Greenhouse Glazing: Thermal Insulation

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Introduction

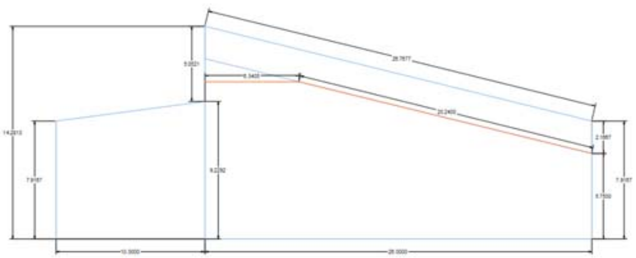
- Dr. Val Eylands is a farmer, scientist, and owner/operator of a hydroponic greenhouse specializing in lettuce
- Throughout the winter months, the greenhouse has a particular issue of overnight heat loss
- Dr. Eylands currently uses propane or wood-powered heaters to maintain temperature
- He would like to implement a system that saves money on heating and reduces the environmental footprint of his facility

Objective

- The purpose of this project is to install an effective insulation system that is low maintenance, cost efficient, and will last 10-12 years
- The system must be designed such that its daytime storage size does not exceed 16 in. high by 12 in. deep

Site Description

- Greenhouse is located in Winslow, Arkansas
- Dr. Eylands owns a series of two greenhouses; however, we have chosen to focus on the newest facility for our design
- According to the blueprints provided, the dimensions of the greenhouse are 30' x 100'
- Trusses run across the roof of the greenhouse in 10' intervals
- Dr. Eylands has specified a minimum temperature of 55° F at all times



- Above: Structural side view of the greenhouse
- The blue lines represent the greenhouse structure and the orange lines show the path of the retractable insulation system.
- The dimensions were obtained by the blueprints provided by the client
- The left section of the greenhouse is not included in the heat loss calculations because it has negligible heat loss.

Analysis

- Our team designed Excel models that would predict:
  - Heat loss during the winter nights
  - Cost of using propane heaters each year
  - Savings in relation to insulative properties of materials
  - Storage size of material

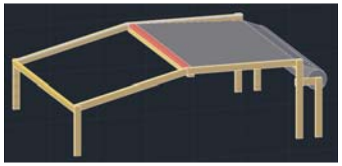
Models

Heat Loss

Current Glazing			
	Total R-Value	2.7	(hr*ft^2*°F)/BTU
	Winter Nights in Use	211	nights per season
	Night Heat Lost per season	73134067	BTU
	Fuel Cost per season	$1,277.45	
	CO2 Emissions per season	8111.81	lb CO2
Night	(T0-Ti)/night (°F/night)		q (BTU/night)
1	308.9		691567.2
2	304.95		682723.9
3	306.65		686529.9
4	309.15		692126.9
5	308.6		690895.5
6	312.2		698955.2
7	315.75		706903.0
8	318.3		712611.9

- The Heat Loss analytical model uses local weather data to generate degree hours based on the minimum temperature of 55° F during the night
- These degree hours were then summed and converted to total heat loss per season in terms of BTU
- This is calculated variable to the chosen R-Value that depends on each material
- Using this value, the model provides a cost estimate spent on fuel each season
- Based on the cost of fuel, the model also estimates total CO2 emissions per season

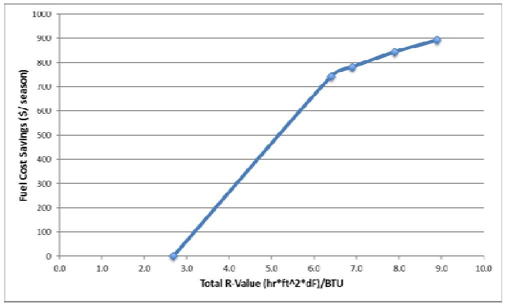
Prototype



- Our final design consists of a thinner fabric material, stored on a roll and drawn out by a leading edge (highlighted in red), as seen above.

- The material, as shown in the image on the right, is a double sided, reflective material with an internal bubble layer.
- The leading edge guides the material along the pre-manufactured tracks, which were mounted to a wooden structure for support and presentation.

Economics



- We used a series of economic models to estimate the fuel cost savings based on each R-value.
- Left: with the addition of a material with just an R-Value of 1, the system shows a large increase in fuel cost savings.
- This concludes that providing the client with any insulating material would provide a great benefit.
- Based on the results of this graph, adding any insulation with an R-value greater than 1 has greatly diminishing returns on the savings obtained

- Below: The table below shows each option and their Total R-Values including a "do nothing" option, Insulation 1, 2, and 3 with R-values 2, 3, and 4 respectively, and a variable alternative.
- Depending on the R-Value of a given alternative the table below displays the Fuel Cost, CO2 Emissions, and their savings.
- The savings of CO2 Emissions and Fuel Cost are comparisons of the current situation to those of each alternative.

Alternative	Total R-Value (hr*ft^2*°F)/BTU	Fuel Cost (per season)	CO2 Emissions (lb CO2 per season)	Fuel Cost Savings (per season)	CO2 Emission Savings (lb CO2/season)
Current	2.7	$1,277.45	8112	N/A	N/A
Insulation 1	6.4	$534.93	3397	$742.52	4715
Insulation 2	6.9	$496.17	3151	$781.28	4961
Insulation 3	7.9	$433.36	2752	$844.09	5360
Chosen Insulation	8.9	$384.67	2443	$892.78	5669

Results and Discussion

- From the weather data collected, we were able to determine the approximate heat loss from the greenhouse each year, and calculate the impacts and savings that various types of insulating materials and thicknesses could have if implemented for the entire system.
- The largest impact from adding insulation was made apparent when just adding any opaque material up to an effective R-value of 1.
- The effects of adding insulation with an R-value of anything greater than 1 were still beneficial but not significantly, seeing as they increased and leveled off.
- Many insulations with low R-values come as fabric-type, so considering our storage space requirements and the benefit of adding any low R-value insulation, we decided to create the final prototype presenting a double sided, reflective material with an internal bubble layer that proves to be very cost effective by our economic analysis.
- As shown above, our prototype was constructed to realistically visualize a fraction of a much larger system, if implemented according to our series of engineering analysis.
- If our analysis and prototype prove attractive to Dr. Eylands, then he may consider implementing a similar system, greater in scale, to be accurate with our models.