NetZero Greenhouse Project

Abigail Clarke-Sather
May 30, 2012
To provide economic, environmental, and social benefits to economically disadvantaged individuals and communities; and to provide education and training that builds local capacity.

• Environment Stewardship
• Social Responsibility
• Economic Viability
The iCAST Model

Educational Institutions

Industry Experts

Government and NGO's

Communities
NetZero Greenhouse Project

Colorado Dept of Agriculture ACRE grant

• Purpose
  ➢ Energy prices and new construction costs are high

• Goal
  ➢ Design, model, and test energy efficiency retrofits

• Deliverables
  ➢ Interview stakeholders
  ➢ Review current best practices
  ➢ Research existing energy efficient greenhouses
  ➢ Analyze data used to drive greenhouse design
  ➢ Modeling potential energy efficiency solutions
  ➢ Install energy conservation measures and assess impact
Greenhouse Energy Efficiency

What is it?
• In Colorado, heating greenhouses is the main energy expenditure over the year
  ➢ *Cooling costs are less than heating costs*
• The basic strategies to retrofit greenhouses to be more energy efficient include:
  ➢ *Reducing greenhouse heat losses*
  ➢ *Increasing efficiency of heating systems*
  ➢ *Employing thermal buffers*
Greenhouse ECMs

Energy Conservation Measures (ECMs)

- **Examples Considered**
  - Wall insulation
  - Increase unit heater efficiency
  - Triple layer polycarbonate glazing
  - Energy curtain
  - Foundation Insulation
  - Internal thermal mass

- **Renewable Energy Examples Considered**
  - Geothermal heat pumps
  - Solar thermal panels (air and water)
Overview

Topics Covered

- Computer Modeling of ECMs
- Modeling and Estimates for Renewable Energy
- Installed Trials and Energy Impacts
- Conclusions
- Recommendations
Three Greenhouses Modeled

- **Small**
  - CSU, Quonset Shape
  - 972 Square feet

- **Medium**
  - CSU
  - 10,534 square feet

- **Large**
  - Fort Collins
  - 85,796 square feet
Small Greenhouse

Heating Energy Use – Natural Gas

Gas consumption (MMBtu)

- Actual
- eQUEST

Month: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Consumption: 100, 80, 60, 40, 20, 0, 0, 0, 0, 0, 0, 0
Small Greenhouse

Electricity Use

<table>
<thead>
<tr>
<th>Month</th>
<th>Actual</th>
<th>eQUEST</th>
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<tbody>
<tr>
<td>Jan</td>
<td>650</td>
<td>670</td>
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<tr>
<td>Feb</td>
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<td>Mar</td>
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<td>Apr</td>
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<td>Jun</td>
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<td>Nov</td>
<td>600</td>
<td>630</td>
</tr>
<tr>
<td>Dec</td>
<td>700</td>
<td>720</td>
</tr>
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</table>
Modeled Energy Savings

Small Greenhouse

- Increasing Furnace Energy Efficiency to 93%
  - Heating Savings of 20.06%, Payback in 3.194 years
- Thermal Mass – 34 Water Barrels
  - Heating Savings of 16.0%, Payback in 2.25 years
- Triple Polycarbonate Glazing 16 mm
  - Heating Savings of 13.89%, Payback in 10.447 years
- Energy Curtain
  - Heating Savings of 13.33%, Payback in 2.941 years
- Wall Insulation R-13
  - Heating Savings of 9.49%, Payback in 1.244 years
Geothermal Heat Pumps

Small Greenhouse

- Energy savings in the short term
- Over long term loss in heat pump efficiency
- Fort Collins is too cold to make these work long term
- Costs based on bored feet
  - Payback period between 18.8 and 254 years
- Costs based on $1000 per ton system needed
  - Payback period between 4.93 and 4.97 years
Solar Thermal Panels

Small Greenhouse

- Concerns
  - Area needed for system
  - Size of system needed to offset heating load
  - Cost of panels

- Solar hot air
  - Payback period greater than 100 years!

- Solar hot water
  - Payback period from 12 to over 100 years

- Other solar thermal options make more sense
  - Thermal mass
  - Phase-changing materials
Two Small Greenhouses

- CSU, Fort Collins
- One experimental, one control greenhouse
- Implemented solutions
  - Insulation – R-factor 6 on bottom 3 feet of wall
  - Thermal Mass – thirty-four 55 gallon water filled plastic drums
  - Phase-changing materials – four pipes of salt hydrates plus a pump and venting system to move heat
Insulation

Two Small Greenhouses

- CSU, Fort Collins
- One experimental, one control greenhouse
- Implemented solutions
  - Insulation – R-factor 6 on bottom 3 feet of wall
  - Thermal Mass – thirty-four 55 gallon water filled plastic drums
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## Experimental Timeline

### East and West Greenhouses at PERC facilities

<table>
<thead>
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<th>Start</th>
<th>End</th>
<th>Experimental</th>
<th>Control</th>
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<tbody>
<tr>
<td>Insulation</td>
<td>12/12/11</td>
<td>12/28/11</td>
<td>East</td>
<td>West</td>
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<tr>
<td>Thermal Mass</td>
<td>1/2/12</td>
<td>1/27/12</td>
<td>East</td>
<td>West</td>
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<td>Phase changing materials</td>
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<td>3/2/12</td>
<td>West</td>
<td>East</td>
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<td>Baseline</td>
<td>1/30/12</td>
<td>2/10/12</td>
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Insulation
Thermal Mass
Predicted Annual Energy Use

Small Greenhouse

- **Annual Heating Energy** = \(24 \times f \times BLC \times DDh / \eta\)
  - \(\eta\) = efficiency of heating equipment (i.e. furnace efficiency, assumed to be 75% efficient)
  - \(BLC\) = Building Load Coefficient
  - \(DDh\) = heating degree days (the cutoff temperature for heating degree days considered was 65 degrees Fahrenheit)
  - \(f\) = % of how much of the day heating occurs, for this work assumed 24 hours/day so \(f = 1\)
  - **Note:** All heating degree day information came from the Western Regional Climate Center for Fort Collins [http://www.wrcc.dri.edu/](http://www.wrcc.dri.edu/)
Natural Gas Use

Insulation Experiment

Experimental Greenhouse (East)

Therm usage over period vs Average Temperature (F) over period

\[ y = -1.4928x + 64.353 \]

\[ R^2 = 0.45062 \]

- Insulation

Linear (Insulation)
Predicted Annual Energy Savings

Small Greenhouses

- Electricity Use had anomalies
  - Impossible to determine energy use
  - Electricity use not necessarily connected to outside temperature

- Natural Gas use showed energy savings

<table>
<thead>
<tr>
<th>Greenhouse</th>
<th>Insulation</th>
<th>Thermal Mass</th>
<th>Phase Change</th>
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<tbody>
<tr>
<td>Experimental</td>
<td>8,569</td>
<td>726</td>
<td>16,231</td>
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<td>Control</td>
<td>13,388</td>
<td>3,043</td>
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<td>Annual Energy Savings</td>
<td>4,819</td>
<td>2,317</td>
<td>6,536</td>
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<tr>
<td>% Energy Savings</td>
<td>36%</td>
<td>76%</td>
<td>29%</td>
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</table>
# Energy Cost Savings

## Natural Gas Use

- **Thermal Mass and Insulation**
  - *Payback period less than 1 year!*
- **Phase-Change Material costs unknown**

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<td>Annual Predicted Energy Savings</td>
<td>4,819</td>
<td>2,317</td>
<td>6,536</td>
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<tr>
<td>Annual Predicted Energy Cost Savings*</td>
<td>$3,946</td>
<td>$1,897</td>
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<td>Cost of ECM</td>
<td>$257</td>
<td>$454</td>
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<td>Payback Period</td>
<td>0.07</td>
<td>0.24</td>
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Conclusions

Simple Solutions = Big Savings

- Low investment in energy efficiency can result in large energy savings
- Insulation and Thermal Mass are good ways to save energy and energy costs
- Real savings may differ from trial solutions
- Geothermal heat pumps and Solar thermal panels don’t make sense in Fort Collins
- Other solar thermal options – thermal mass and phase-changing materials better options
  Over long term loss in heat pump efficiency
Questions?
www.iCASTusa.org
NetZero Greenhouse Project

Abigail Clarke-Sather
May 30, 2012

Webinar: Energy-Efficient Greenhouses

Larry Kinney
Synergistic Building Technologies
May 30, 2012