What is an energy curtain?

What effect has a curtain ?

1. Direct effects:

- Reduces the energy losses from the greenhouse.
- Reduces light / increases humidity
- Reduces the greenhouse volume
- Reduces peak demand, and helps Kyoto!

What effect has a curtain?

2. Indirect effects:

- During the day, the reduced light level reduces production !!!
- It affects plant temperature, humidity and carbon dioxide.

Types of curtain material

- Photoperiod + Energy (black-out)
- Energy curtain : aluminized material
- ‘Energy and Humidity : clear plastic
- ‘Energy’ + ‘Shade’ curtain : white cloth or aluminized / polyester strips

In floricultural greenhouses, we often find the energy / shade option.

How to control an energy/shade curtain during winter??

- **During night time, it is generally closed for the obvious reasons**
- **During the day time ???**

During the night

- Close the curtain when $\Delta T > 10$ °C
- Maintain proper seals!!
- Move air to reduce horizontal temperature differences
- Open the curtain in steps (0.5-1.0%) with pauses
- Open different sections at different times

During the day

- **How do we determine when to close / open the curtain ?**

What are some of the options?

- Delay opening / closing at SR / SS, respectively ?? If so, when?
- During day time based on outside radiation, temperature differential or both??
- Provide a higher night than day time temperature (- DIF) while achieving a similar average T_{24} ??

How can we determine these costs / benefits??

- I will try to do this in a few steps based on a number of simple assumptions and equations.
- Most of the calculations will be based for a glasshouse on a $ per ha per hr basis: $ / ha / hr.

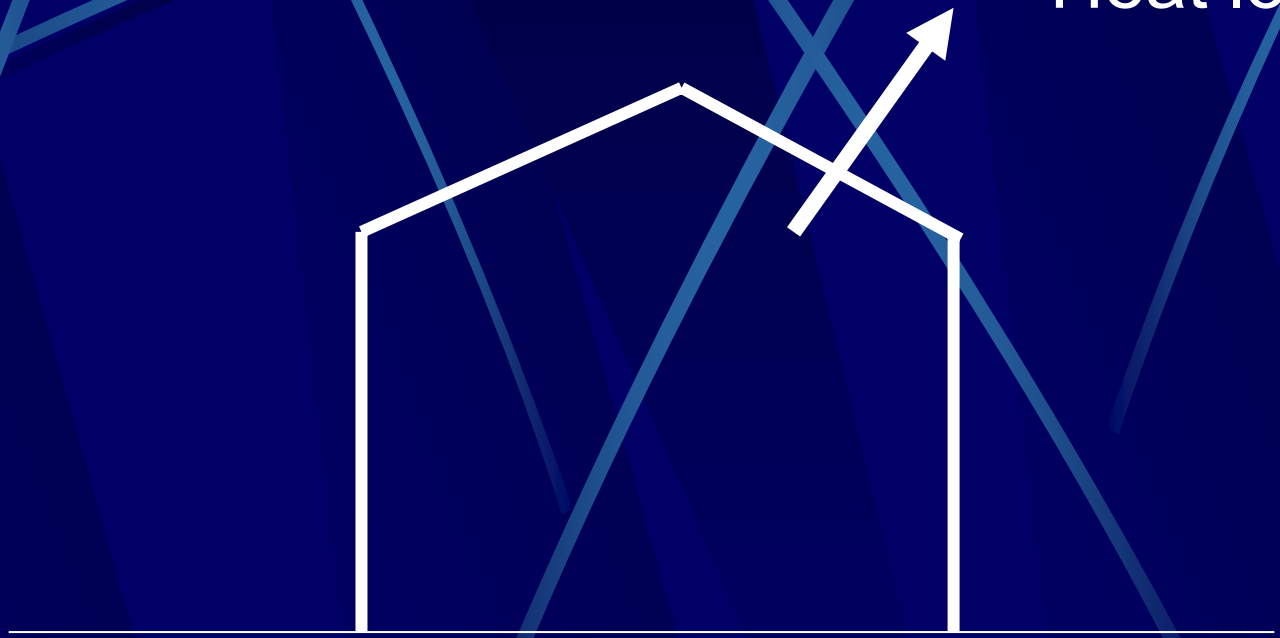
What to include?

- Fuel price
- Energy savings
- Light shading
- Indoor-outdoor temperature (ΔT)
- Effect of light shading on production

Step 1

- How do we estimate the heat loss of a greenhouse?

Heat loss (1)



How to calculate the cost of heating?

-The U-value of a gutter connected glass greenhouse.

-Temperature differential (ΔT) between inside and outside

-Surface area of the greenhouse shell

-Gas consumption can be calculated using 80% conversion in the boiler.

-The price of fuel, e.g. gas ($0.40 / m^3)

Example of how much it Cost to heat 1 ha of greenhouse?

- 1 ha of glass greenhouse.
- Heat loss : 9 W / m^2 / ºC
- The cost of heating: 4.30 x Δ T ($ / ha / hr)
- For Δ T = 25ºC differential, this will be about 107 $ / ha / hr

Is this true for day and night?

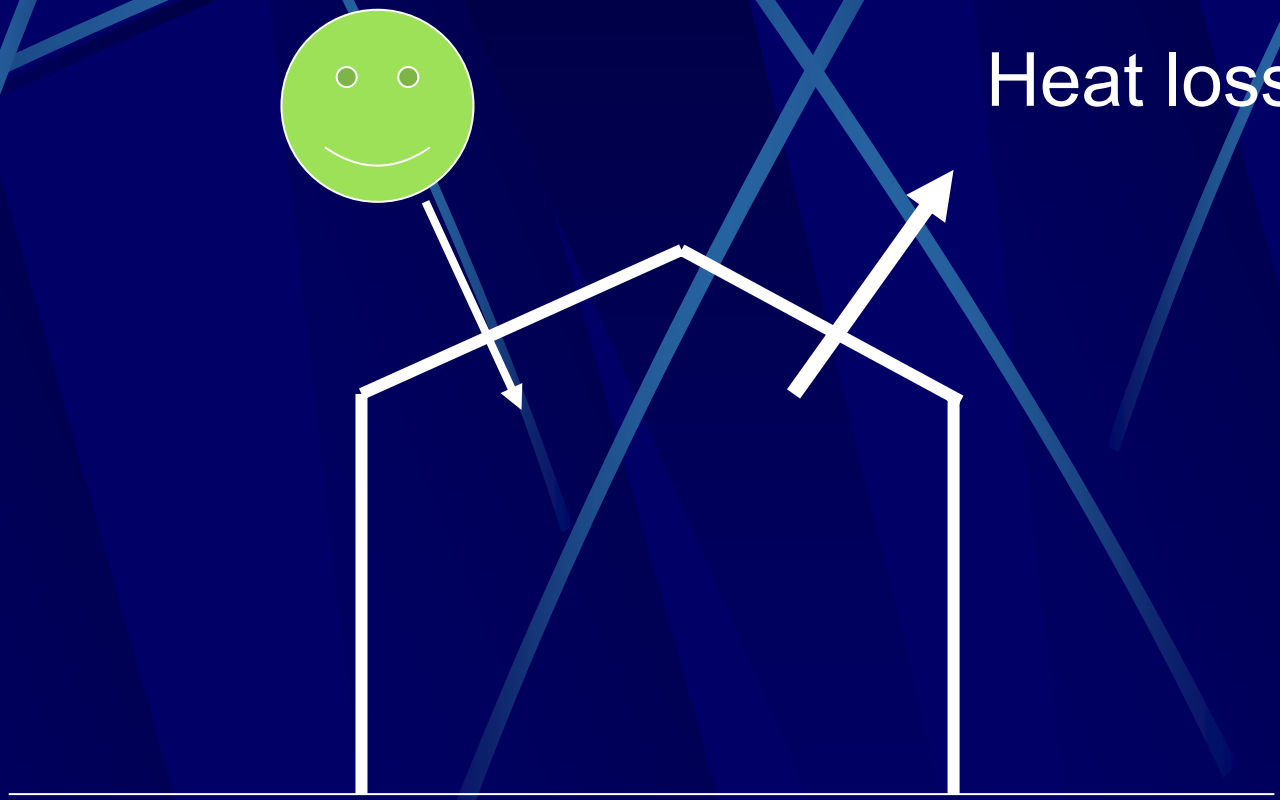
- **Answer is NO**
  - **During the day time, we have to adjust for the incoming global radiation (0 - 1000 W / m^2.**
  - **Day time temperature is usually about 5 ºC warmer than night temperature during the winter.**

Step 2

- What is the effect of solar radiation on heating costs?

Solar radiation(2)

Heat loss(1)



Heat loss minus incoming radiation.

- Assume 70% of the global radiation enters a glass greenhouse
- The cost of 1 ha of glass greenhouse per hour depends on 2 variables:

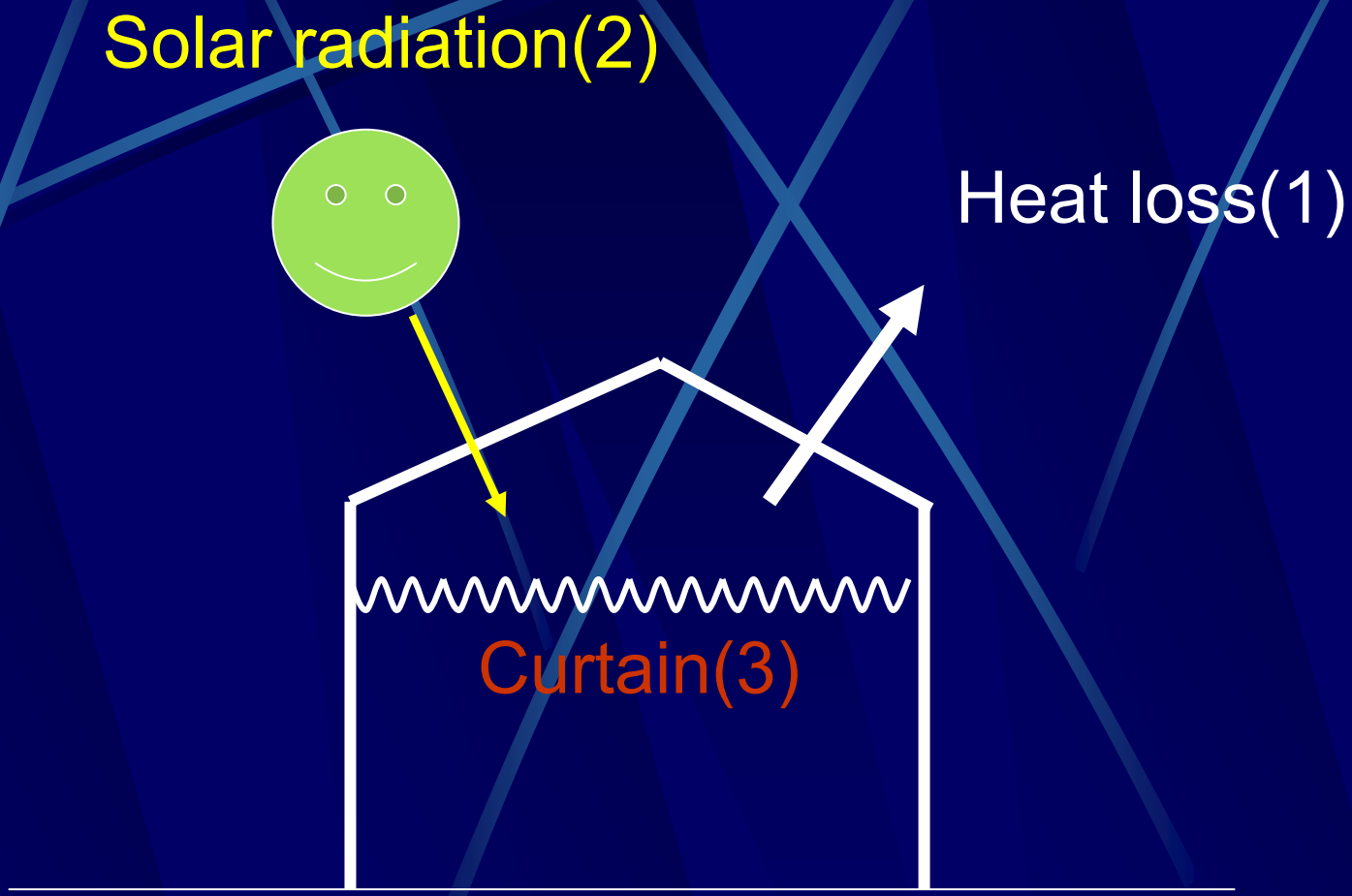
$$4.30 * \Delta T - 0.33 * R \text{ (\$ / ha / hr)}$$

What does this mean??

- When the previous equation is equal to zero then the boiler does not have to run!!! $4.30 * \Delta T - 0.33 * R = 0$
- For instance for a ΔT of 20C then the boiler does not have to run at outside radiation of 260 W / m^2

Step 3

- What happens when you use a curtain?
- Let's assume a shade curtain with 30% energy savings and 50% light loss


Solar radiation(2)
Heat loss(1)
Curtain(3)

Effect of curtain at night?

- During the night, we have to account for the energy losses from the greenhouse

- If we assume, that the curtain saves 30%, then the savings are:

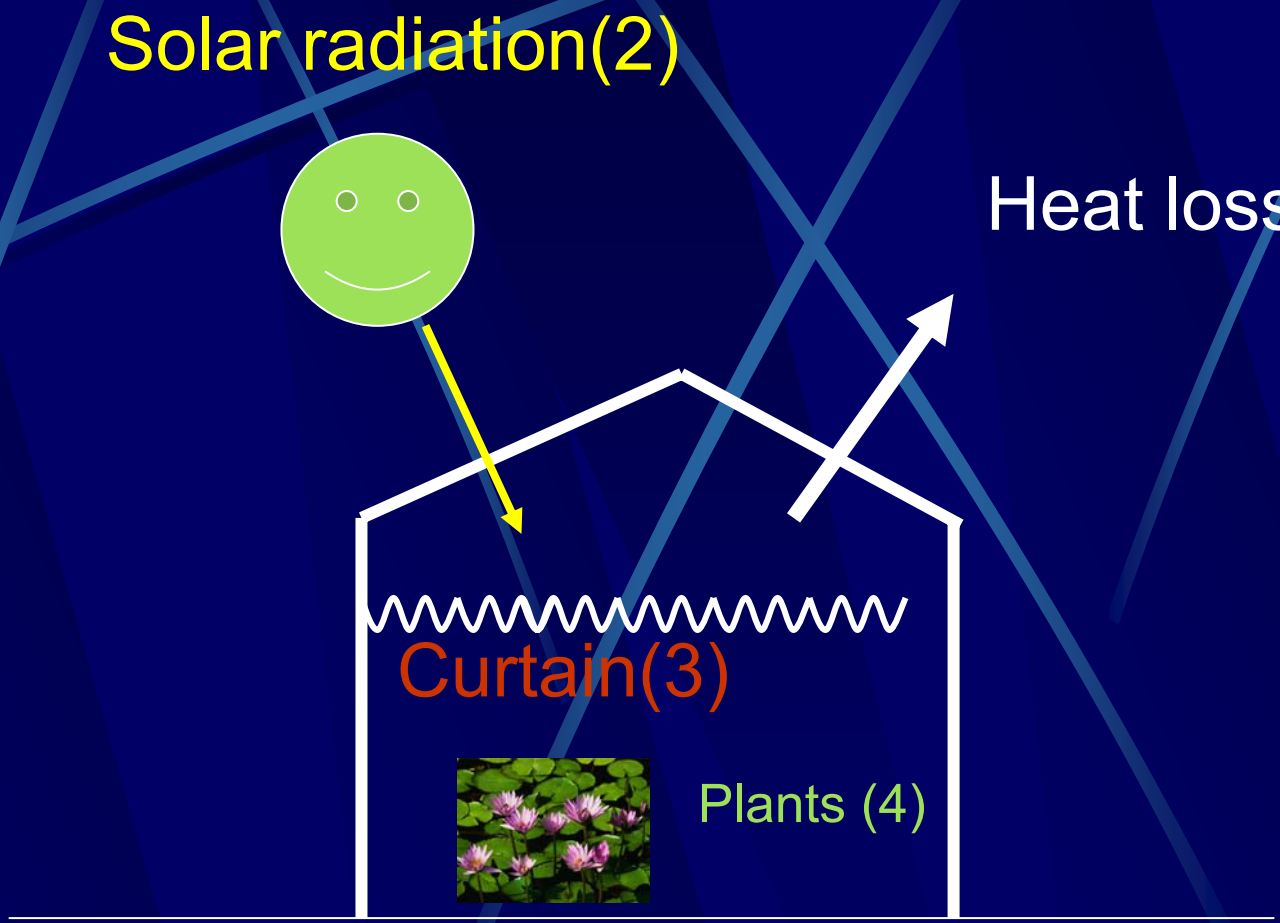
$$1.29 \times \Delta T \text{ (\$ / ha / hr)}$$

Effect of curtain during the day on energy savings?

- During the day, we have to account for both heat losses and incoming radiation
- If we assume that the curtain has a 50% shading factor, then the heat savings are : **1.29 x ΔT – 0.17 x R ($ / ha / hr)**
- So for a ΔT of 20ºC and curtain closed then the boiler does not have to run when outside radiation=150 W/m^2

Step 4

- What is the effect of the curtain on the crop loss due to the reduced light?


Solar radiation(2)
Heat loss(1)
Curtain(3)
Plants (4)

How do we estimate the light losses in terms of $

- As the energy curtain also affects light so it will affect growth / dry matter (DM).
- Based on a number of assumptions such as (1 MJ=0.5 g DM = $ 0.025), then the energy savings have to be greater than the crop loss to close the curtain. **(Note. I used dry matter data for cut flowers and annual revenue for cut flowers in Ontario)**

Based on a glass greenhouse; $0.40 / m3 gas; an shade curtain with 30% energy saving and 50% light shading, the curtain should be closed when:

$$\Delta T > 0.37 \times R \quad \text{or} \quad R < 2.7 \times \Delta T$$

So when outside radiation is 50 W / m^2, then you close the curtain when $\Delta T > 19^{\circ}C$; or when you know ΔT (say 10ºC), then close the curtain at 27 W / m^2 or less.

What other effects does a curtain have ?

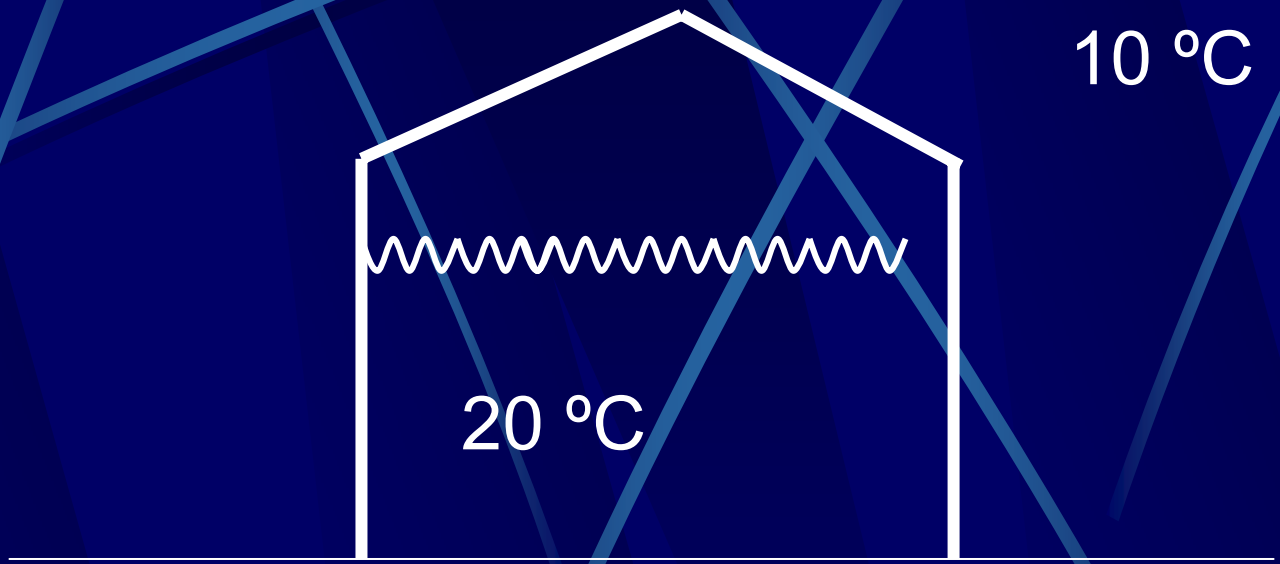
- **(Plant) temperature ↑**
- **Pipe temperature ↓**
- **Humidity ↑**
- **Transpiration ↓**
- **Carbon dioxide losses / consumption ↓**
- **Horizontal temperature differences ↑**

From the calculations:

- Curtains can be closed / opened based on some scientifically based relationships and assumptions.
- Curtain should be closed when:

$$R < 2.7 \times \Delta T$$

For $\Delta T = 10\ ^{o}C$



Close curtain if  is less than 27 W / m^2

Open curtain if  is more than 27 W / m^2

Based on a curtain with a 30% energy saving, 50% shading factor and using \$0.40 / m^3 gas and incorporating an estimated production loss due to shading in a glass greenhouse.

- Close curtain depending on $T_i - T_o$ (ΔT)

for ΔT = 10C at R < 27 W / m^2 ;

for ΔT = 20C at R < 55 W / m^2 ;

for ΔT = 30C at R < 80 W / m^2 ;

Some practical implications

1. **For more valuable crops, and / or when light is more important, the curtain should be closed at lower radiation level**
2. **When fuel price increases, then the curtain should be closed at higher radiation. The reverse is also true.**
3. **When the curtain has lower energy savings than the 30% stated, then the curtain should close at a lower radiation level.**

Additional notes:

- This means that a curtain does not have to open in the morning unless the light intensity reaches a given level
- When similar calculations are done for a double poly house, the same equation is applicable (approximately)

What savings to expect from combinations of curtain and –DIF(T_d<T_n)?

Curtain	-DIF
-	0
+	0
-	-4
+	-4

Comparisons for glass greenhouse and $0.40 / m^3 gas for Niagara and January

Curtain	DIF (ºC)	Heating costs $ / ha /day	Comparison
-	0	$1885	
+	0	$1450	Saving of curtain: 435 $ / ha/ d
-	- 4	$1890	Saving of - DIF is -5 $ / ha / d
+	- 4	$1425	Savings of curtain and – DIF: 460 $/ ha/ d

Conclusions

- **Based on a simple model, heating costs can be further reduced by closing the curtain during the day under certain conditions.**
- **If you have a curtain, the use of –DIF will actually save you $$ in heating.**

Thank you !

tblom@uoguelph.ca