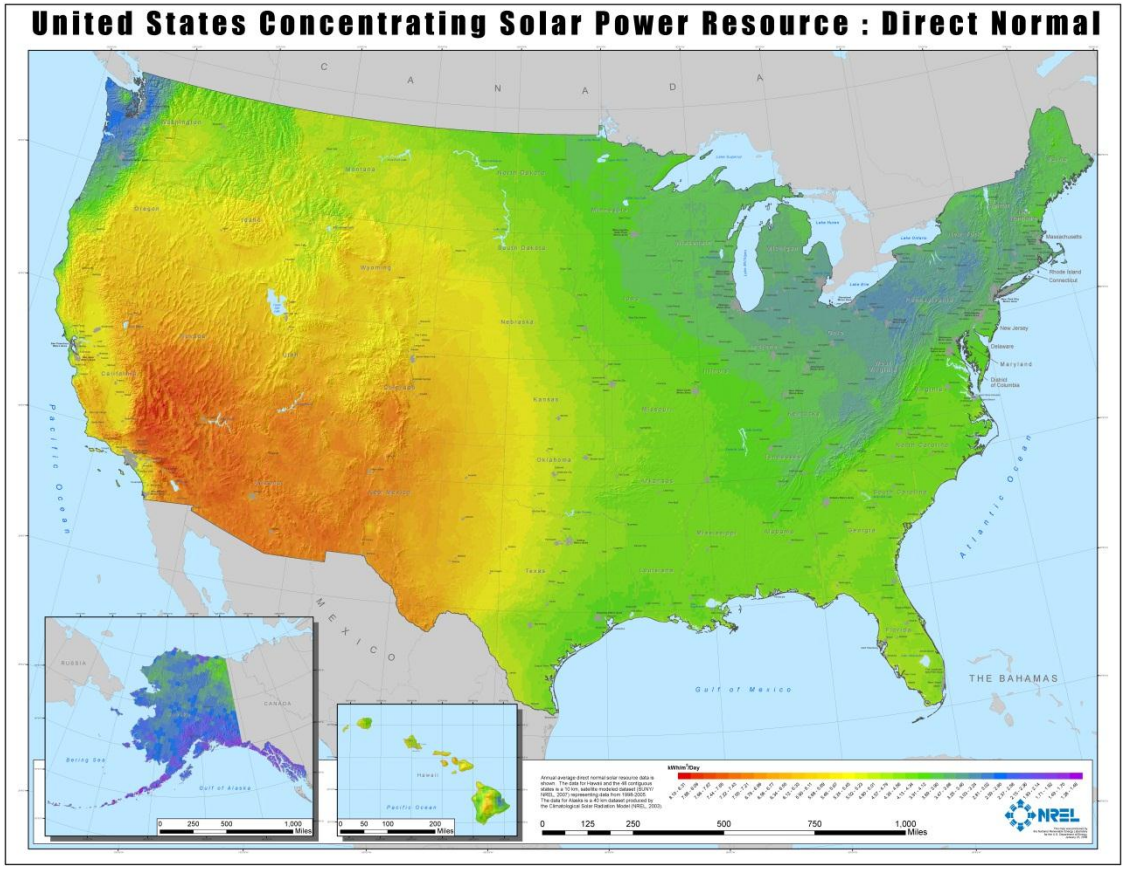
Evaluating Energy Sources - Cooling

- Direct Current fans
  - Powered by photovoltaics
- Why PV?
  - Reliable production
    - Produces strongly on hot days
  - Reliable operation
    - No moving parts in panels
  - Modular
    - Easy to find a small panel

Evaluating Energy Sources – Solar Heating

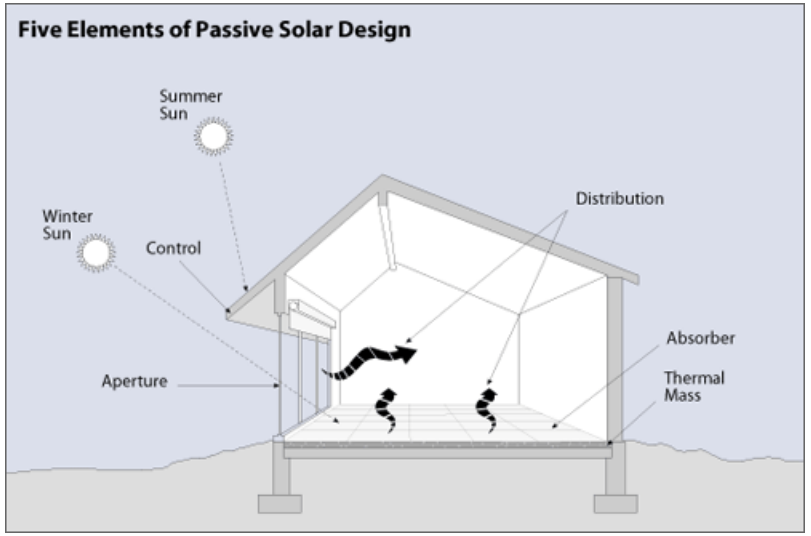
- Passive solar thermal
  - Few controls or required power inputs
- Active solar thermal
  - Use of pumps, controls, etc.
- Why not photovoltaics?
  - Very expensive capital costs
  - Converting a high value energy source (electricity) into a low value energy source (heat).

Evaluating Energy Sources – Solar Heating



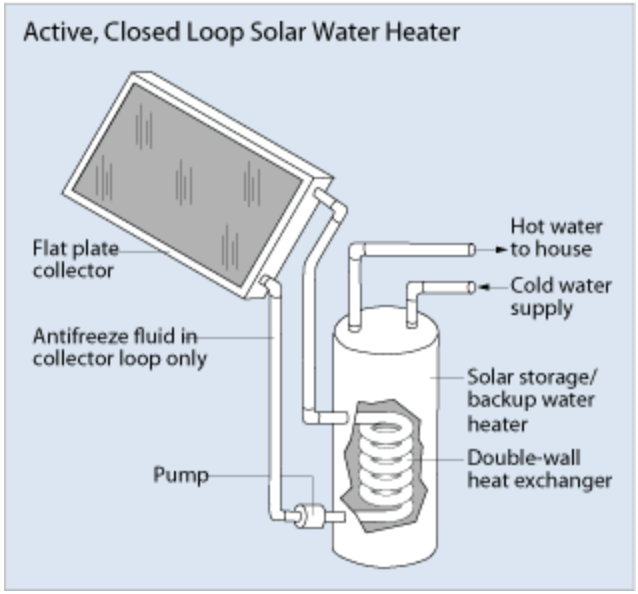
Evaluating Energy Sources – Passive Solar Heating

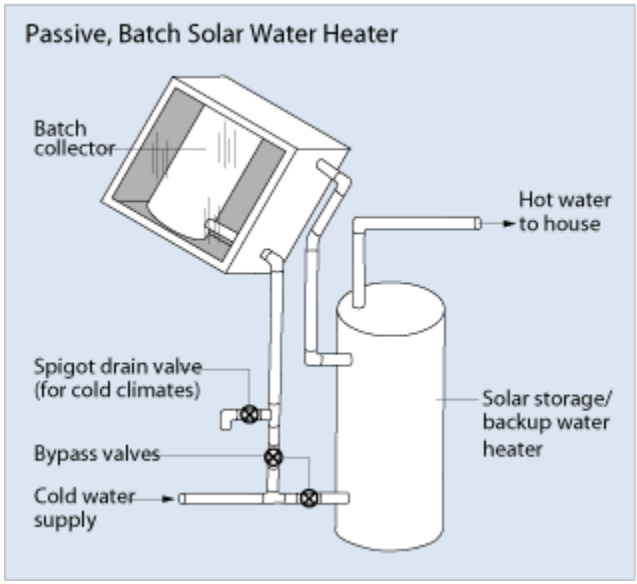
- Two options for enhancing existing passive solar design
  - Storage
  - Additional insolation collection



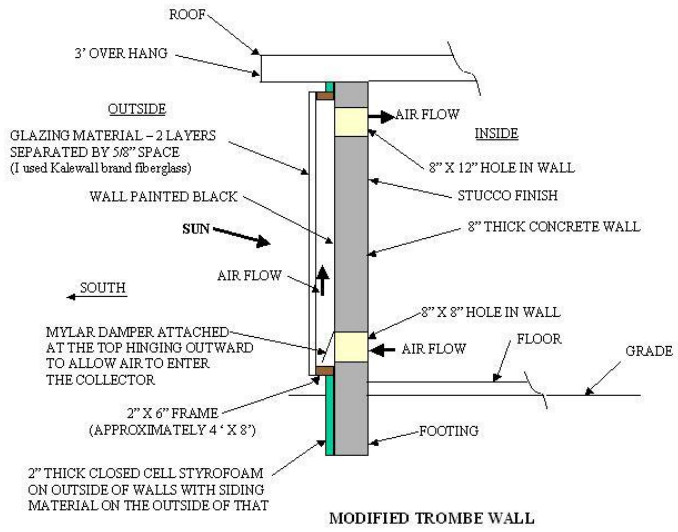
Source: DOE EERE

Evaluating Energy Sources – Active Solar Heating



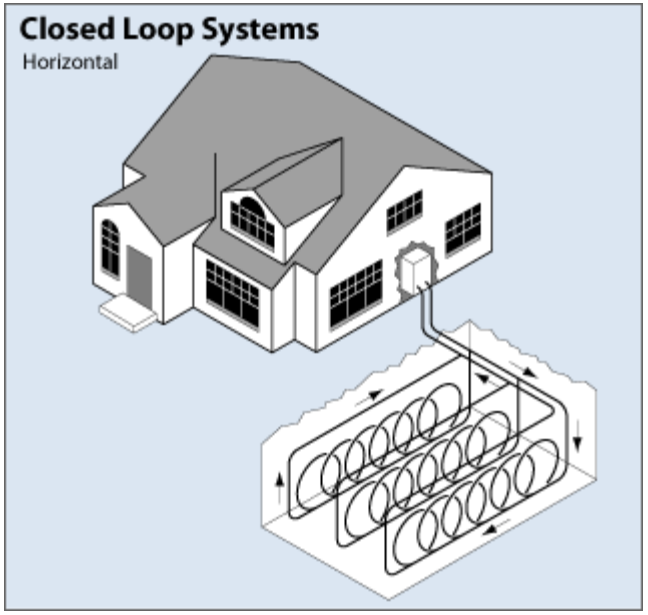


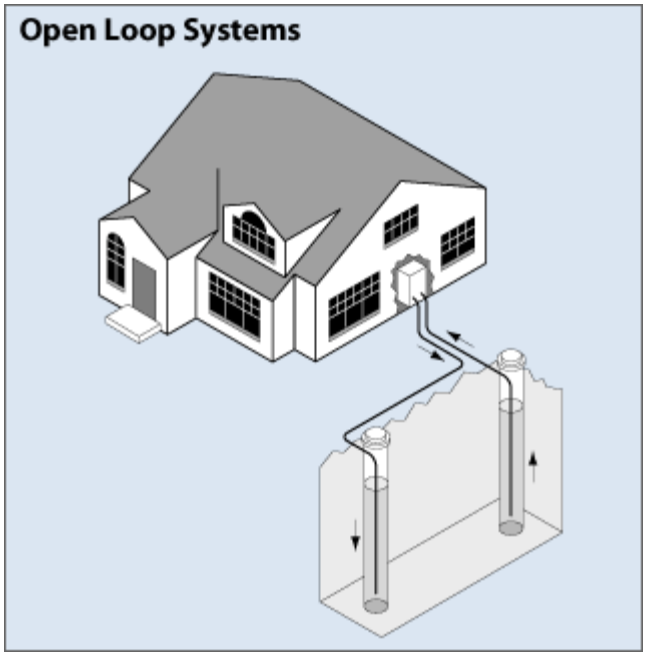
Evaluating Energy Sources – Active Solar Heating



MODIFIED TROMBE WALL

Evaluating Energy Sources – Geothermal Heat Pumps



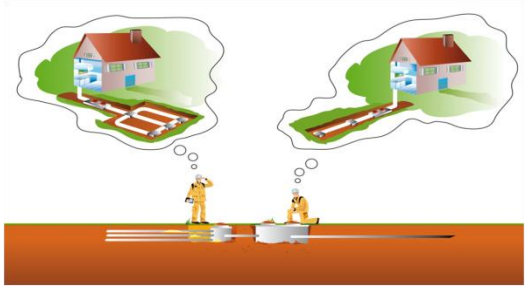


Evaluating Energy Sources – Geothermal Heat Pump

- Space heating, cooling, and potentially water heating system for buildings and other structures
  - Requires no backup, although electric backup often provided
  - Uses stored solar energy of the ground as heat source or heat sink (cooling mode)
  - Uses electricity to run pump and heat exchanger
- Generally 300-600% "efficient"
  - 1 unit of electricity yields 3-6 units of heating or cooling

Evaluating Energy Sources – Geothermal Heat Pump

- Uses relatively constant temperature of sub-surface to heat and cool buildings
  - Like a cave
- Fluid circulated to exchange heat
  - Like a refrigerator



Evaluating Energy Sources – Biomass

- Wood or other biomass combustion
- Composting
  - Many difficulties, even in controlled greenhouse settings

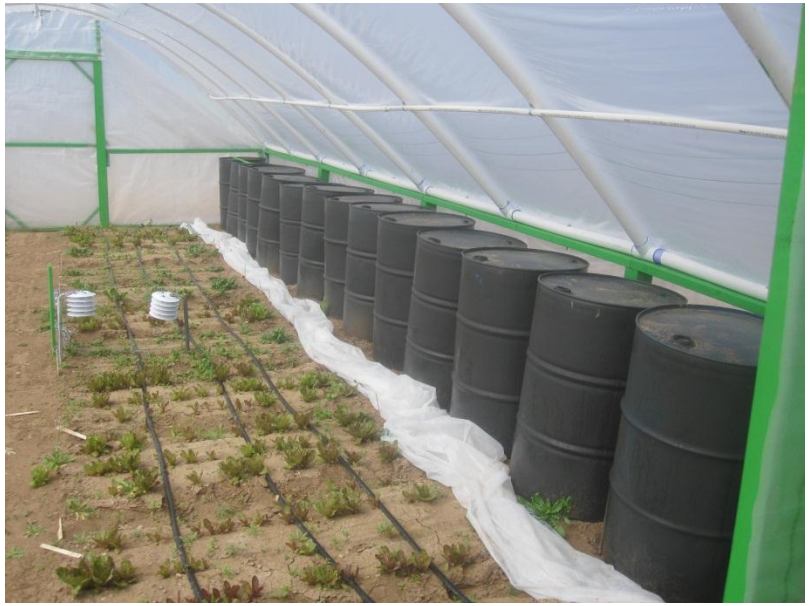
Designs and Ideas – Cooling

- Cooling with solar electric powered fans
  - $500-1500 to move significant (250-1000 cfm) air
  - Is an source of A/C power close or would it be cheaper to bring it to the high tunnel?
    - A/C fans are generally much cheaper

Design and Ideas – "Energy Efficiency"

- Keep available heat inside the high tunnel!
  - Double membrane
    - Greenhouse?
  - Seal air leaks
  - Shelter from the wind

Designs and Ideas – Thermal Storage



Designs and Ideas –Thermal Storage

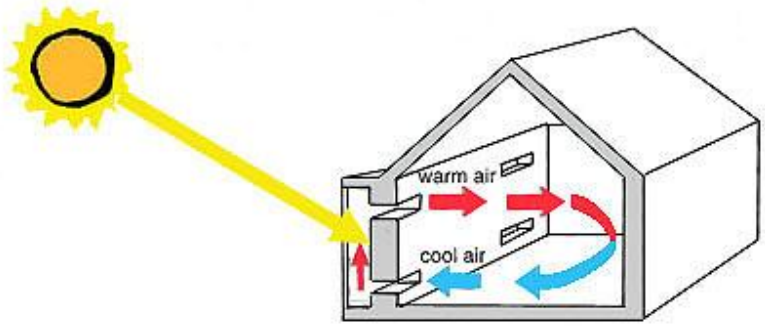
- Principles
  - Store heat for night time
  - Moderate temperature swings in the high tunnel
- Design
  - High surface area to volume gathers and releases heat more quickly
- Materials
  - Water
  - Rock
    - Lower heat storage capacity and transfer than water
    - Small rocks ½ to 1½ inches should be used
  - Others
    - Tile, cement, cinder block, etc.

Designs and Ideas –Thermal Storage

- Locate thermal mass on north side of structure
  - Allows light penetration and air heating throughout structure
    - Captures otherwise "lost" energy
- Potentially insulate the northern exposure
  - Don't want thermal mass touching the outside membrane
- Approximately 5 gallons of water or 200 lbs of rocks per square foot of southern exposure
  - Very rough rule of thumb!
- Remember a "full" high tunnel has more thermal storage capacity
  - Also takes longer to heat up…
- Incorporate storage with any more involved active system to enhance overall efficiency

Designs and Ideas –Trombe Walls

- Trombe walls
  - Combine solar thermal storage and enhanced solar collection
  - Involve a more permanent structure
  - Impedes southern light infiltration



Designs and Ideas – Solar air heating

- Generally more effective to heat the ground or thermal mass as opposed to the air
- Uses solar collectors to heat air to 100-180°F

Courtesy: Northland Community & Technical College

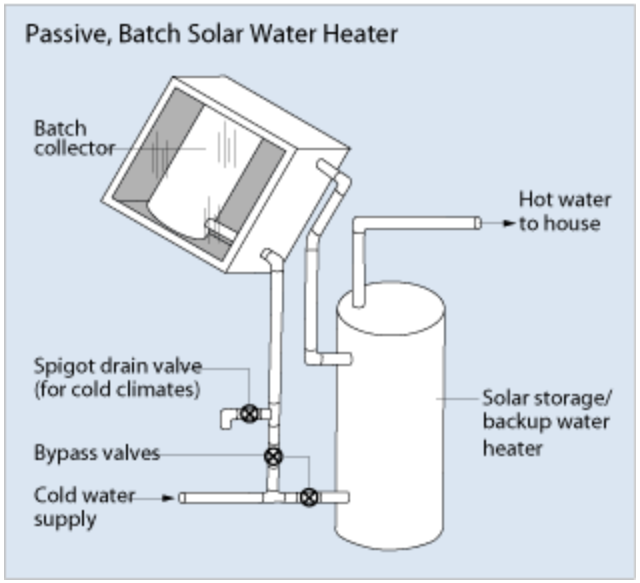
Designs and Ideas – Solar air heating

- Requires planning prior to design
  - Buried pipes (18-24” deep)
  - Solar collectors
    - Unobstructed southern exposure
  - Very close to being a permanent structure
- Must be careful to regulate soil temperature
- Could also be used for soil cooling if desired

Courtesy: Northland Community & Technical College

Designs and Ideas – Solar water (fluid) heating

- Thermosyphon systems
  - Passive fluid movement through convection
  - Tanks must be both above and near the collection panels
  - Most basic fluid based system
  - Could be closed loop to address freezing issues



Designs and Ideas – Solar water (fluid) heating

- Similar design to solar air system
  - Typically more expensive than air source systems
- Liquids are better at transferring heat
  - Requires introduction of antifreeze solution
- More complex plumbing and wiring
  - Requires either A/C power or the inclusion of a solar electric panel for a D/C pump
  - Typically closed loop in cold climates
- Year-round operation could help keep soil warmer for earlier spring plantings

Designs and Ideas – A solar/fossil fuel system

- Use solar thermal storage
- Integrate fossil fuel based, such as propane or natural gas, root zone heater
- Lower initial costs but higher operating costs than a RE system
- Can always add additional solar as needed
- Consist of tubing installed under high tunnel, solar collector panel, and a propane heater

Designs and Ideas – Robust active thermal systems

- Integrate with nearby building
  - Geothermal heat pumps
  - Active solar thermal
- The energy production of the system may be “surplus” in spring and autumn
- Permits use of system year-round
  - Maximizes use of capital intensive equipment

Making it pay!

- "Payback" is a unique value to each ag producer
  - Do you value the environmental attributes of your renewable energy system?
    - Independence?
    - Education?

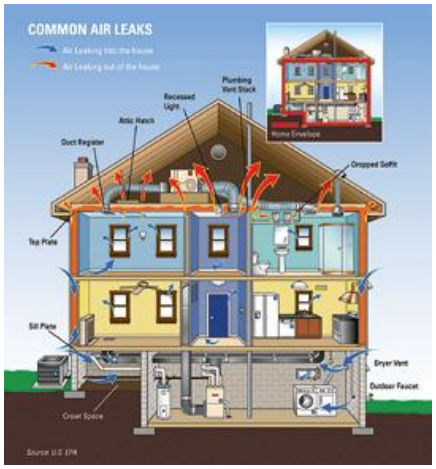
You and your neighbor may feel very different about what an acceptable economic return is!

Making it pay – Evaluating payback

- Assessing the value of your renewable energy systems
  - Heating (cooling) a low cost structure
    - Don’t want to spend $2 per square foot to heat a $2 per square foot structure
  - Do you know the value of your additional production?
    - Do you have a market for the produce?
  - How much do you value the reduction in risk from freezing or overheating?
    - Has it been a problem in the past?

Making it pay – Federal Incentives

- Residential Tax Benefits
  - 30% tax credit on solar (thermal & PV), wind, & geothermal heat pumps (no limit)
  - 30% tax credit on water heaters, furnaces, boilers, heat pumps, air conditioners, insulation, windows, doors, & roofs ($500 max) (Expires 12/31/11)



Making it pay – Federal Incentives

- Commercial and agricultural
  - Tax credits
    - 30% for solar
      - Both thermal and electric
    - 10% for geothermal heat pumps
  - Modified Accelerated Cost Recovery System (MACRS)
    - Rapid depreciation

Making it pay – Federal Incentives

- USDA Programs
  - Rural Development Rural Energy for America Program (REAP) grants and loans
    - 25% grants for renewable energy systems and energy efficiency improvements
    - $10,000 minimum project size
      - Can be part of a whole farm energy makeover
    - UW CES just received funding to complete 137 reduced cost energy audits
      - $1000 audit for $250!
  - NRCS
    - Conservation Innovation Grant Potential
      - Hurry the grant cycle closes April 15th!

Making it pay – Characteristics of profitable system

- Low-cost (passive)
  - Limited additional labor
  - Limited interference with production
  - Limited risk
- High cost (active)
  - "Better" than traditional alternative
    - E.g. grid electric vs. photovoltaics
  - Year-round use of energy system
    - E.g. Integration of system with building
  - Able to use incentives
    - Tax credits and grants

Discussion and Brainstorming!

- What are your needs for season extension?
- What are you willing to pay?
- What if fossil fuel alternatives are cheaper?

Select Resources

- eXtension: Farm Energy Group
  - *Introduction to Greenhouse Efficiency and Energy Conservation*
  - www.extension.org
- National Sustainable Agriculture Information Service - ATTRA: Farm Energy Alternatives
  - *Solar Greenhouses* by Barbara Bellows
  - http://attra.ncat.org/attra-pub/farm_energy/solar.html
- Database of State Incentives for Renewables (DSIRE)
  - www.dsireusa.org

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