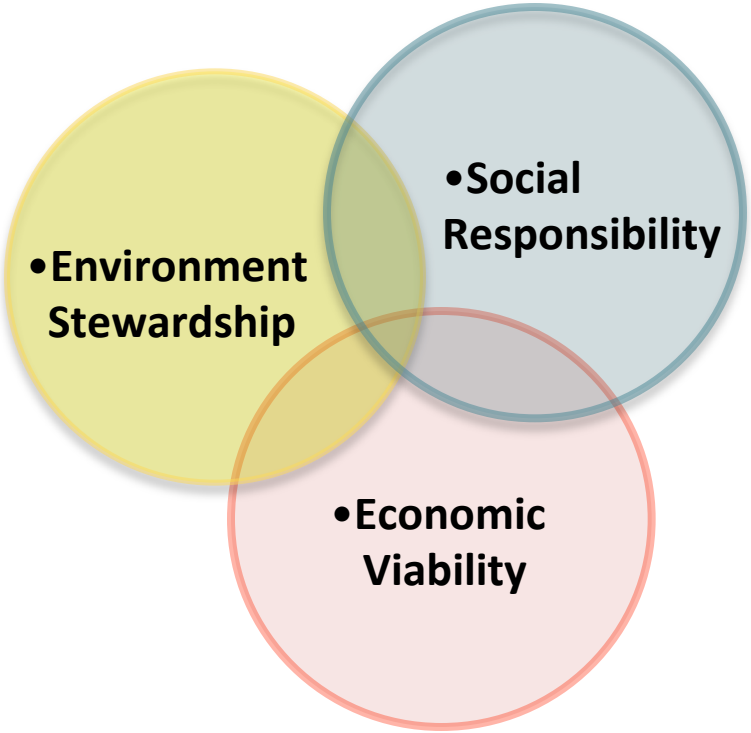
NetZero Greenhouse Project

Abigail Clarke-Sather

May 30, 2012

iCAST Mission

To provide economic, environmental, and social benefits to economically disadvantaged individuals and communities; and to provide education and training that builds local capacity.



The iCAST Model

Educational Institutions

Industry Experts

Government and NGO's

iCAST
community powered results.

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

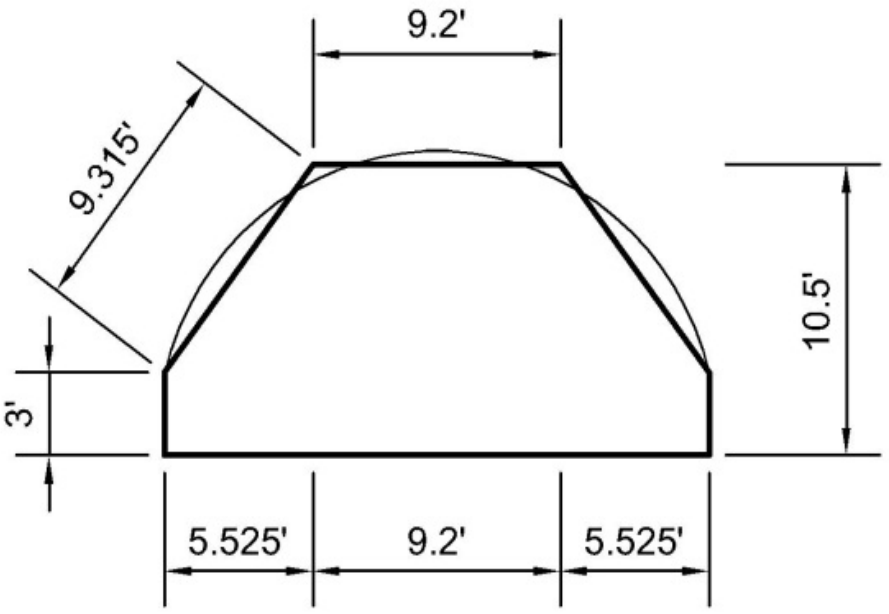
Topics Covered

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

Computer Modeling of ECMs

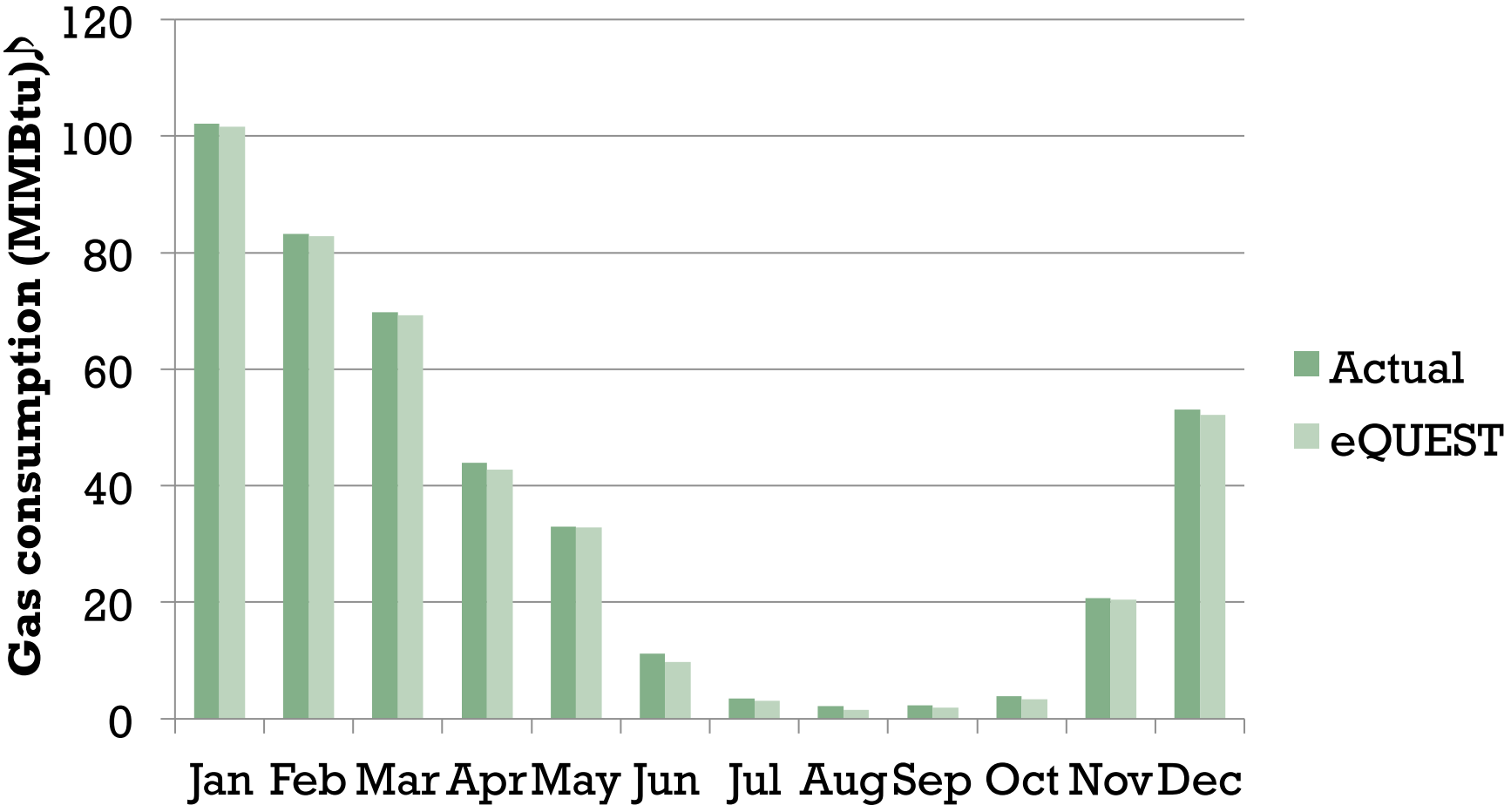
Three Greenhouses Modeled

- **Small**
  - *CSU, Quonset Shape*
  - *972 Square feet*
- **Medium**
  - *CSU*
  - *10,534 square feet*
- **Large**
  - *Fort Collins*
  - *85,796 square feet*



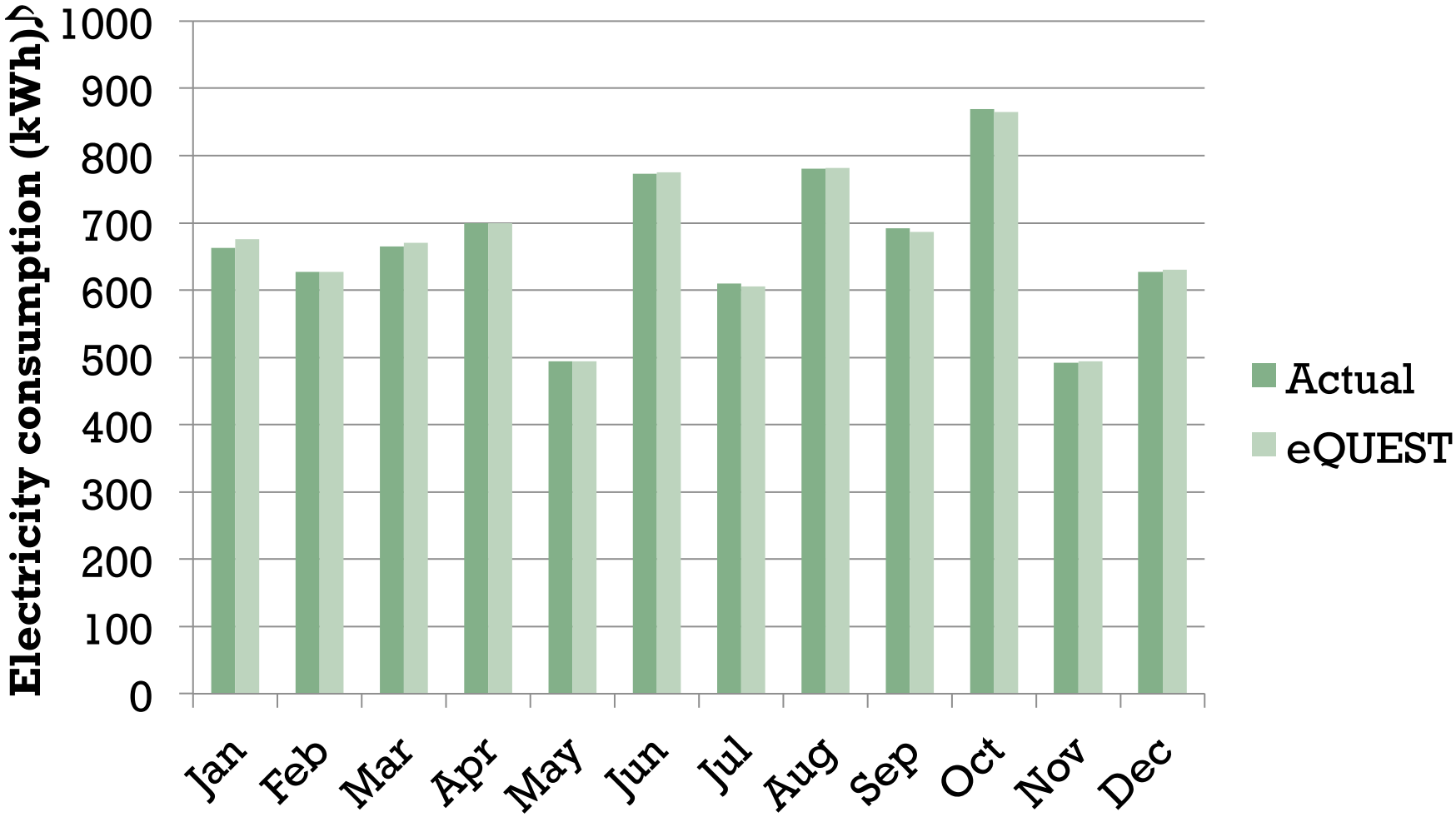
Small Greenhouse

Heating Energy Use – Natural Gas

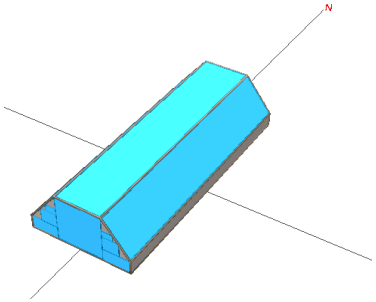


Small Greenhouse

Electricity Use



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***

Trial Solutions

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

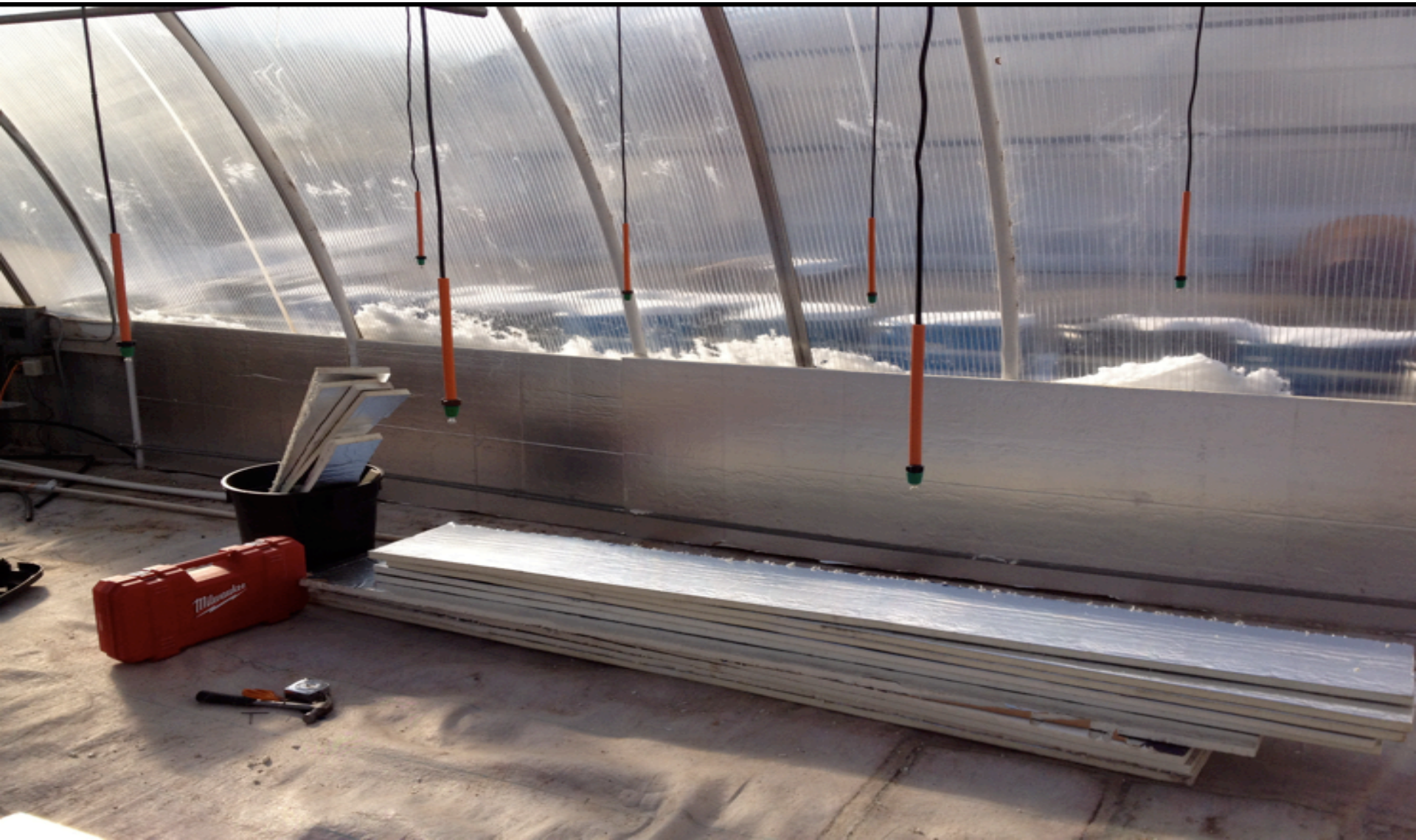
- CSU, Fort Collins
- One experimental, one control greenhouse
- Implemented solutions
  - ***Insulation – R-factor 6 on bottom 3 feet of wall***
  - ***Thermal Mass – thirty-four 55 gallon water filled plastic drums***
  - ***Phase-changing materials – four pipes of salt hydrates plus a pump and venting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

Experimental Timeline

East and West Greenhouses at PERC facilities

	Start	End	Experimental	Control
Insulation	12/12/11	12/28/11	East	West
Thermal Mass	1/2/12	1/27/12	East	West
Phase changing materials	2/20/12	3/2/12	West	East
Baseline	1/30/12	2/10/12	n/a	n/a

Insulation



Thermal Mass

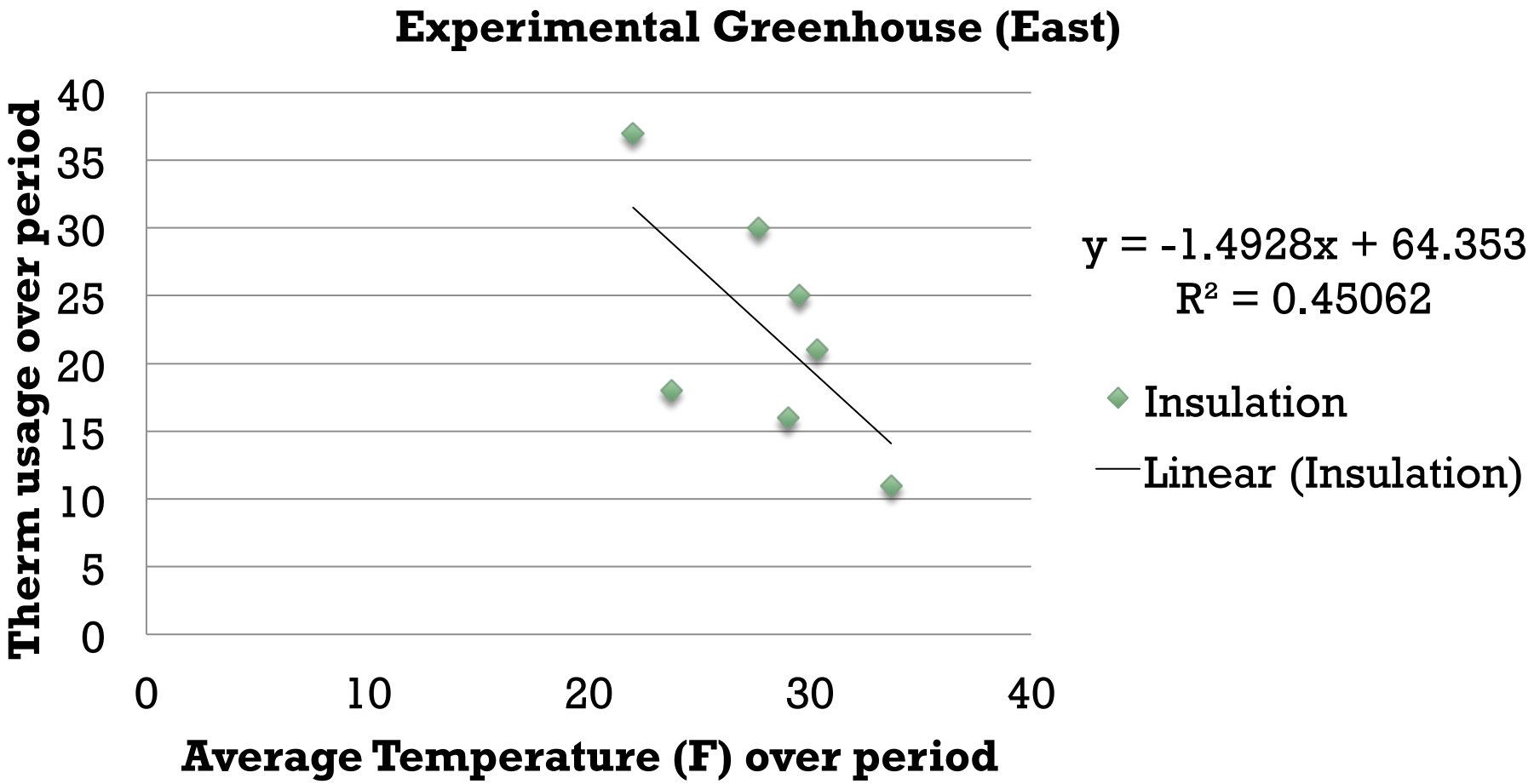
Predicted Annual Energy Use

Small Greenhouse

- **Annual Heating Energy = 24*f*BLC*DDh/η**
  - ***η= 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/***

Natural Gas Use

Insulation Experiment



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**

	Experiment		
Greenhouse	Insulation	Thermal Mass	Phase Change
Experimental	8,569	726	16,231
Control	13,388	3,043	22,766
Annual Energy Savings	4,819	2,317	6,536
% Energy Savings	36%	76%	29%

Energy Cost Savings

Natural Gas Use

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

	Experiment		
Greenhouse	Insulation	Thermal Mass	Phase Change
Annual Predicted Energy Savings	4,819	2,317	6,536
Annual Predicted Energy Cost Savings*	$3,946	$1,897	$5,352
Cost of ECM	$257	$454	unknown
Payback Period	0.07	0.24	n/a

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

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Webinar : Energy-Efficient Greenhouses

Larry Kinney
Synergistic Building Technologies
May 30, 2012