GREENHOUSE - Q AND A

TIPS AND ADVICE

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Question : This question was asked of us from a grower client in the Central United States. How do you calculate the solar loading and the cooling required.

As stated in the preamble on the Frequently Asked Question sheet there are many items that will effect the total solar loading on your greenhouse which result in the selection and sizing of the cooling/ventilation systems.

The primary tools/devises/methods used to offset the solar loads are primarily:

- The plants themselves - they cool /remove solar heat gain levels by up to 50%. (This of course is related to the crop, the crop density and crop maturity.) To get this point across just visit a tomato house verses at partially empty bedding crop house on the same day where max. solar loads are occur and you'll quickly see the power of plant transpiration.
- The building ventilation/ cooling systems
- Shading systems
- High Pressure Fog Cooling / Evaporative Cooling.

The items that effect the solar loading on your structure are:

- The location of the project both in terms of latitude and elevation above sea level.
- Local environmental factors: Ie temperature, humidity, air clarity / haze etc.
- Orientation of the structure. The smaller the structure the greater the effect.
- Cladding selection materials.

In the Previous vent write-ups we have been asked how we arrived at the 15,000,000 BTU/hour total solar load.

The project information from the example is as follows:

"Say a grower is planning on building a 10 bay gutter connect project that is located near Fort Wayne, Indiana. The project is comprised of 30' wide gutter houses each 240 feet long for a total area of 72000 sq. ft . and wishes to use only roofing vents for cooling.

Environmental Data for the site is 92 deg. F DB (dry bulb)/73 deg. F WB (wet bulb) summer outdoor design and -4 deg. F winter outdoor design, the project is located at 41 deg. F north latitude at a elevation of 793 feet above sea level."

At our office we use a computer model that allows hourly calculations but here by we will demonstrate the method by hand calculations.

Using ASHRAE standards, this is the rational.

At 40 deg. N latitude solar load imposed on the greenhouse structure will be predominately roof load. At 40 deg. north latitude the greatest solar loading will occur on June 21 at 12:00 PM. Based on Simpson's rule with time interval equal to 10 minutes. (ASHRAE - fundamentals/fenestration) the load is 267 BTU's per sq. ft. (826 watts/M^2). This is used for our max. load calculations.

Note: We assumed no shading factor (SC) other than the cladding product which is 0.91 and based on a clear day.

Chart One

	Area (sq. Ft.)	SHGF	SC/trans factor	Load-Btus/hr
East Wall	2880	41	0.91	107,452
West Wall	2880	41	0.91	107,452
North Wall	4500	38	0.91	155,610
South Wall	4500	95	0.91	389,025
Roof	72000	267	0.91	17,493,840
Slope factor on roof	28800	(38+95)/2	0.091	1,723,680
Total Solar Heat gain				18,253,377

Note: The above chart assumes to be a perfectly clear day, free of clouds and haze, and in the real world this seldom happens so we like to apply a haze/cloud factor, as illustrated below.

June 21: 12:00 PM, 40 deg. N latitude

Chart Two

Corrected	Area (sq. Ft.)	SHGF	SC/trans factor	Load-Btus/hr
East Wall	2880	41	0.77	90,921
West Wall	2880	41	0.77	90,921
North Wall	4500	38	0.77	131,670
South Wall	4500	95	0.77	329,175
Roof	72000	267	0.77	14,802,480
Adjusted Solar Heat Gain				15,445,167

Note: The above chart would closer reflect an average typical day.

Now to throw a real kicker.

Let's move this entire greenhouse to Logan Utah.

According to weather data (again as published in ASHRAE - fundamentals) Logan has a 1% summer design of 93 deg. F DB design which is not that different than Fort Wayne at 92 deg. F DB. Both projects are located at about 41 deg. N latitude.

So would it be safe to say the loads will be the same ?

If you did you would be incorrect.

The greenhouse in Logan Utah would be faced with a higher solar load just by virtue of the increased elevation from sea level. .... Logan is 4,775 feet about sea level. Whereas, Fort Wayne is 791 feet. ...... Solar loading increases 0.07% every 1000 feet in elevation. So the solar loading at Logan would be that much greater.

Rule of Thumb

Typically, (again by rule of thumb), plant transpiration (we're assuming the house is full of crop), will look after 1/2 of the solar gain. So the ventilation and cooling systems will need to look after 7,700,000 BTU's of heat. For those that wish this expressed in refrigeration terms this is a 641 Tons mechanical cooling load.

Just to back track a bit. Lets assume the grower wished to use fan cooling. What would the total airflow rate be if they wished to maintain a spacial temperature of no more than 10 deg. F from ambient.

Using $Q = H / 60 X C * D (ti-to)$

where H = 7,700,000 BTUs/hr
C= specific heat of air = 0.245 BTU/Lb X F
D = density of air 0.075 lbs/ft 3
Ti - To = 10 deg. F

which yields an air flow rate of 698,412 CFM of air flow.

Check using .... the Rule of thumb air flow rate of 1 AC/min based on 8 foot height.

= 72,000 sq. ft. X 8 feet = 576,000 CFM

By now you should realize that the "old rule of thumb can leave you short". 698,000 CFM verses 576,000 CFM. (The old rule of thumb may work well in a greenhouse with soil or gravel floors - where an additional evaporative cooling base is created. However, in modern houses with covered floors and drip irrigation, this evaporative cooling base is not available.). Basically ... if you short yourself on cooling and ventilation, the crop will suffer stress simply by the increased in transpiration rates. " They ... the plants are spending all their energy just to keep cool, not growing or producing fruit etc. "

Daily Load Profile Curve

For those interested the chart below is a sample of a the cooling load profile curve for the roof only on the above project. The values calculated is solar loading in BTU's/hr. Only the months of Jan to Aug have been listed.

Chart 3 - Roof Only (Jan to Aug)

Solar Time	Jan	Feb	Mar	Apr	May	June	July	Aug
5	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
6	Nil	Nil	Nil	609840	1718640	2217600	1774080	665280
7	Nil	Nil	1441440	3381840	4823280	5377680	4878720	3437280
8	776160	2383920	4712400	6819120	8094240	8482320	8038800	6763680
9	3049200	5433120	7927920	9812880	10810800	11143440	10755360	9646560
10	5322240	7927920	10311840	12030480	12972960	13194720	12806640	11864160
11	6874560	9480240	11808720	13471920	14248080	14414400	14081760	13250160
12	7373520	9979200	12363120	13970880	14691600	14802480	14525280	13693680
13	6874560	9480240	11808720	13471920	14248080	14414400	14081760	13250160
14	5322240	7927920	10311840	12030480	12972960	13194720	12806640	11864160
15	3049200	5433120	7927920	9812880	10810800	11143440	10755360	9646560
16	776160	2383920	4712400	6819120	8094240	8482320	8038800	6763680
17	Nil	Nil	1441440	3381840	4823280	5377680	4878720	3437280
18	Nil	Nil	Nil	609840	1718640	2217600	1774080	665280
19	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
20	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
21	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
22	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
23	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
24	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	Jan	Feb	Mar	Apr	May	June	July	Aug
Daily totals	39417840	60429600	84767760	106223040	120027600	124462800	119196000	104947920

LATITUDE

What would happen if we moved this project further north say up to 48 deg. north latitude.

June 21: 12:00 PM, 48 deg. N latitude

Chart 4

Corrected	Area (sq. Ft.)	SHGF	SC/trans factor	Load-Btus/hr
East Wall	2880	40	0.77	88,704
West Wall	2880	40	0.77	88,704
North Wall	4500	37	0.77	128,205
South Wall	4500	134	0.77	464,310
Roof	72000	252	0.77	13,970,880
Adjusted Solar Heat Gain				14,740,803

Note: The above chart would closer reflect a typical day.
Compare this with Chart 2.
Even though this structure is further north, the solar loading does not really fall that much.
The roof loading sure dropped, but take a look at how the south wall gain increased. Interesting.

AIR SPEED

Air speed influences many factors in plant growth. These include transpiration and evaporation, leaf temperature and humdity and carbon dioxide. In general air speeds of 20 to 50 feet per minute across the leaf surfaces facilitate the uptake of available carbon dioxide, promotes transpiration/evaporation and reduces leaf temperature. At high air speeds 100-200 feet per minute plant growth is inhibited.

Here's a way to check the air speed.

Say a greenhouse structure is comprised of 21' wide X 10' feet high under the gutter gutter houses. Each house is ventilated with an exhaust fan rated at 19,000 CFM air flow. The exhaust fans are located at mid point of the height under the gutter.

The air flow rate would be 19,000 / (21 X 10) = 90 feet per minute, assuming a bench type crop.

If it was a tall vine like crop such as tomatoes or cucumbers, the face area could be as high as 180 feet per minute.

In the case of the tomato house, it would be unwise to add more air flow for cooling, if cooling was problem since all that would occur is greater mechanical induces stress on the crop. here the grower may wise to consider evaporative cooling of high pressure fog cooling to reduce the heat gain of the structure or by adding some form of shading which would also limit the solar gains.

PLANT TRANSPIRATION

In the project sample above, assume the grower is wishing to raise tomatoes. The plant density that they are targeting for a one plant per four sq. feet. Therefore, in the 72,000 sq. feet of greenhouse structure, they should try to achieve 18,000 plant spaces. Generally it is accepted to provide at least 1.0 US Gal (4 litres) per plant per day, irrigation water demands.

Now lets assumed the “old 50% rule of thumb” (ie 50% of the daily solar load is offset by plant transpiration. If you look at chart 4 for the month of June, the total (average/projected) daily solar load is 124,462,800 BTU's. 50% of this load is assumed to be controlled by plant transpiration. So 50% of 124,462,800 62,231,400 BTU's.

To offset this load would require the evaporation of 59,268 lbs of water (7,115 US Gals or 26,933 litres) or 0.39 US gal/plant (1.4 litres/plant). So almost 1/2 of the water uptake by the plants on this day is just just for cooling. The question to ask is ...... gee’s not much growing or production is left available for the plants ?

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