Understanding Greenhouse Environmental Controls

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Disclaimer

- Get Help
- Don’t make an expensive mistake

What does it cost to build a commercial greenhouse?

Cost to build one free standing 30 x 96 Greenhouse (2880 ft2)						
	Item	**Qty**		**Unit cost**		**Cost**
Structure	Construction Cost	1	$	12,500	$	12,500
	Electrical	1	$	1,500	$	1,500
	Greenhouse frame	1	$	8,000	$	8,000
	Plastic covering	1	$	1,000	$	1,000
	Locking system	1	$	225	$	225
Cooling	Half Fans	4	$	120	$	480
	Exhaust Fans	2	$	1,270	$	2,540
	Evaporative Cooling System	1	$	1,912	$	1,912
	Cooling pads	1	$	1,000	$	1,000
	Environmental control controls	1	$	2,000	$	2,000
	Wall Vent	1	$	2,000	$	2,000
	Shutters	1	$	198	$	198
Heaters	200,000 BTU Heaters and Accessories	1	$	1,000	$	1,000
Total					$	34,355

What does it cost to own a greenhouse?

Estimated Monthly Cost of a Greenhouse		
Total Amount Needed	$	35,000.00
Total Loan Amount (20% down)	$	28,000.00
Interest Rate (10 year)		5.50%
Monthly Payment Amortized over 10 years	$	305.00
Estimated Power (Fans and Cooler)	$	1,200.00
Estimated LP Gas Cost	$	3,000.00
Estimated yearly repair cost	$	350.00
Total Yearly Cost	$	8,210.00
Total Monthly Cost	$	684.17
Total area (30 ft x 96 ft Greenhouse,in ft^2)		2880
Cost per square foot per month	$	0.24

Does not include: Labor, growing system, marketing, and chemicals

Buying Used Frames

The cost of poor design

90% Mortality, Output 90%

Revenue, Operating and Fixed Costs and Net Return

	Item	Qty	Unit cost	Cost
I. Revenue	Heads of lettuce	**38,271.3**	$ 1.50	**$ 57,407**

Enterprise Budget 30 x 96 NFT Lettuce Greenhouse

		Item	Qty	Unit cost	Cost
I. Revenue		Heads of lettuce	38,271	$ 1.50	$ 57,407
II. Variable Cost					
	Plant Materials	Seeds (cans of 5000)	9	100	850
		Oasis (boxes)	9	90	765
		Fertilizer (cost per head)	47,248	0.023	1,087
	Labor	(25 MH x 52 weeks)	1,300	10	13,000
	Energy	Liquid Propane	1	3,000	3,000
		Fans (KW for 9 months	10,950	0.1	1,095
		Blower (KW for 12 months)	14,400	0	1,440
		Cooler ($/month)	12	65	780
	Packing	Boxes	2,551	2	5,103
		Box Liners (rolls)	5	30.00	153
Interest on Operating Costs			20,455	10%	1,534
	Total Variable Cost				$ 28,808
III. INCOME ABOVE VARIABLE COSTS				$ 28,599	
IV. Fixed Costs	Depreciation	$ 13,205	0.50	$ 6,602	
	Interest on loan	$ 1,477	0.50	$ 739	
	Manager/Marketi	$ 520	18.00	$ 9,360	
Total Fixed costs				**$ 16,701**	
V. TOTAL COSTS				**$ 45,509**	
	Total cost per head			**$ 1.189**	
VI. Net Return Above: Operating Costs				**$ 28,599**	
Net Return: Above All Costs				**$11,898**	

***assumptions - 90% capacity sold, 90% mortality, 35 day crop cycle, 5% interest on loan, 15 heads per box**

90% Mortality, 75% Output

Revenue, Operating and Fixed Costs and Net Return

	Item	Qty	Unit cost	Cost
I. Revenue	Heads of lettuce	**31,892.7**	$ 1.50	**$ 47,839**

Enterprise Budget 30 x 96 NFT Lettuce Greenhouse

		Item	Qty	Unit cost	Cost
I. Revenue		Heads of lettuce	31,893	$ 1.50	$ 47,839
II. Variable Cost					
	Plant Materials	Seeds (cans of 5000)	7	100	709
		Oasis (boxes)	7	90	638
		Fertilizer (cost per head)	47,248	0.023	1,087
	Labor	(25 MH x 52 weeks)	1,300	10	13,000
	Energy	Liquid Propane	1	3,000	3,000
		Fans (KW for 9 months	10,950	0.1	1,095
		Blower (KW for 12 months)	14,400	0	1,440
		Cooler ($/month)	12	65	780
	Packing	Boxes	2,126	2	4,252
		Box Liners (rolls)	4	30.00	128
Interest on Operating Costs			19,596	10%	1,470
	Total Variable Cost				$ 27,598
III. INCOME ABOVE VARIABLE COSTS				$ 20,241	
IV. Fixed Costs	Depreciation	$ 13,205	0.50	$ 6,602	
	Interest on loan	$ 1,477	0.50	$ 739	
	Manager/Marketi	$ 520	18.00	$ 9,360	
Total Fixed costs				**$ 16,701**	
V. TOTAL COSTS				**$ 44,299**	
	Total cost per head			**$ 1.389**	
VI. Net Return Above: Operating Costs				**$ 20,241**	
Net Return: Above All Costs				**$ 3,540**	

***assumptions - 90% capacity sold, 90% mortality, 35 day crop cycle, 5% interest on loan, 15 heads per box**

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90% Mortality, 50% Output, ½ Labor

Revenue, Operating and Fixed Costs and Net Return

	Item	Qty	Unit cost	Cost
I. Revenue	Heads of lettuce	**21,261.8**	$ 1.50	**$ 31,893**

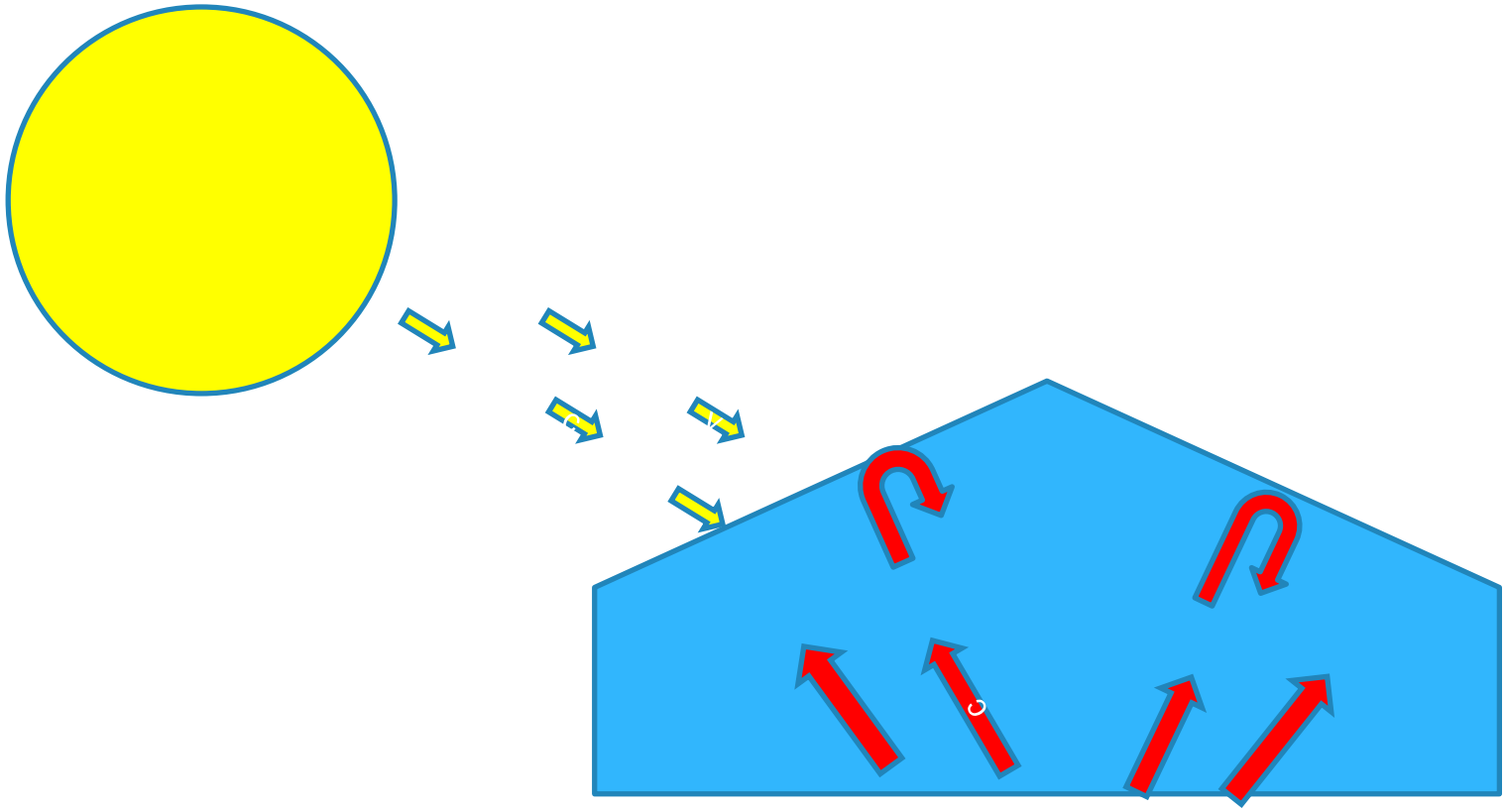
Enterprise Budget 30 x 96 NFT Lettuce Greenhouse

		Item	Qty	Unit cost	Cost
I. Revenue		Heads of lettuce	21,262	$ 1.50	$ 31,893
II. Variable Cost					
	Plant Materials	Seeds (cans of 5000)	5	100	472
		Oasis (boxes)	5	90	425
		Fertilizer (cost per head)	47,248	0.023	1,087
	Labor	(25 MH x 52 weeks)	520	10	5,200
	Energy	Liquid Propane	1	3,000	3,000
		Fans (KW for 9 months	10,950	0.1	1,095
		Blower (KW for 12 months)	14,400	0	1,440
		Cooler ($/month)	12	65	780
	Packing	Boxes	1,417	2	2,835
		Box Liners (rolls)	3	30.00	85
Interest on Operating Costs			12,315	10%	924
	Total Variable Cost				$ 17,343
III. INCOME ABOVE VARIABLE COSTS				$ 14,550	
IV. Fixed Costs	Depreciation	$ 13,205	0.50	$ 6,602	
	Interest on loan	$ 1,477	0.50	$ 739	
	Manager/Markete	$ 520	18.00	$ 9,360	
Total Fixed costs				**$ 16,701**	
V. TOTAL COSTS				**$ 34,044**	
	Total cost per head			**$ 1.601**	
VI. Net Return Above: Operating Costs				**$ 14,550**	
Net Return: Above All Costs				**$ (2,151)**	

***assumptions - 90% capacity sold, 90% mortality, 35 day crop cycle, 5% interest on loan, 15 heads per box**

How does a greenhouse work?

How do greenhouses work

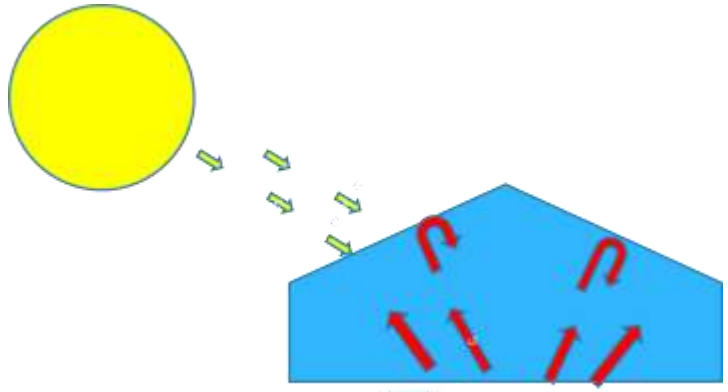


Heat Energy

- (BTU) British Thermal Unit
  - The amount of energy needed to raise 1 lb. of water 1 °F

Greenhouses Get Hot!

- On a clear beautiful summer day
- 30 x 96 ft. greenhouse = 1 Million BTU's per hour
- Per Hour
  - 10 gallons of LP
  - 10 therms of NG
  - 3 car tires
  - 50 kitchen ovens running



But plants like it hot. Right?

- Most plants become less productive >85°F
- Crops have an optimum operating range

Greenhouse Crop	Day Temp (°F)	Night Temp (°F)
Tomato	70 – 82	64-60
Lettuce	62 - 75	57 (50)
Cucumber	78.8 – 84.2	70

Too Hot or Too Cold

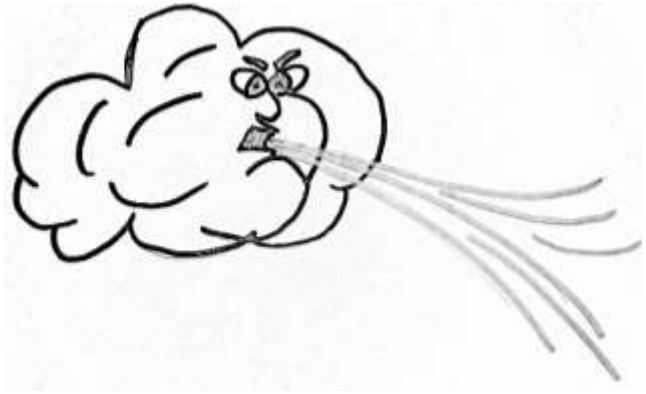
- Tomato
  - > 85°F lycopene is inhibited and pollen production is reduced
  - If night temperatures are <50 °F they will not set fruit.
  - Flowers will abort if > 60 to 64 °F
- Lettuce
  - Bolting
  - Tip burn
  - Bitterness
  - Increases pest pressure

How do you reduce greenhouse temperatures

- Ventilation
  - Natural
  - Mechanical
- Shade
- Evaporative Cooling

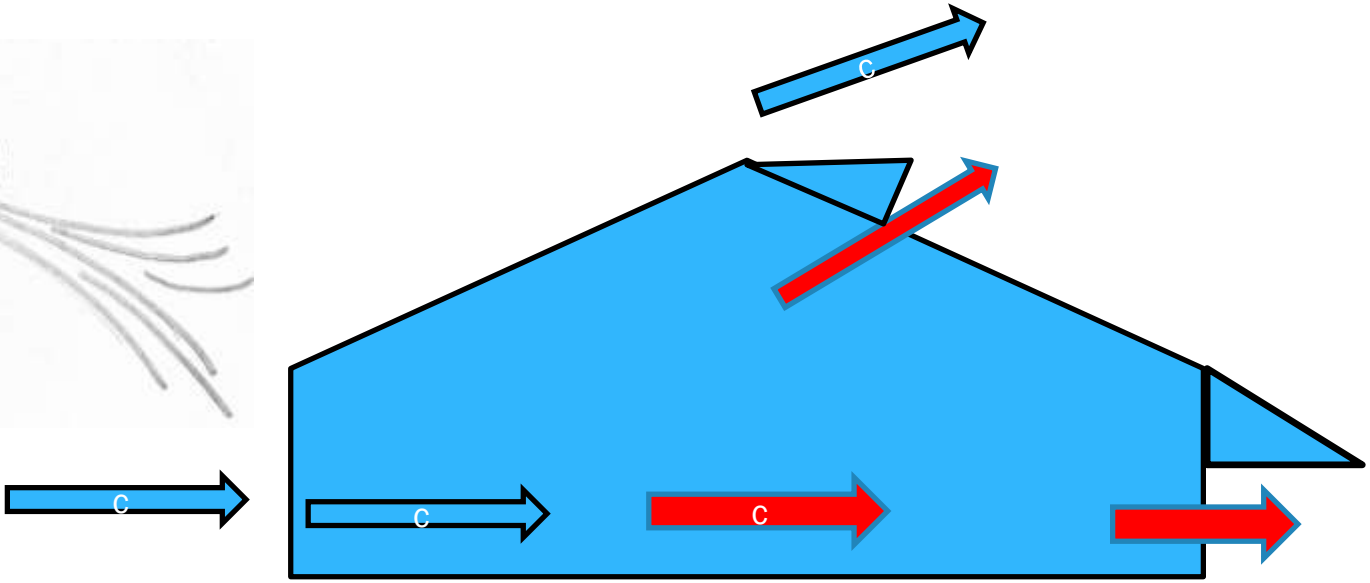
Natural Ventilation:

- Wind is the major driving force behind natural ventilation
- Even a small amount of wind can be effective in pushing air through the greenhouse or high tunnel
  - 2 to 3 mph



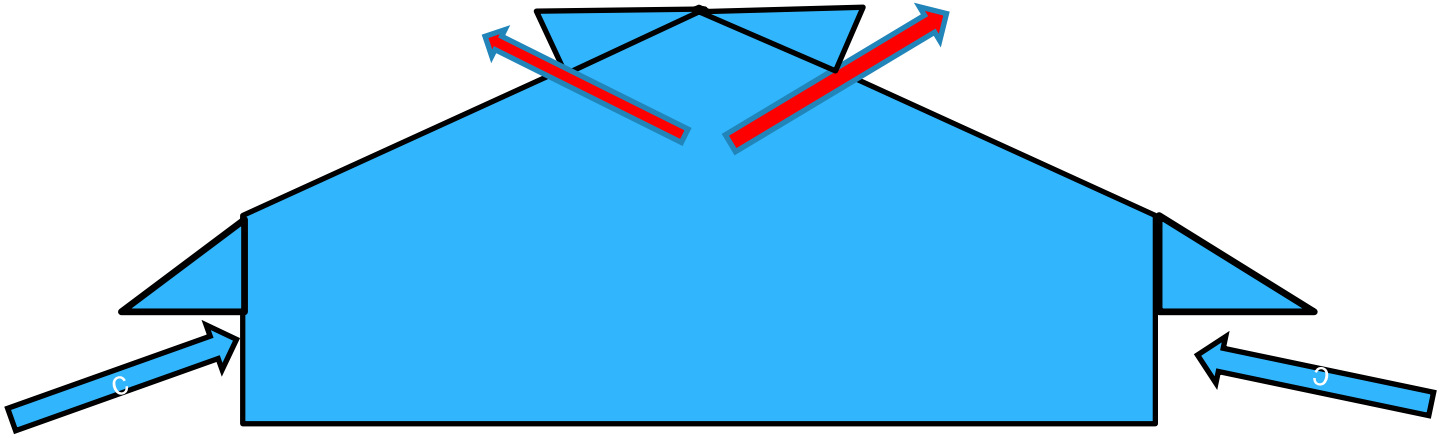
Natural Ventilation: Wind

- Pushing effect
- Pulling (vacuum)



Natural Ventilation: Buoyance

- Hot air rises because it is less dense
- Water vapor is less dense than air



Natural Ventilation

Vent to floor ratio

- ASAE recommends ventilation area = 15 to 25% of floor area
- 60 air exchanges per hour

Greenhouse Height

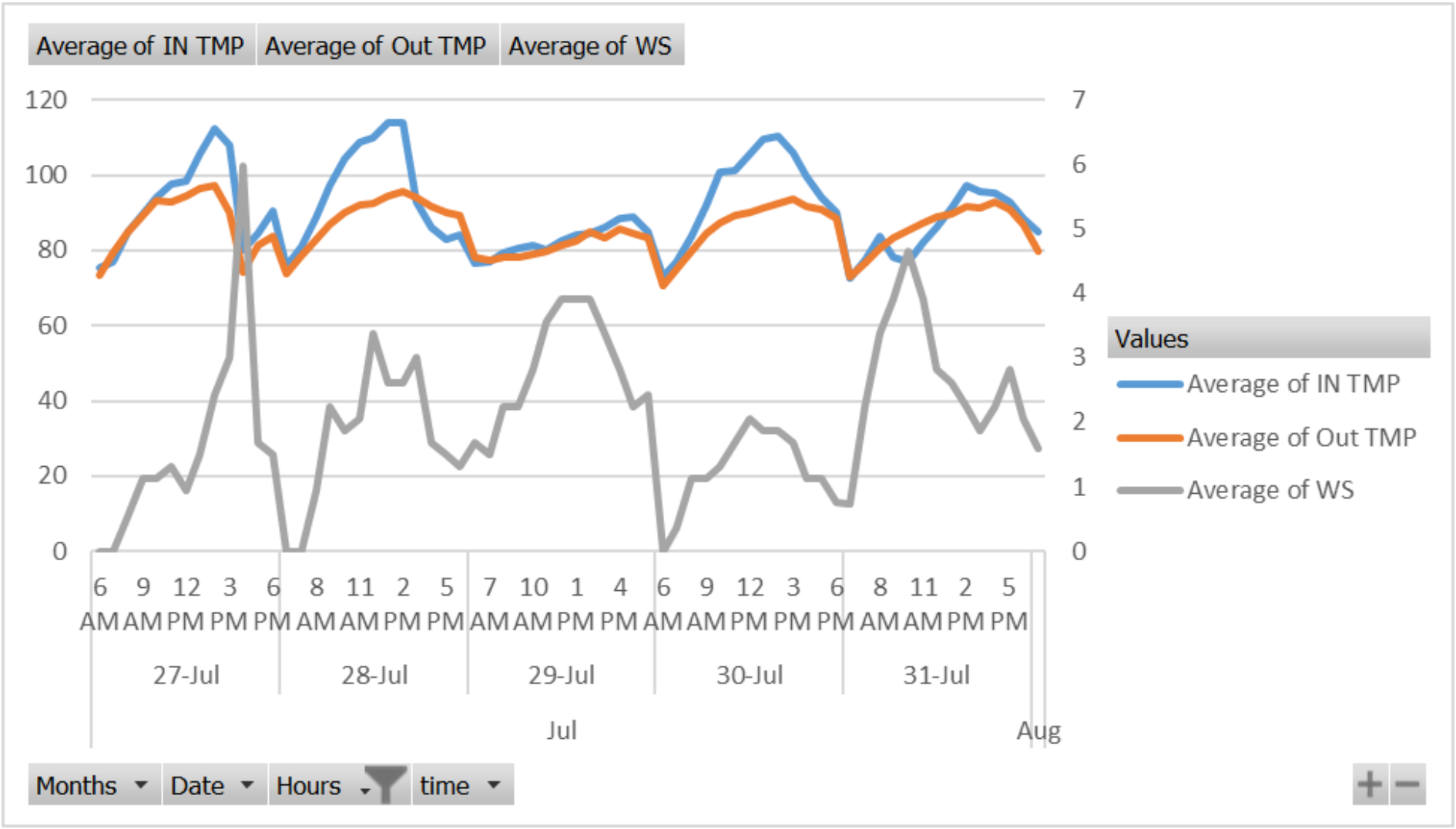
- The taller the house, the better
  - Minimum of 8’
  - >12’ even better
- The taller the house the more expensive

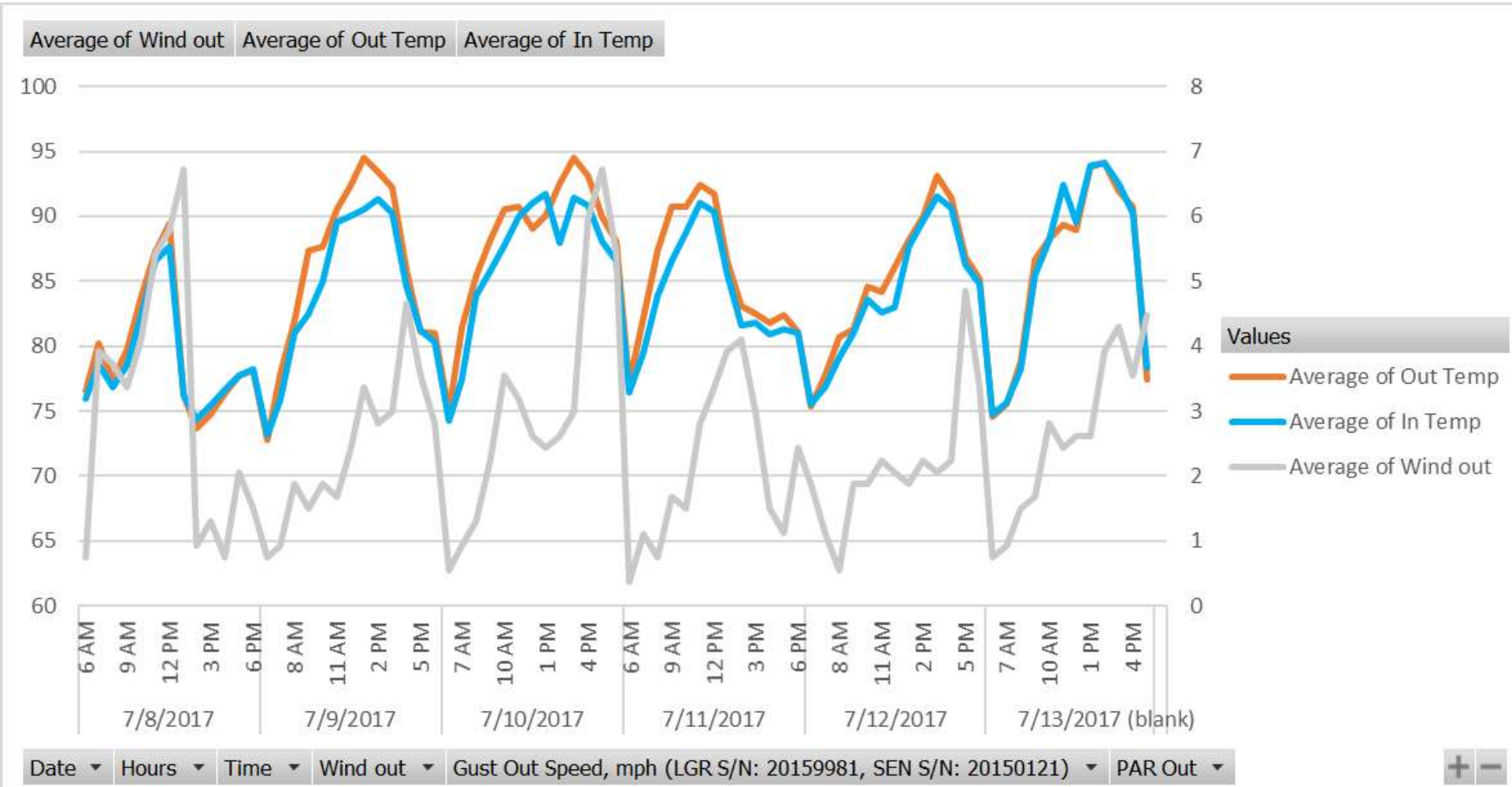
30 x 96 Greenhouse

Gutter Height	Total Cubic Feet	Exchanges per hour	Exchanges per minute	Vent:Floor
4	25084.8	275.5	4.6	35%
8	36604.8	377.7	6.3	70%
12	48124.8	430.9	7.2	105%
16	59644.8	463.5	7.7	140%

5 Bay (30x96) Gutter Connected Greenhouse

Gutter Height	Total Cubic Feet	Exchanges per hour	Exchanges per minute	Vent:Floor
4.0	125424.0	55.1	0.9	14%
8.0	183024.0	75.5	1.3	27%
12.0	240624.0	86.2	1.4	41%
16.0	298224.0	92.7	1.5	55%


Average of IN TMP
Average of Out TMP
Average of WS
120
100
80
60
40
20
0
7
6
5
4
3
2
1
0
6 AM
9 AM
12 PM
3 PM
6 PM
8 AM
11 AM
2 PM
5 PM
7 AM
10 AM
1 PM
4 PM
6 AM
9 AM
12 PM
3 PM
6 PM
8 AM
11 AM
2 PM
5 PM
27-Jul
28-Jul
29-Jul
30-Jul
31-Jul
Jul
Aug
Values
Average of IN TMP
Average of Out TMP
Average of WS
Months
Date
Hours
time


Average of Wind out
Average of Out Temp
Average of In Temp
100
95
90
85
80
75
70
65
60
8
7
6
5
4
3
2
1
0
6 AM
9 AM
12 PM
3 PM
6 PM
8 AM
11 AM
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5 PM
7 AM
10 AM
1 PM
4 PM
6 AM
9 AM
12 PM
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8 AM
11 AM
2 PM
5 PM
7 AM
10 AM
1 PM
4 PM
7/8/2017
7/9/2017
7/10/2017
7/11/2017
7/12/2017
7/13/2017 (blank)
Values
Average of Out Temp
Average of In Temp
Average of Wind out
Date
Hours
Time
Wind out
Gust Out Speed, mph (LGR S/N: 20159981, SEN S/N: 20150121)
PAR Out

Mechanical Ventilation: Exhaust Fans

- Pulling not pushing
- 36” to 56” blades
- ½ HP – 2 HP motors
- Single or 3 Phase

Fan Sizing

Rules of Thumb

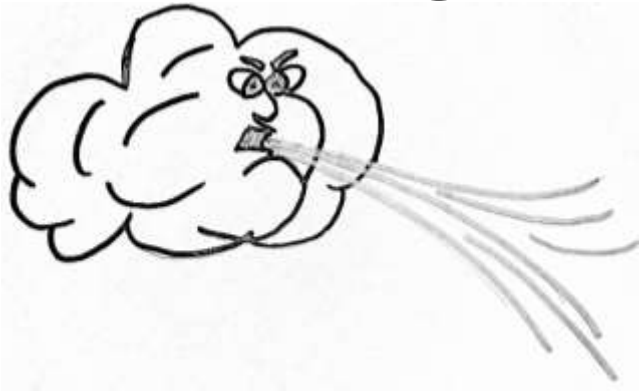
- Fans should not be spaced more than 25’ apart

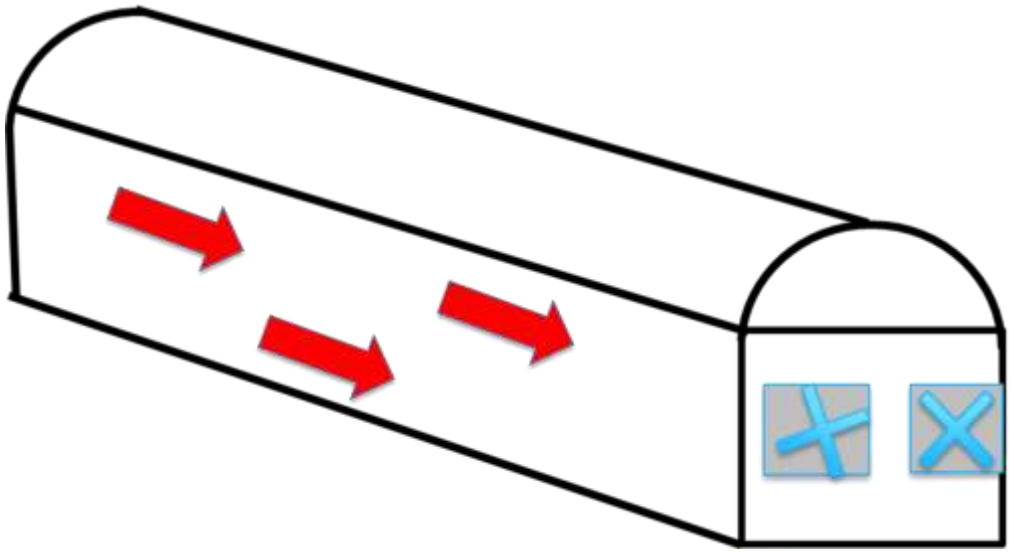
Rules of Thumb

- Avoid pulling over 150 ft.

Rules of Thumb

- Exhaust in the same direction as the prevailing wind

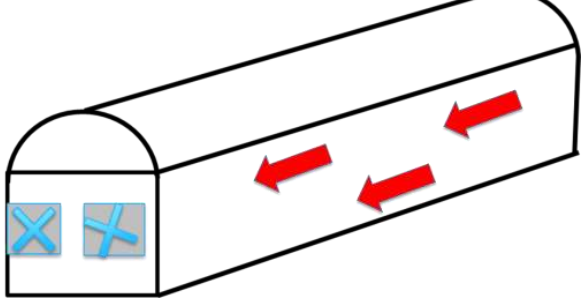




Rules of thumb

- Vents should be 1.25 to 1.5 time the combined area of the exhaust fans.
- 25’ clearance for exhaust outside of GH

Fan Sizing



- The goal is uniform and adequate air flow
- Goal - 1.0 to 1.5 times the volume of the greenhouse per minute
- The volume calculation may only include height up to 8 to 10 ft.
- Length x width x 8 ft. = GH volume in ft^3

Fan Sizing

- GH volume = 23,040 ft^3 x 1.5 exchanges per minute
  - Exchange rate 34,500 $ft^3 \cdot min.$
- Exchange rate ÷ Fan output = # of fans needed

Table 1. Examples of fan performance data.

Blade size (inches)	Motor HP	Fan output (CFM)	
		0.05-inch SP[1]	0.10-inch SP
36	1/2	10,308	9,553
	3/4	11,911	11,253
48	3/4	18,180	16,989
	1	20,628	19,563

[1]SP = static pressure (measured in inches of water)

Fan Check

- Anemometer and measure wind speed on output side of fan
- 14 mph x 1.5 (fps) = 21 fps
- 21 fps x 60 sec/min = 1260 fpm
- 48” = 16ft^2
- 16 ft^2 x 1260 fpm = 20,160 CFM

More is better right?

- Recommended not going over 3.3 fps or 2.25 mph

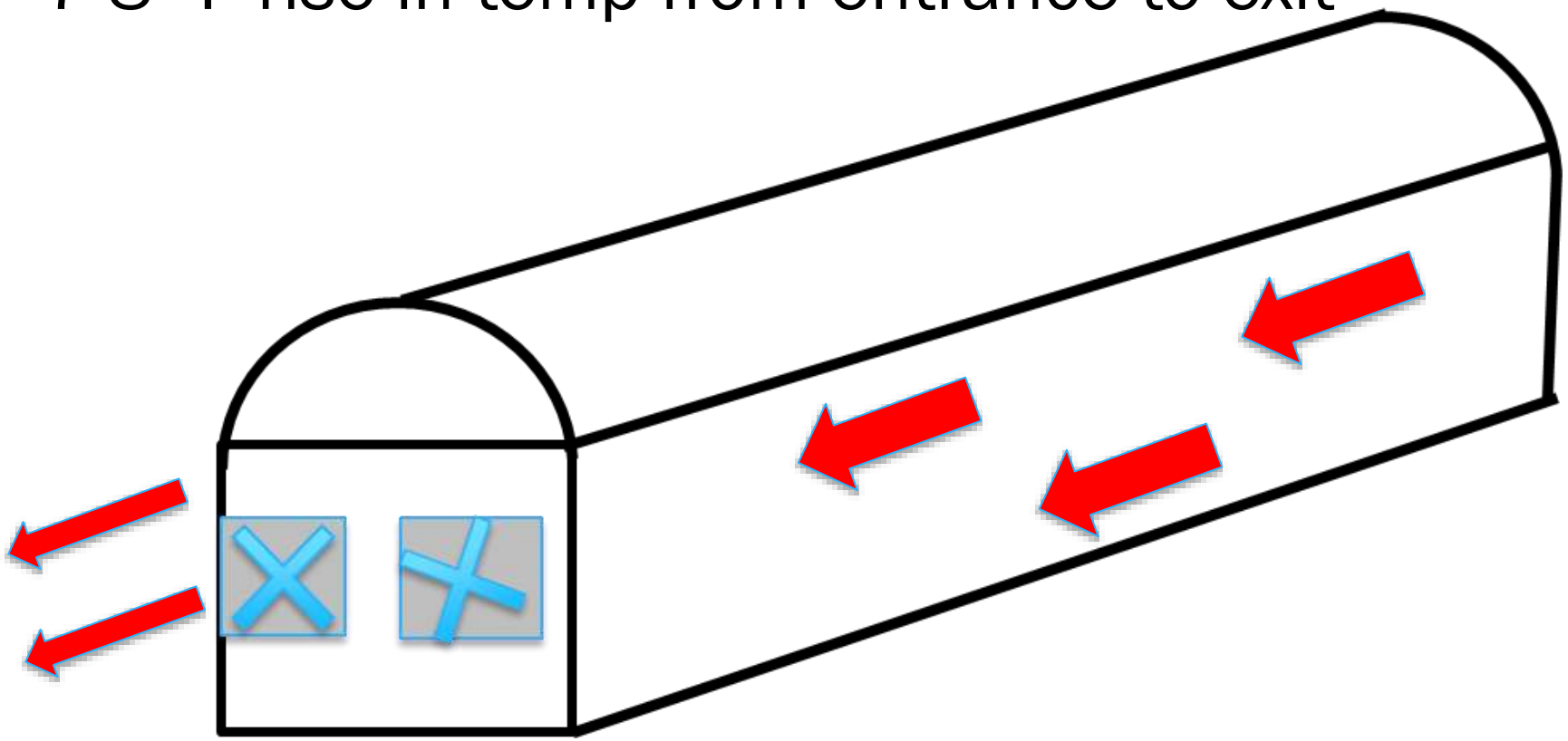
Fan Consideration

- Use 3 phase motors if available.
- Two speed fans
- Variable speed fans

Exclusion Systems and Fans

Fan Vented Greenhouse

- 7-8°F rise in temp from entrance to exit



Evaporative Cooling Systems

Cellulose Pads

- Cellulose pads
- 4” operate best with 250 fpm
- 6” operate best at 400 fpm

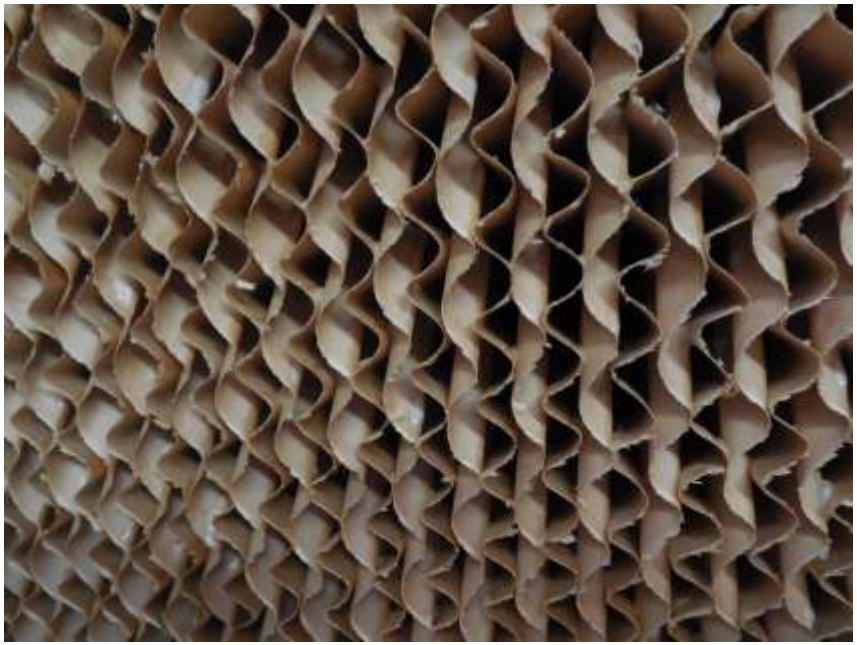


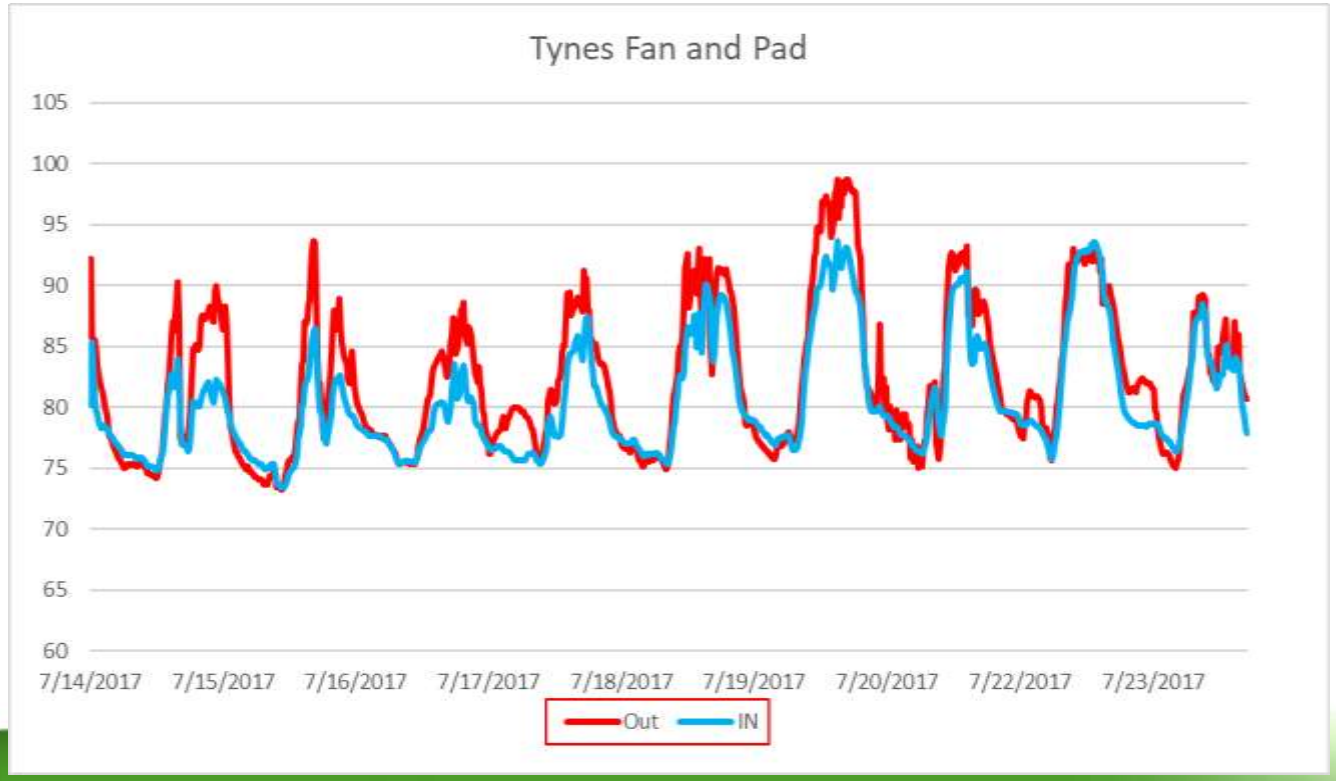
Table 1. Percent of hours within Wet Bulb Depression Ranges (WBD)

WBD (F°)	Percent of hours	
0	3%	
1-5	33%	
6-10	23%	
11-15	25%	= 64%
15-20	16%	

* WBD (F°) = Dry Bulb Temperature - Wet Bulb Temperature and represents the cooling potential that can be reached through evaporative cooling

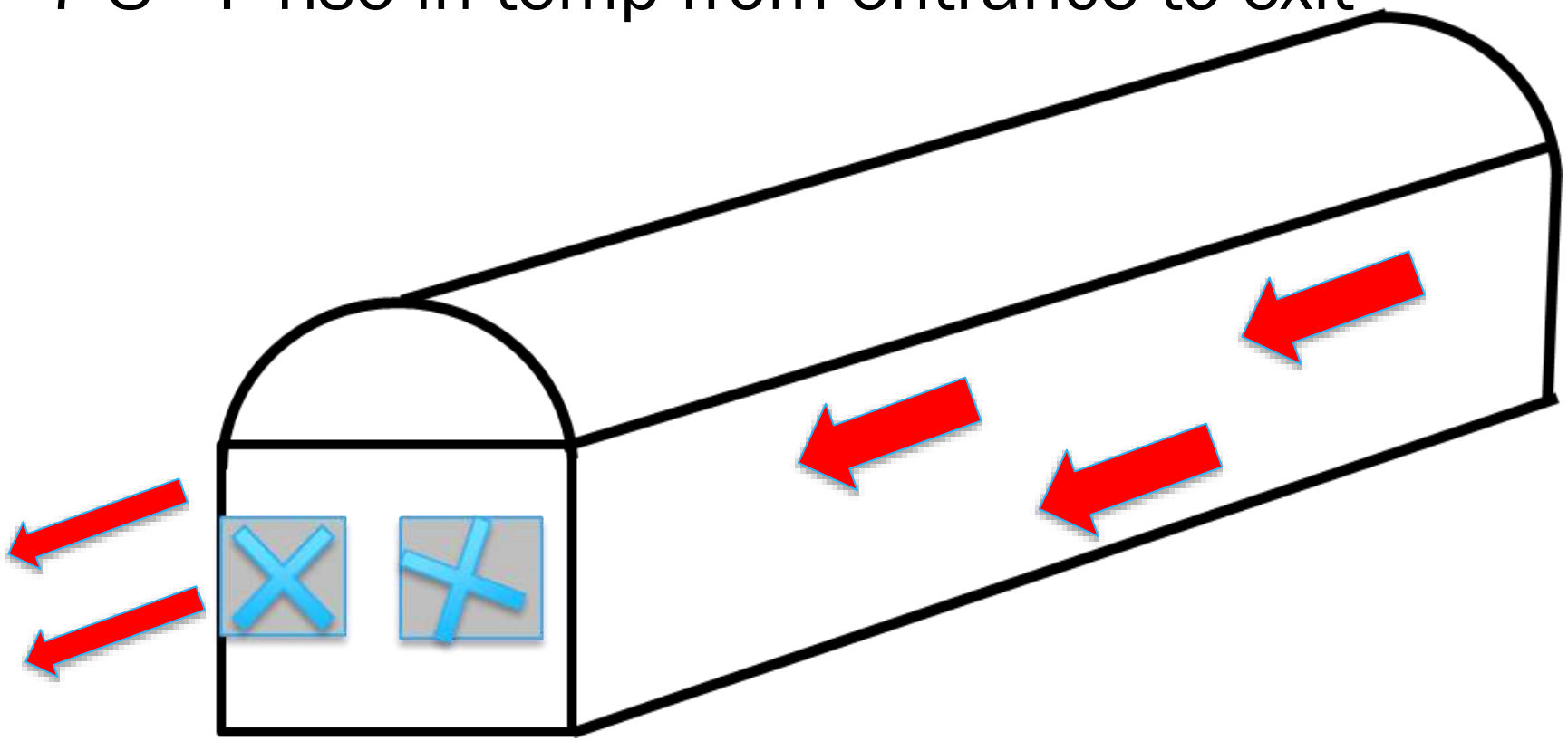
**Calculated from historic weather data from weather station located at the Mobile Regional Airport.

***Only includes hours from 11:00 AM to 3:00 PM during the Month of July in 2014.


Tynes Fan and Pad
105
100
95
90
85
80
75
70
65
60
7/14/2017
7/15/2017
7/16/2017
7/17/2017
7/18/2017
7/19/2017
7/20/2017
7/22/2017
7/23/2017
Out
IN

Fan Vented Greenhouse

- 7-8° F rise in temp from entrance to exit



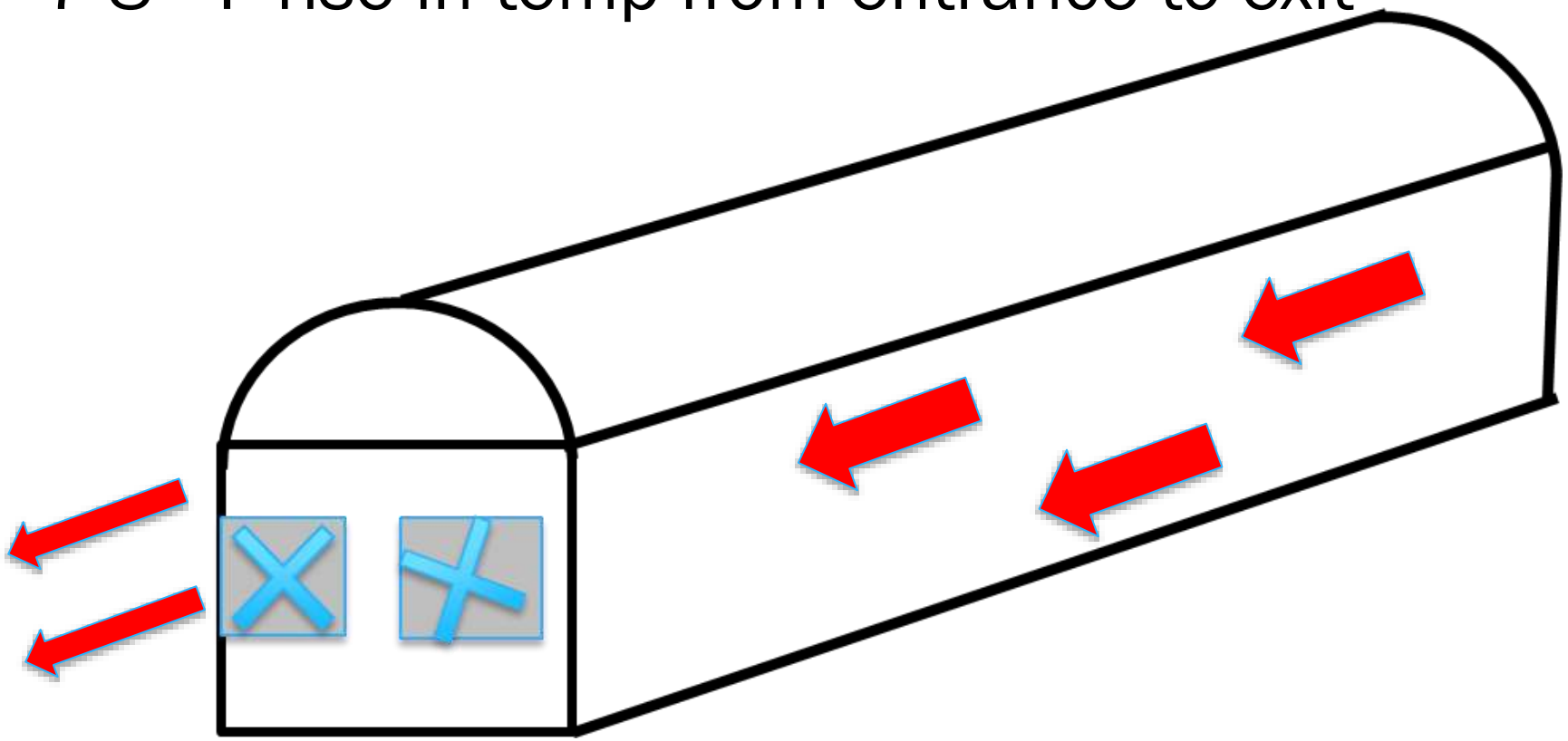
Shade

- Shade cloth comes in variety of types and colors
- Shade percentage
  - 30, 50, 60, and 80 %
  - > 50 for vegetable production
- Shade % does not correlate to temperature reduction….a 50% shade doesn't reduce temperature by 50%

Mist Systems

Fan Vented Greenhouse

- 7-8° F rise in temp from entrance to exit



Louvers

Wall Vents

Roll-up sides and fans

Retractable Structures

Greenhouse Type	Priced for area (ft^2)	$/ft^2$
Gutter connected - fan and pad	13,000	6.2
Free standing- fan and pad	2,880	6.5
Cravo retractable roof	23,616	4.36
Cravo retractable roof	53,136	2.8
High tunnel	2,880	2.18

Humidity

- High humidity = disease
- Condensation
- Ways to reduce condensation
  - Horizontal Flow Fans
  - Vent the greenhouse

Jet Fan


Super Saver
Heater

Greenhouse Heating

Greenhouse Heating

- Heat retention
  - Well sealed house
    - Check runner boards and seal all cracks
    - Make sure fan and louvers shut
  - Double Poly Houses
    - Increases heat retention by 20-30%.

Calculating Heat Loss

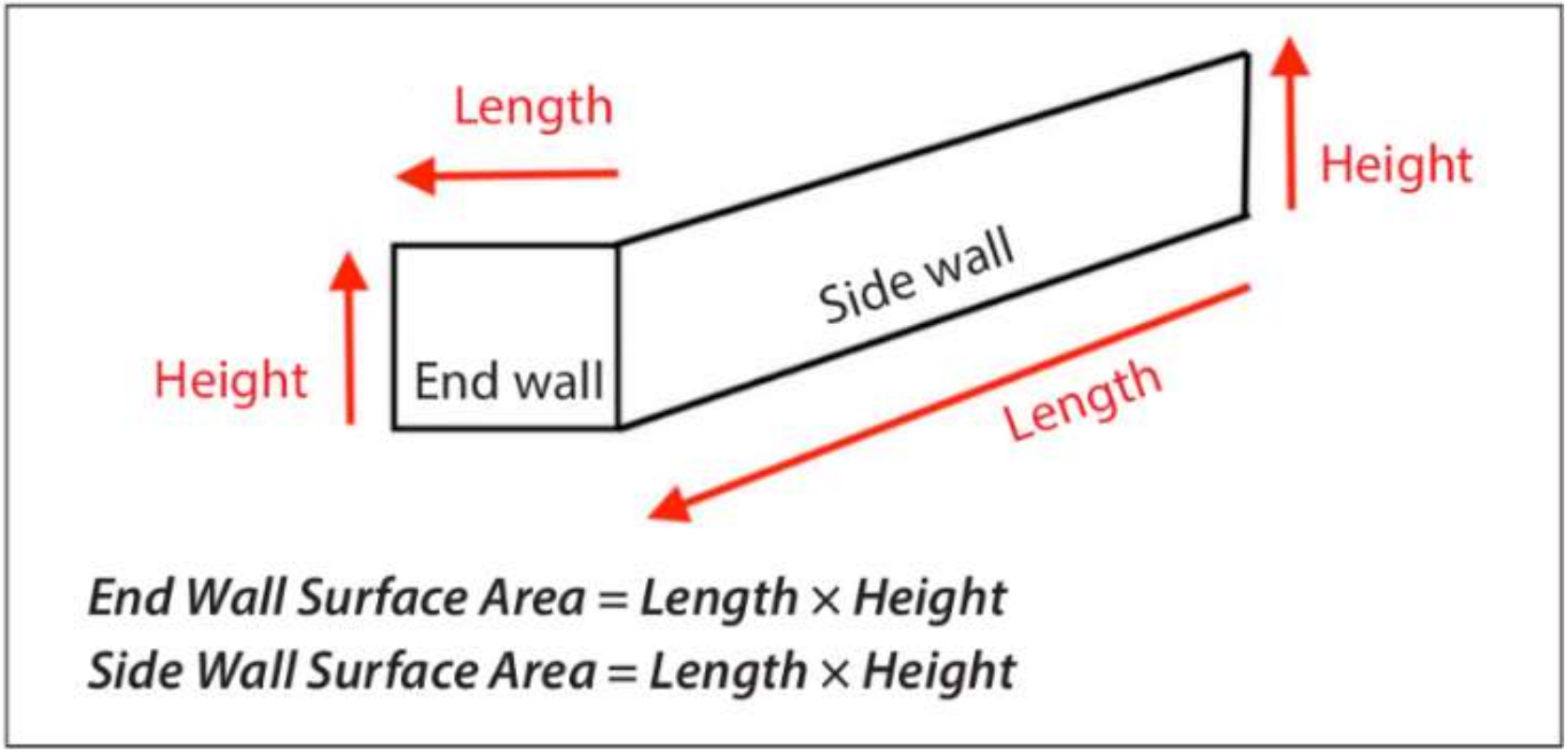
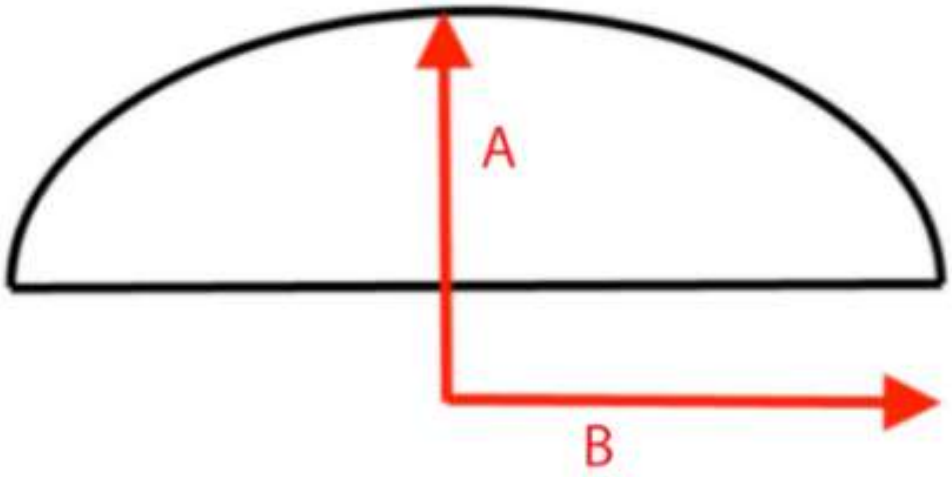


Figure 5. Calculating end wall and side wall area.

Calculating Heat Loss



$$\textit{Surface Area of Quonset Gable} = \frac{A \times B \times \pi}{2}$$

Figure 6. Calculating Quonset gable area.

U- Value (BTU·ft2·°F)	
Single Poly	1.15
Glass	1.13
Double Poly	0.7

Table 1. Greenhouse BTU Requirements 62160 ft^2 Greenhouse Range, Bonnie Plant Farm, Union Spring AL.

Surface Area	Area ft^2	Covering	U-value		BTU Loss (without curtain)	BTU Loss (with curtain)
Roof	71,040.00	Double poly (w/curtain)	0.8 (0.5)		56,832.00	35,520.00
Gables	4,665.00	Dynaglass (w/curtain)	1.2 (0.75)		5,598.00	3,499.00
Endwalls	8,400.00	Dynaglass	1.2		10,080.00	10,080.00
Sidewalls	2,960.00	Dynaglass	1.2		3,552.00	3,552.00
				Total	76,062.00	52,651.00

Energy Curtains

Alternative Fuels

Cost associated with heat source			
Fuel	Cost	Unit	$/MMBTU
Propane	$2.30	gal	$30.00
Natural Gas	$1.34	Therm	$8.84
Geothermal	-	-	$5.58
Wood Pellets	$250	ton	$14.5

Take an integrated approach

Table . Frequency of outside temperatures Union Spring, AL. 2011-2012

	24 Hour Period				Night Only 6:00 AM - 6:00 PM			
	Dec 14 - Jan 18		Jan 19-Feb 15		Dec 14 - Jan 18		Jan 19-Feb 15	
Outside Temperature F°	*No. of Hours*	%Total Hours	*No. of Hours*	Total Hours	*No. of Hours*	% Total Hours	*No. of Hours*	% Total Hours
10-15	0	0%	0	0%	0	0%	0	0%
15-20	8	1%	2	0%	6	2%	1	0%
20-25	10	1%	12	2%	8	2%	10	3%
25-30	34	4%	28	4%	18	5%	20	6%
30-35	44	5%	30	4%	36	9%	21	7%
35-40	69	8%	44	7%	42	11%	31	10%
40-45	96	11%	60	9%	67	17%	36	12%
45-50	129	15%	88	13%	63	16%	54	18%
50-55	132	15%	90	13%	59	15%	43	14%
55-60	112	13%	88	13%	44	11%	37	12%
60-65	101	12%	120	18%	36	9%	38	12%
65-70	73	9%	83	12%	11	3%	17	6%
70-75	41	5%	20	3%	0	0%	0	0%
75-80	5	1%	7	1%	0	0%	0	0%
Total	854	100%	672	100%	390	100%	308	100%

- Let gas make up the difference
- 86% of hours were > 35°F
- 46% of hours were > 55°F

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Heater Considerations

- Advantages of multiple units
- Make sure your house is tight
  - Gaps around doors, and runner boards
  - Louvers operational
  - Roll-up sides
  - Get a meter
- Avoid unvented heaters

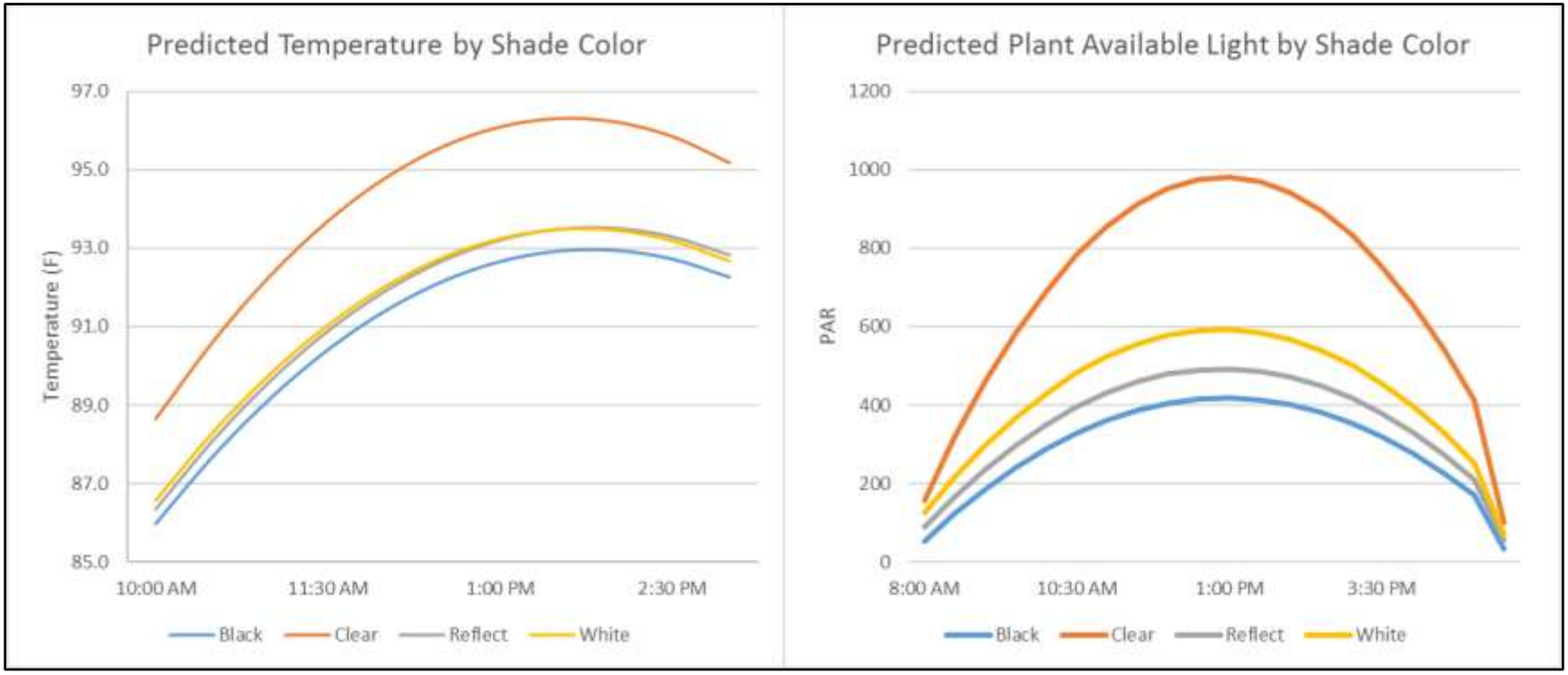
Controllers


GROWMATE
75°


Aspirator

Homemade systems

Research at Auburn: Shade Evaluation


Predicted Temperature by Shade Color
97.0
95.0
93.0
91.0
89.0
87.0
85.0
Temperature (F)
10:00 AM
11:30 AM
1:00 PM
2:30 PM
Black
Clear
Reflect
White
Predicted Plant Available Light by Shade Color
1200
1000
800
600
400
200
0
PAR
8:00 AM
10:30 AM
1:00 PM
3:30 PM
Black
Clear
Reflect
White

Reducing Heating Cost

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Controlling the Greenhouse Environment for Aquaponics

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Controlling the greenhouse environment is challenging because greenhouses gain heat during the day and lose it rapidly to low nighttime temperatures. The principles behind managing a greenhouse environment are the same, regardless of its purpose. While this fact sheet explains these principles, the reader should seek professional expertise when designing a greenhouse and sizing environmental controls because the capital cost is too great to risk any design mistakes.

Ventilation and cooling

environment can be the difference between success and failure in any greenhouse business.

Natural ventilation

Natural ventilation capitalizes on air movement to push and pull hot air out of the greenhouse through open wall sections or the roof. Wind is the driving force behind most natural ventilation. Even a small amount of wind can be effective in pushing air through the greenhouse, over a crop canopy, and out through vents installed on end walls, side walls or through the roof. Warm, humid

Questions?

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