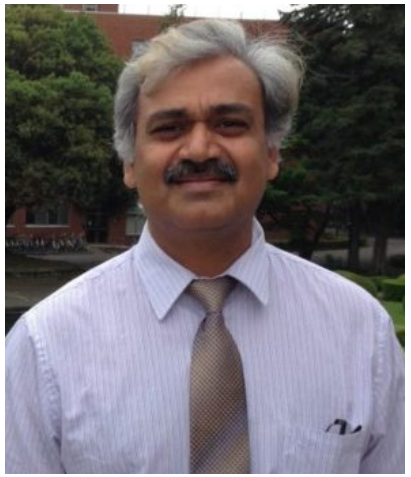

Greenhouse Construction

Dr. Krishna Nemali
knemali@purdue.edu, 765 494 8179

Webinar will be starting soon. Thank you for joining

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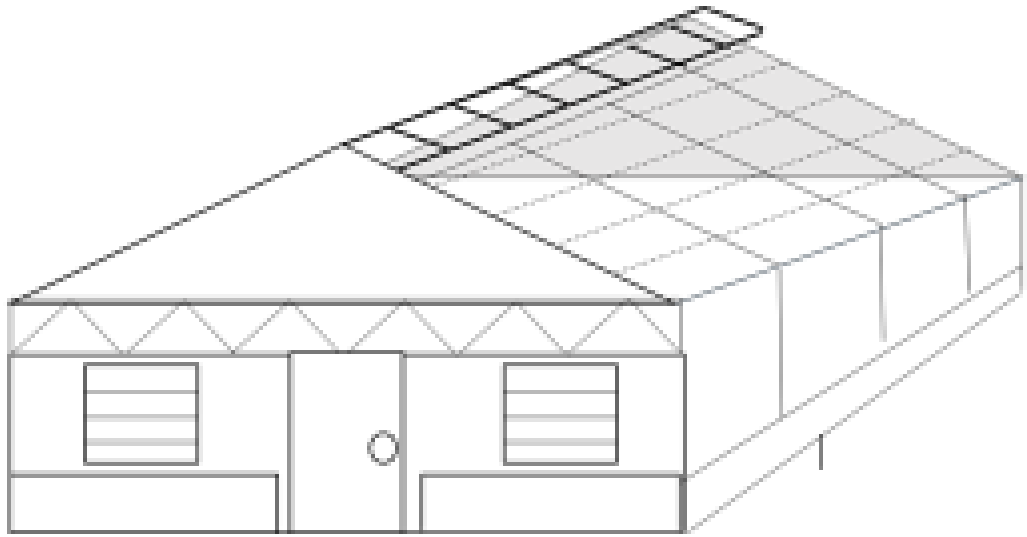

- The webinar series is planned to continue our commitment to provide science-based training to greenhouse and indoor growers in Indiana and Midwestern states

- We plan to continue the webinar series through the rest of the year. There will be one seminar on the last Wednesday of every month (next session on July 29th). A separate registration link will be sent by email for each session

- Experts from different areas will be invited to present during the seminars

- There will be lot of technical information presented in seminars. We will be happy to provide a pdf of presentations to participants. However, we ask participants to complete a quick online survey intended for improvements to receive the presentation

- Presentations will be for a duration of 30 to 45 minutes. Following each presentation, there will be 15-20 minutes for Q & A

- We request that participants wait until the end of each presentation to ask questions using both voice (preferable) and chat options

- All correspondence related to webinars can be sent to:

Dr. Krishna Nemali
Assistant Professor and Extension Specialist (CEA)
Horticulture and Landscape Architecture
Purdue University
625 Agriculture Mall Drive, West Lafayette, IN 47907
Tel: 765-494 8179
Email: knemali@purdue.edu

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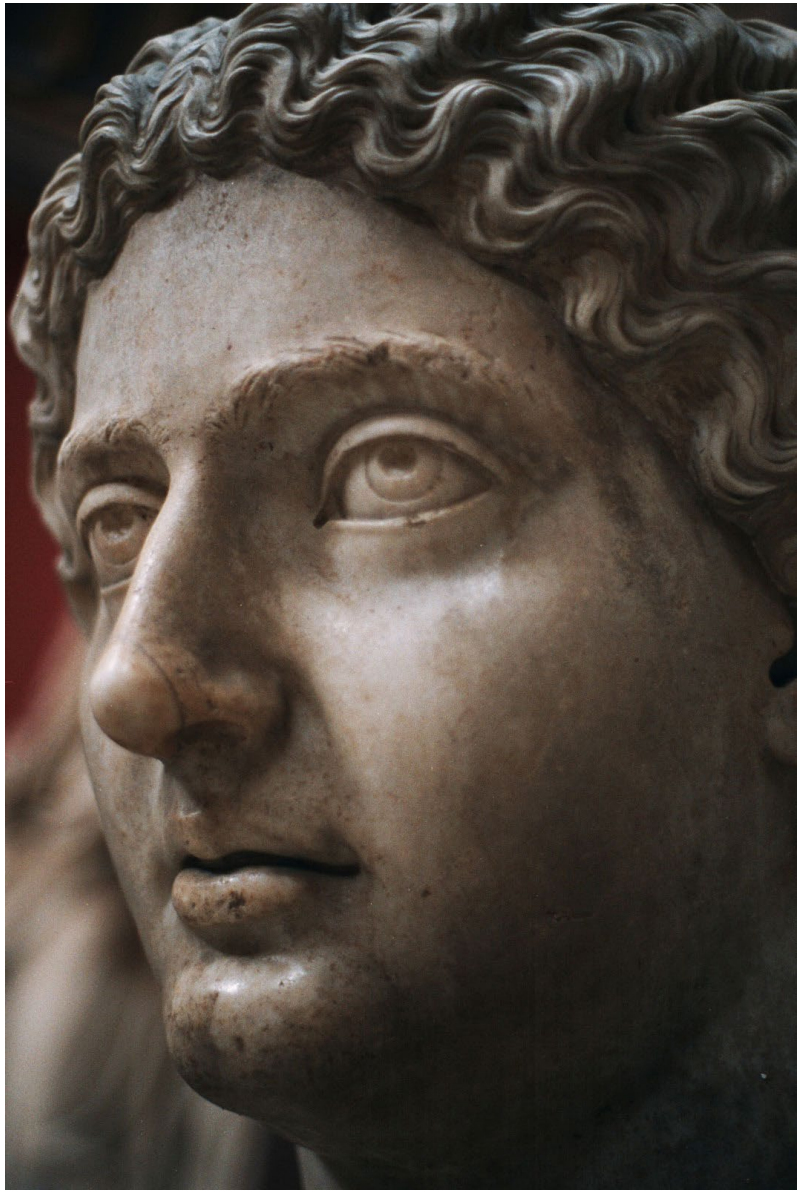
Greenhouse Construction

First Greenhouse?

Roman gardeners (AD 14-37) used artificial methods of growing cucumbers to have them available for emperor Tiberius every day of the year

The cucumbers were stored in ‘cucumber houses’ known as *Specularia* during winter



- Andrew Faneuil, a well-to-do Boston merchant, is the builder of the first American greenhouse in 1737

- Wye House, MD is the oldest surviving greenhouse in the U.S. Recent evidence suggests that, through their decades of toil within the greenhouse, the workers were also conducting a series of agricultural trials on medicinal and food plants

Wye House, MD

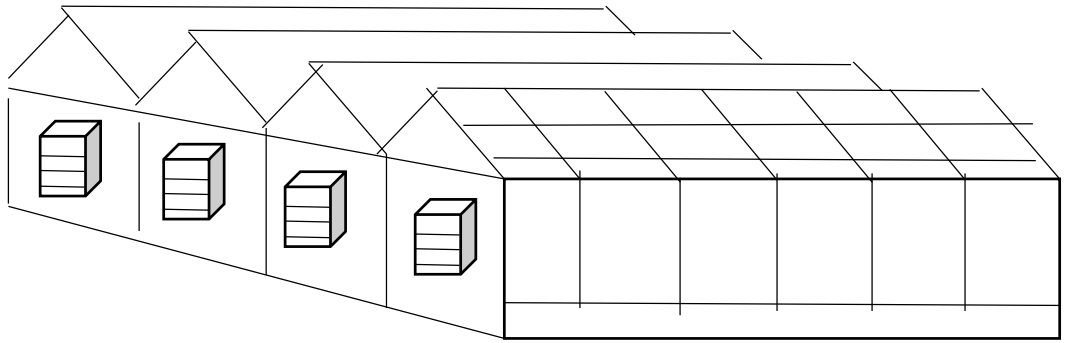
Greenhouse Construction

1. Location considerations
2. Orientation
3. Designs
4. Roof pitch
5. Structural loads
6. Glazing materials

Location

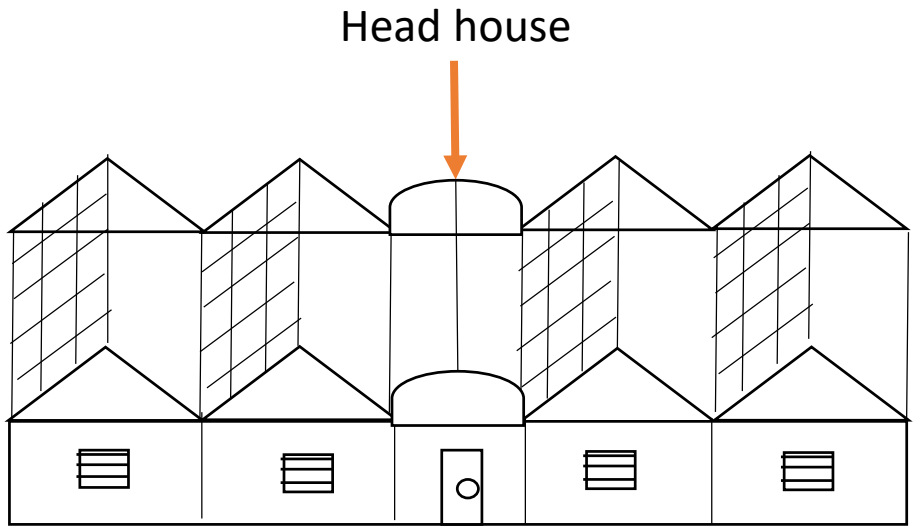
#1. Total area should be at least twice the greenhouse area

2X



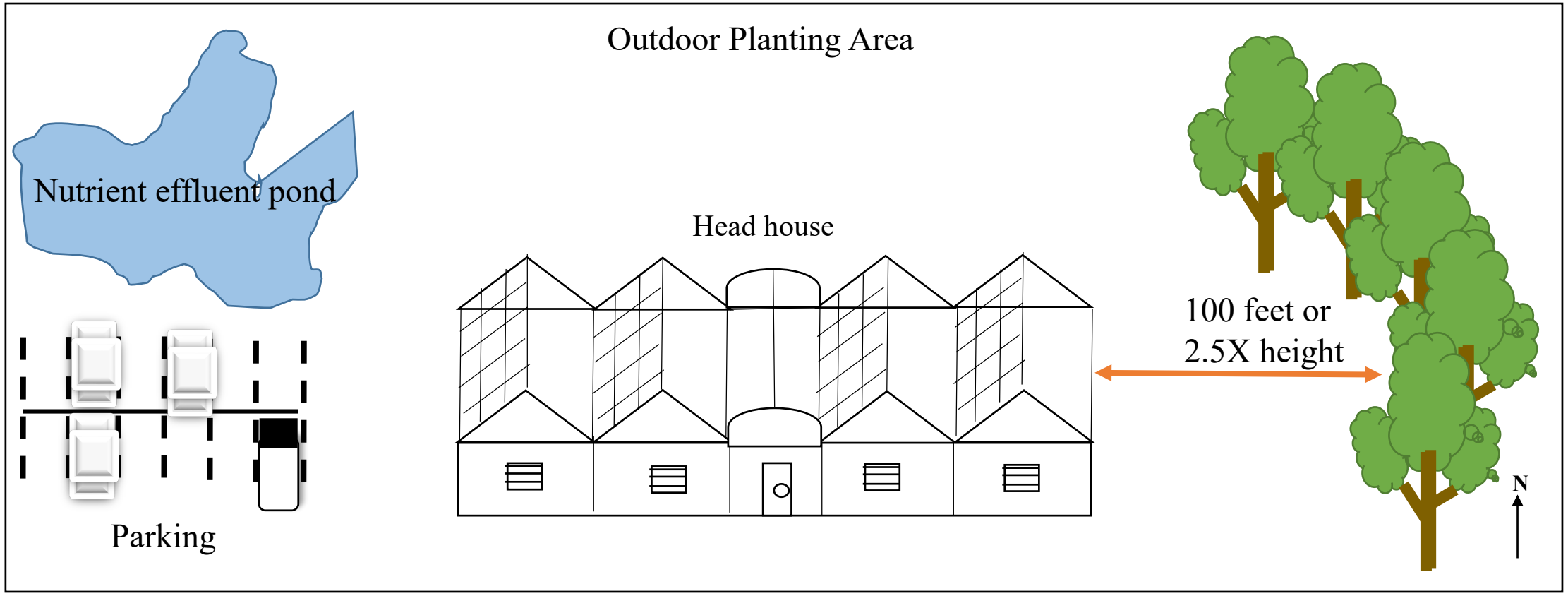
Location

#2. Head house should be at least 10% of greenhouse area and easily accessible to all sections



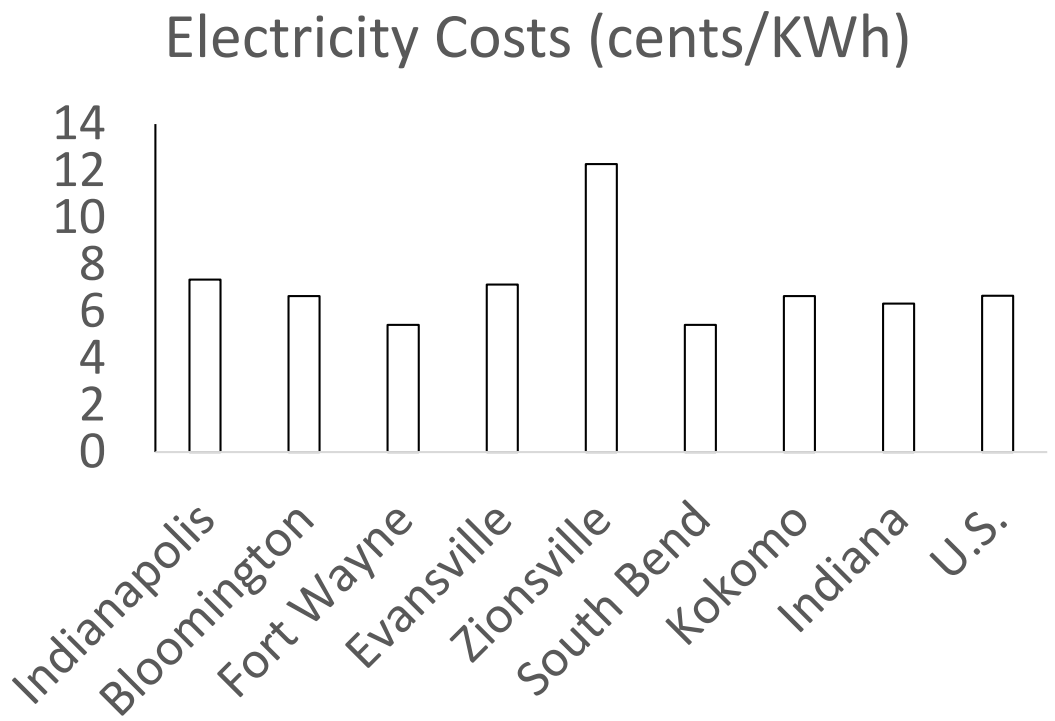
Location

#3. Maintain the longer of 2.5 times the height of trees or 100 feet distance from tree line to avoid snow drifts and shadows



Location

4. Lower electricity costs reduce operational costs



Many daily operations in a greenhouse use electrical energy

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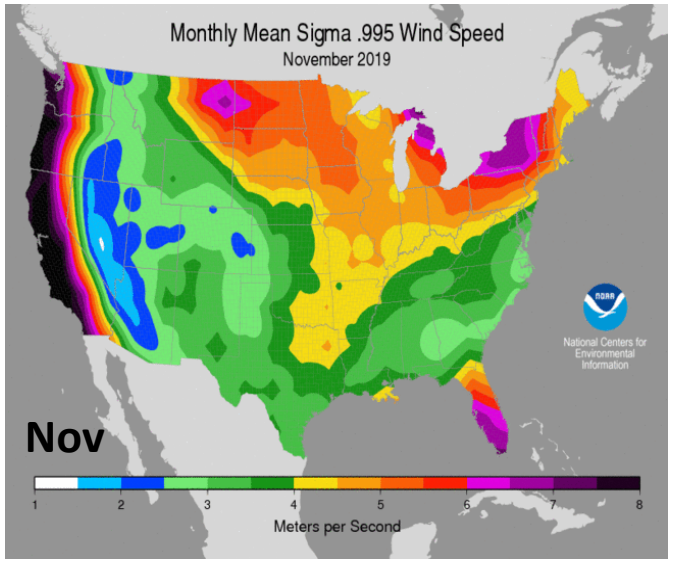
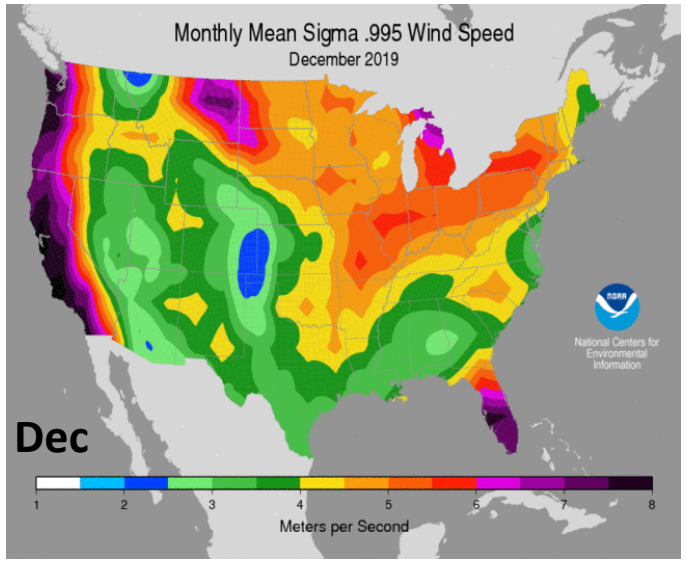
Location

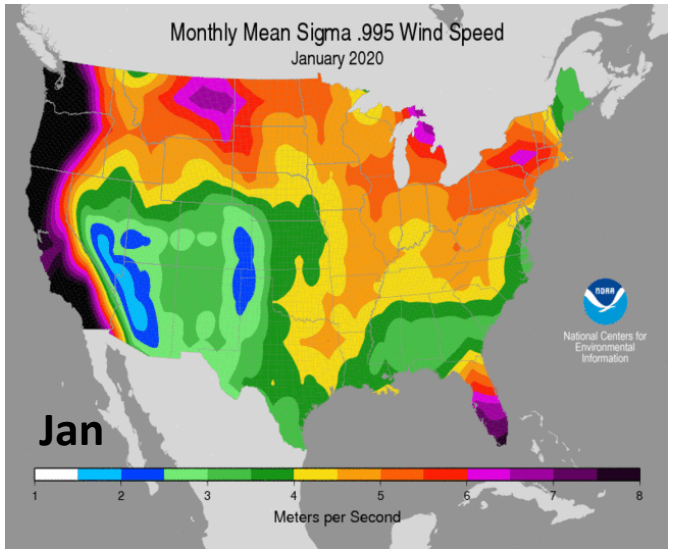
5. Avoid high wind areas

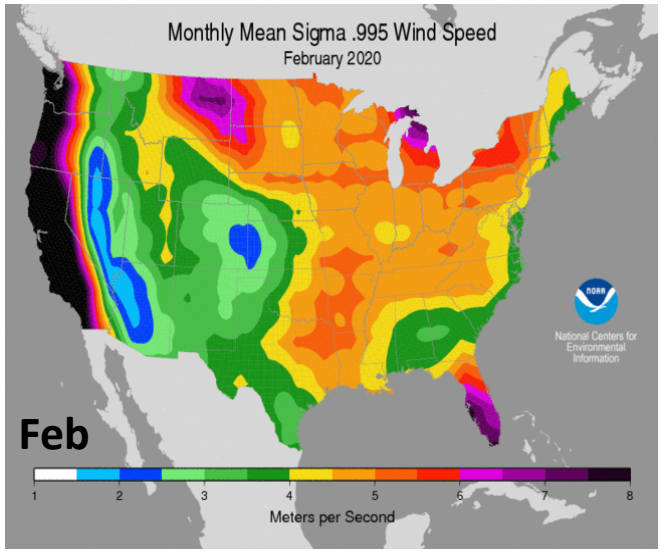
- Average wind speed during winter 2019-20 : 11 mph
- High wind speeds increase heating costs during winter
- Damaging winds can destroy roof and structure

Source: ncdc.noaa.gov









Location

6. Greenhouses require reasonably high amount of water

- Water is needed for crops, cleaning and cooling system
- Nearly 30,000 gal/acre/day is used
- High alkalinity and pH issues common
- A nutrient effluent collection pond may be needed

Location

#7. Be aware of urban growth

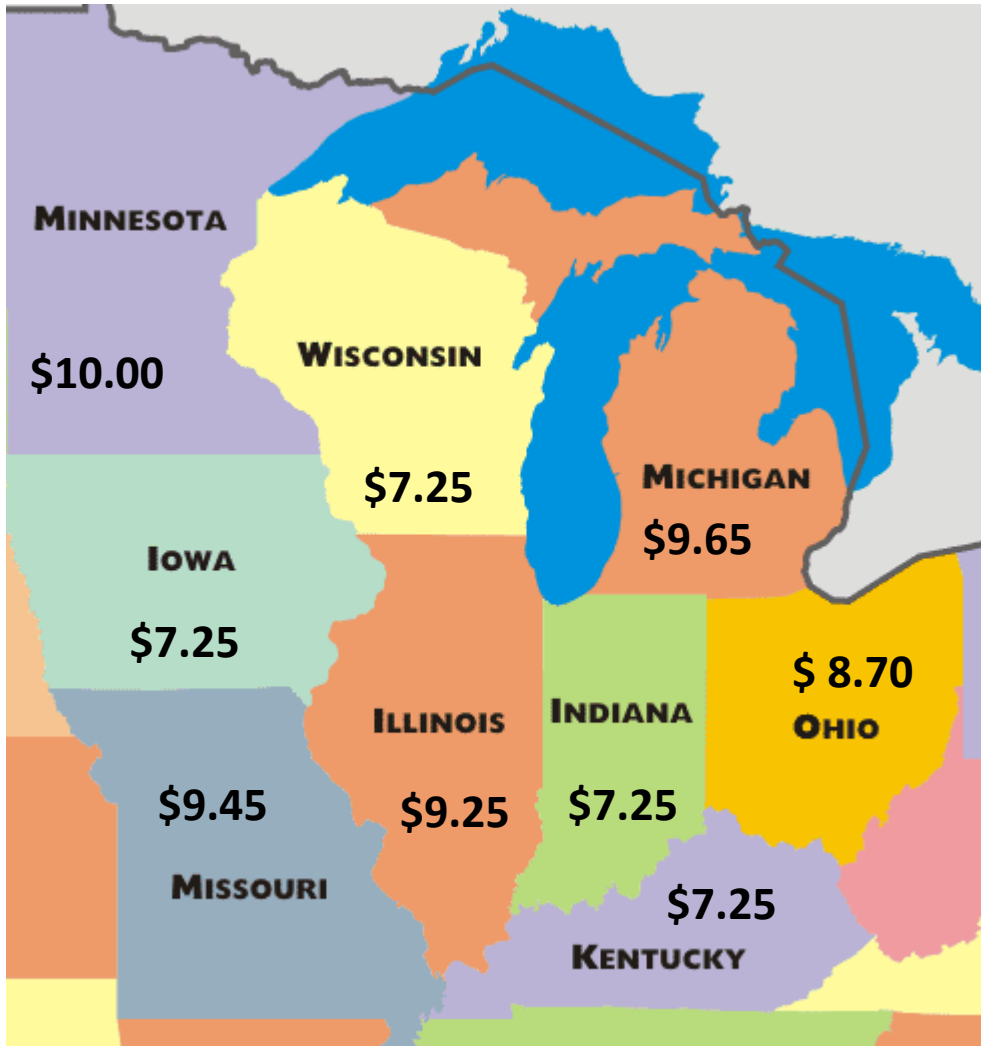
People may not like many greenhouse operations, excessive lighting in the evenings, smoke from burning dried materials, nutrient runoff from pond etc.

Location

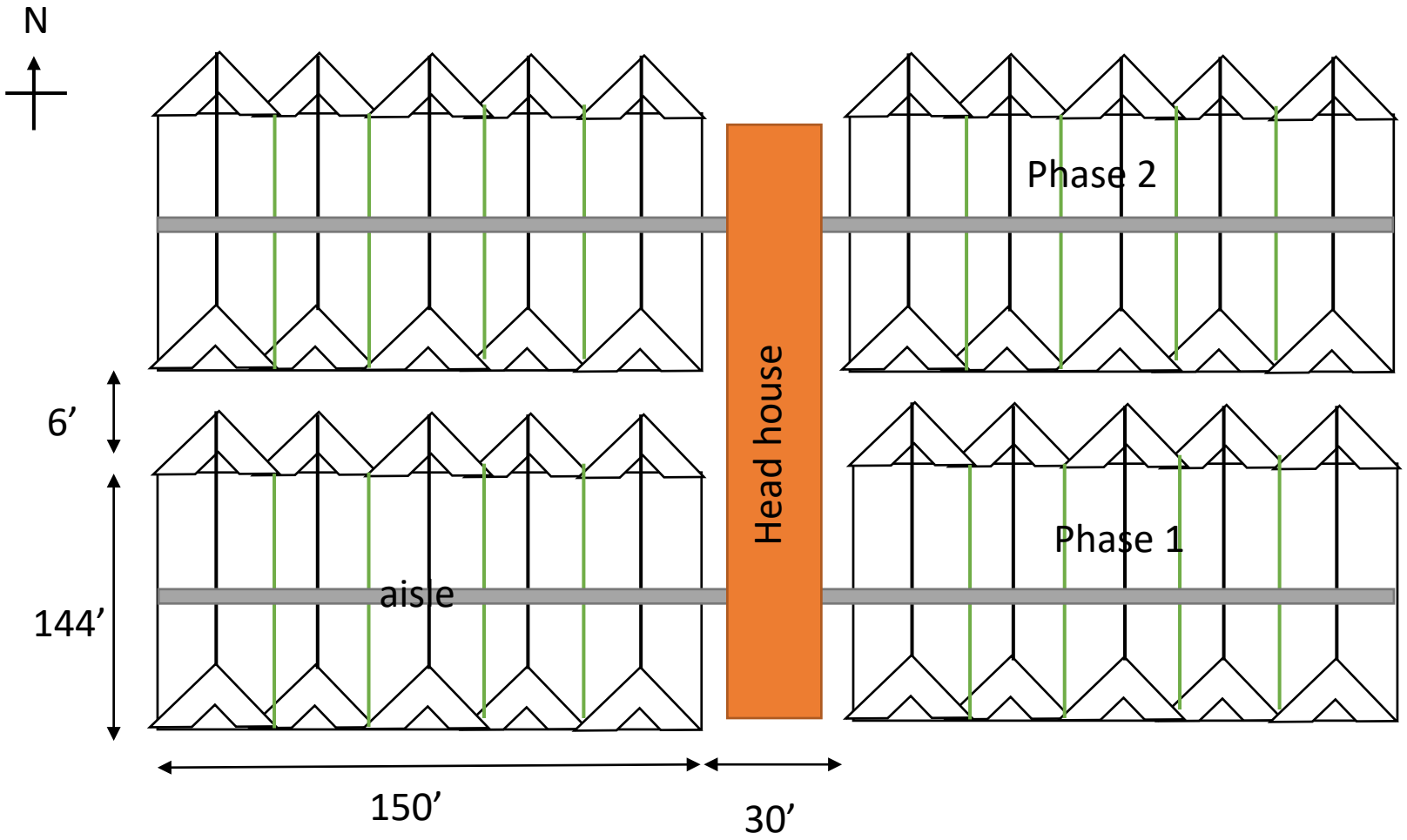
#8. Availability of work force

- Healthy economy = higher wages
- Trained work force = higher wages
- Competition for untrained workforce

Consolidated State Minimum Wage
(source: Dept. Labor)



Location: Floor Plan



- Allow for future expansion
- If there is slope, begin construction in the middle
- Head house centrally located
- Doors to be ~ 10’x 10’
- High (12’) gutters better for hanging baskets and supplemental lights
- Enquire material specifications prior to design
- If length >150’, then cooling may be problem

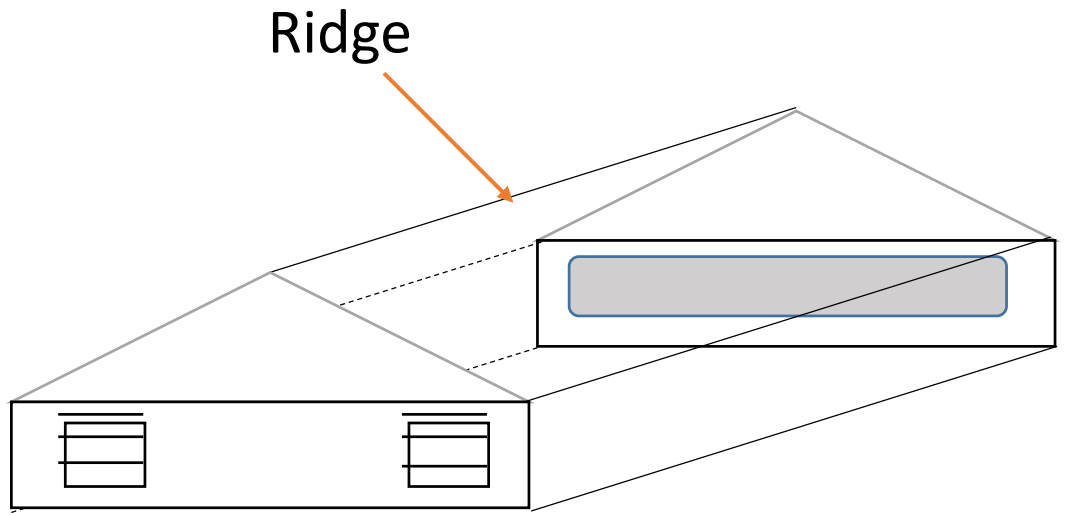
Greenhouse Orientation

Refers to the directional alignment of greenhouse ridges

Proper greenhouse orientation is important for:

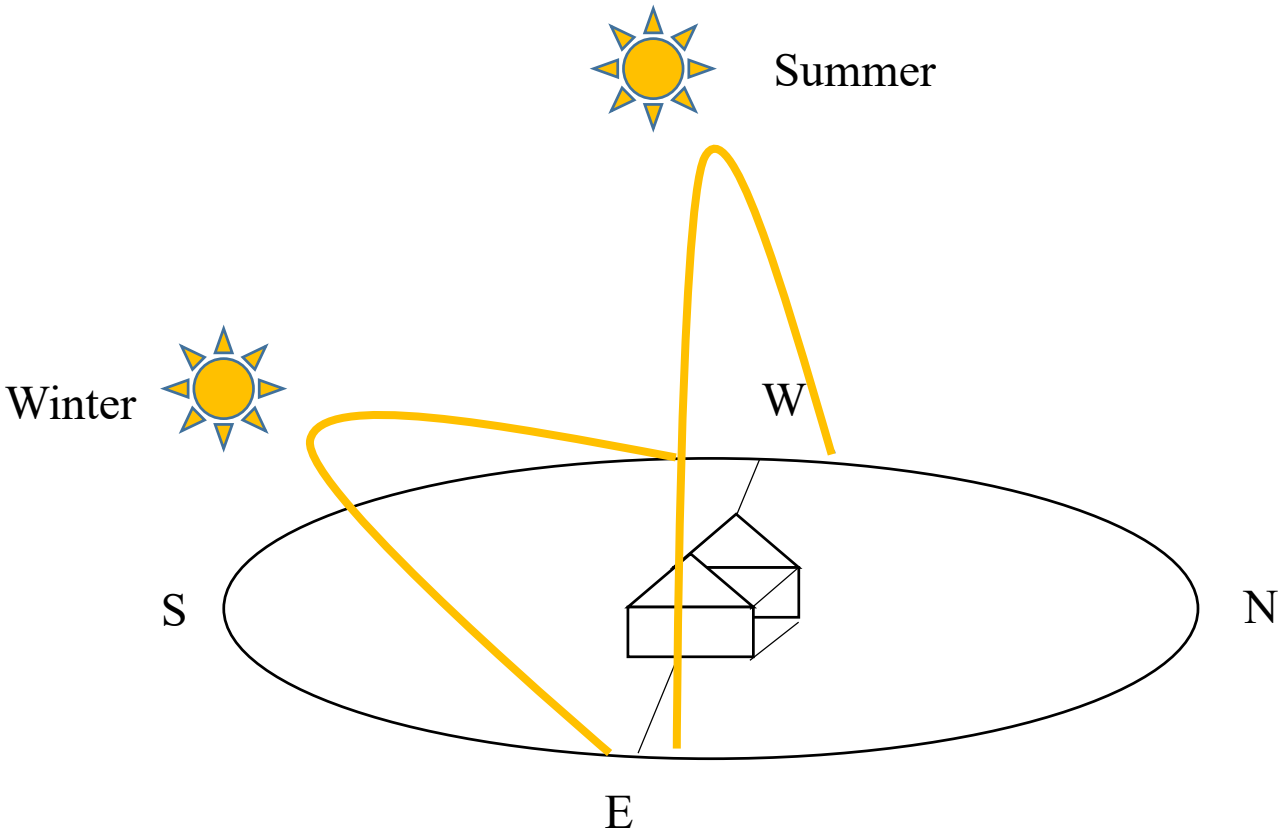
- maximizing light intensity and distribution inside a greenhouse
- minimizing effect of shadows from structures or hot spots inside a greenhouse

Guidelines vary by region (latitude) and type of greenhouse (single span versus multi-span greenhouses)



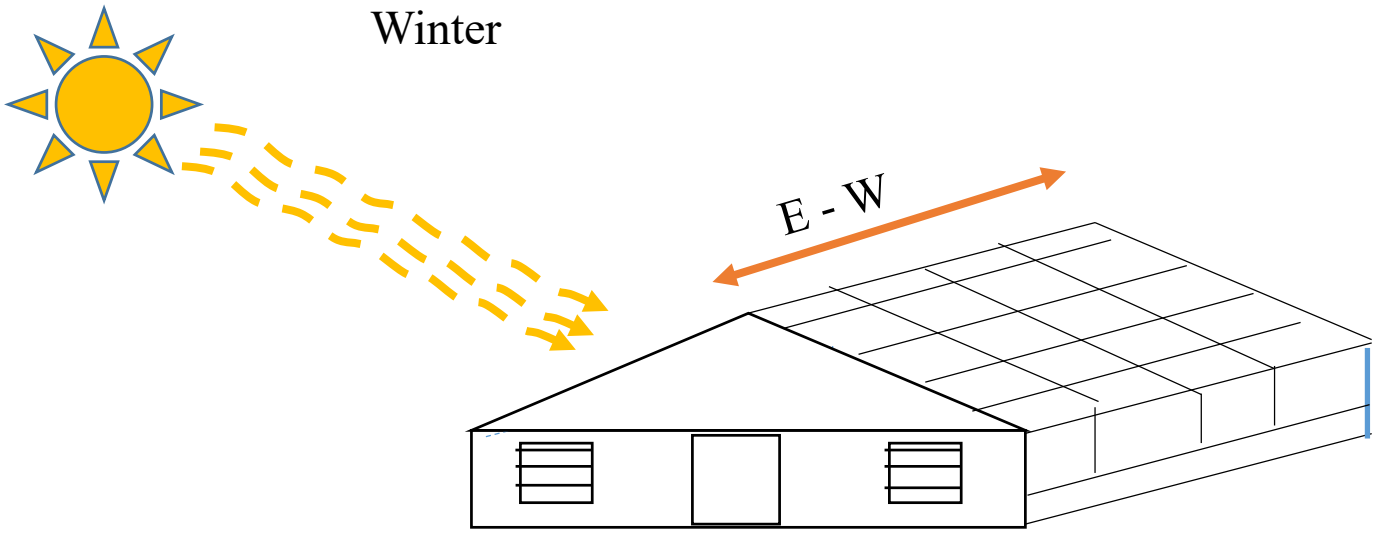
Solar path during summer and winter in Indiana

- Sunlight enters greenhouse mostly from southern side during winter
- Low angle, long shadows and low intense light during winter

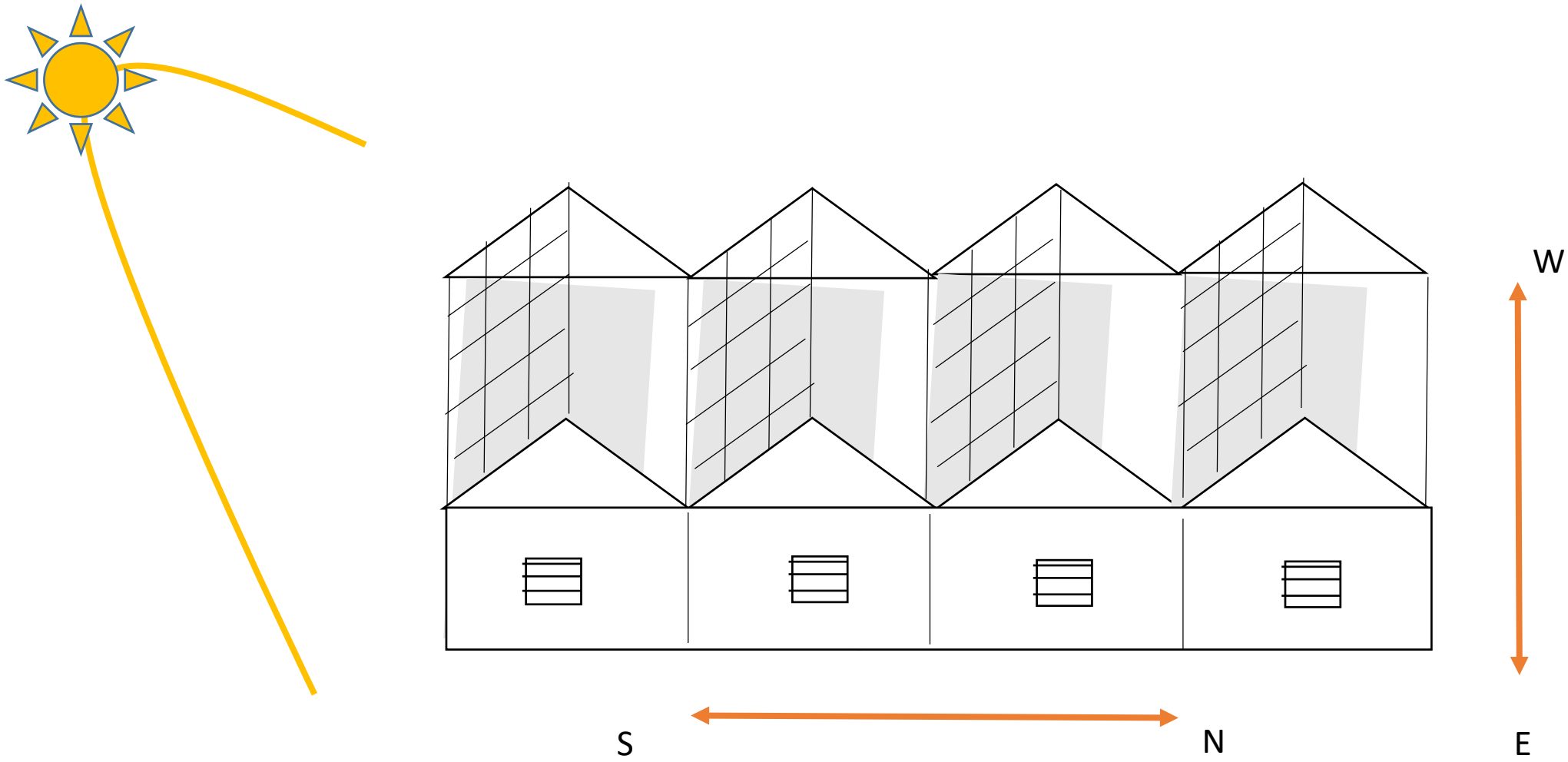


Single-span greenhouses above 40° N latitude

- Plant for worst case scenario, i.e., winter
- Run greenhouse ridge in the E-W direction
- This will expose long side of the greenhouse to sunlight coming from the south

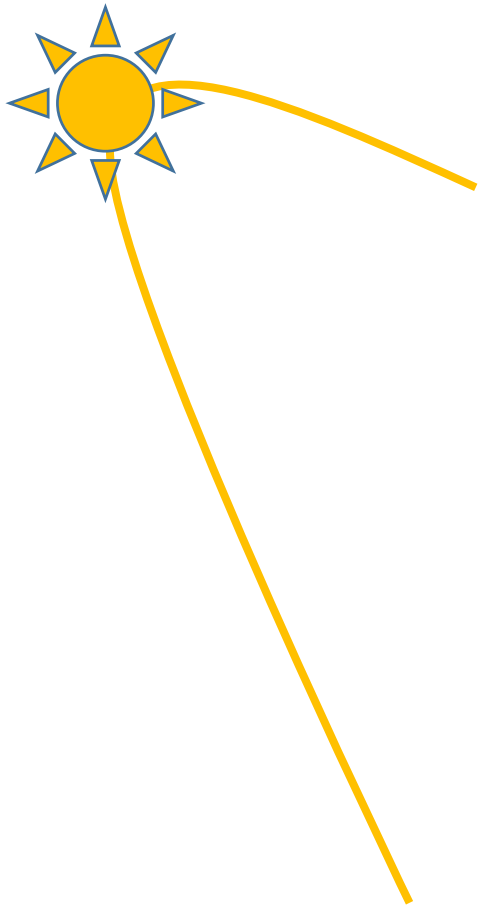


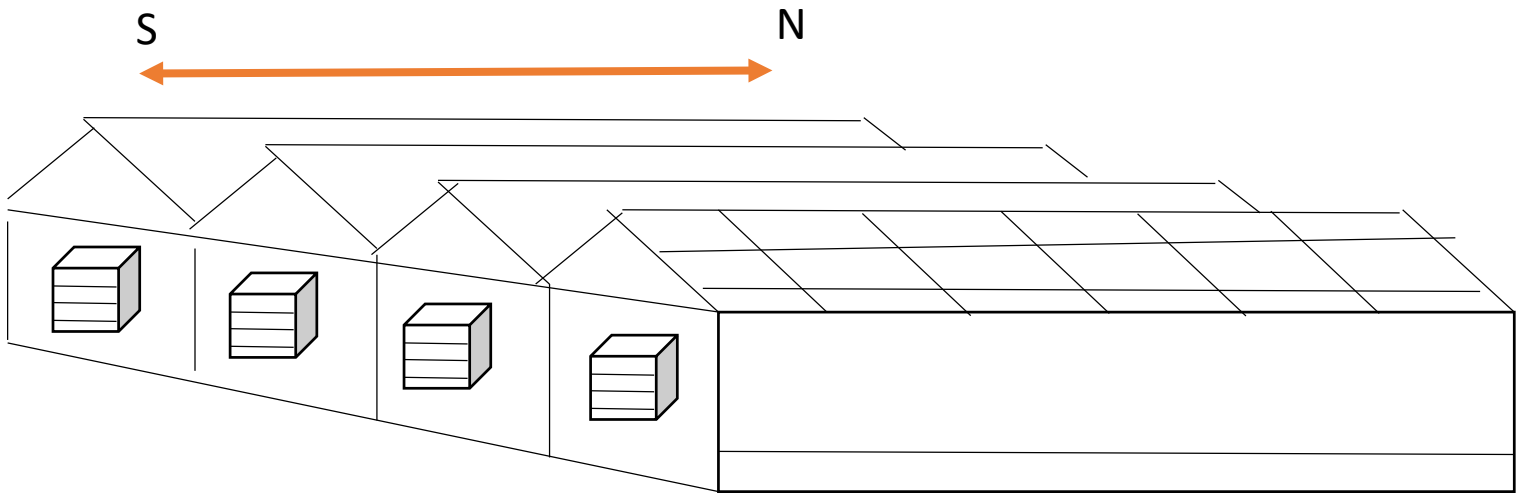
Multi-span greenhouse above 40° N latitude



- Light distribution is more important than intensity received
- Structural elements like trusses and gutters cause shadows in multi-span greenhouse
- East-West orientation increases shadows inside a multi-span greenhouse

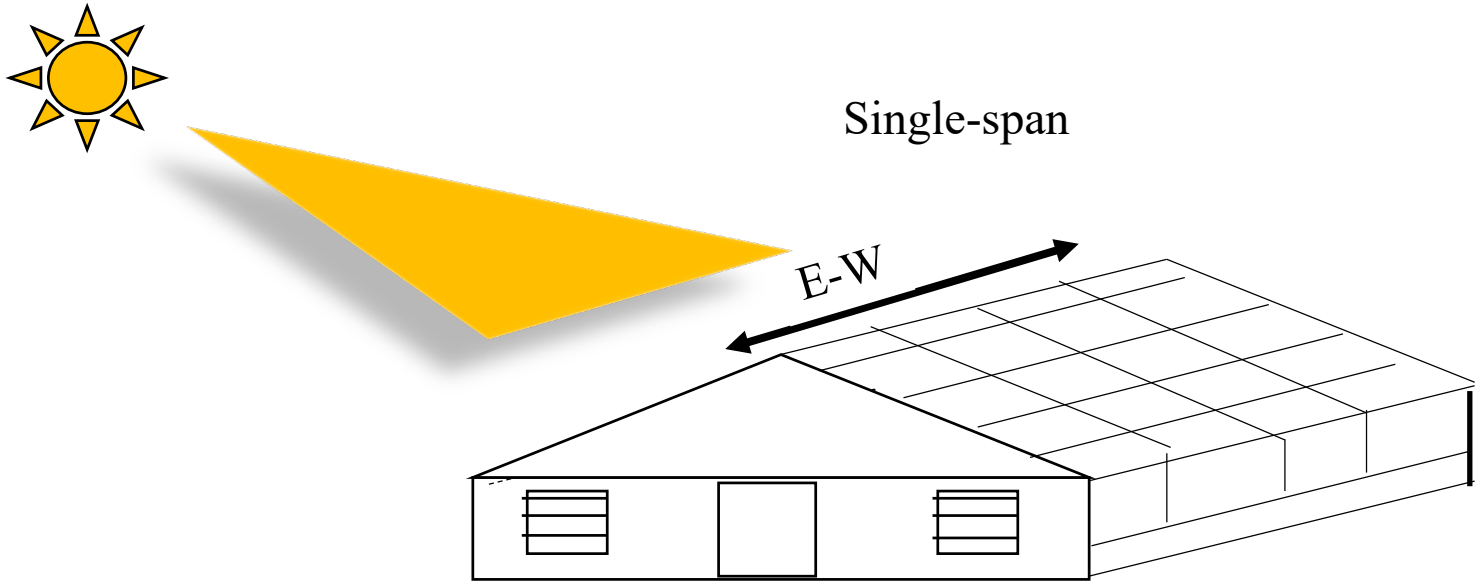
Multi-span greenhouse above 40° N latitude



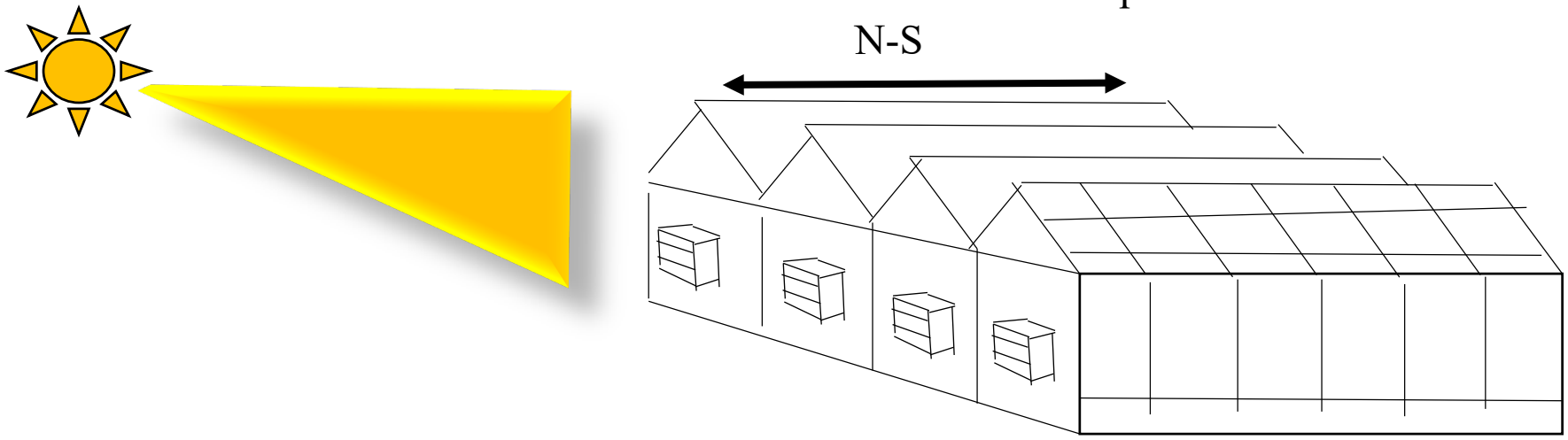


- Shadows are smaller when ridge is oriented in the N-S direction
- Light distribution is better in N-S orientation
- Run ridges of a multi-span greenhouse in the N-S direction

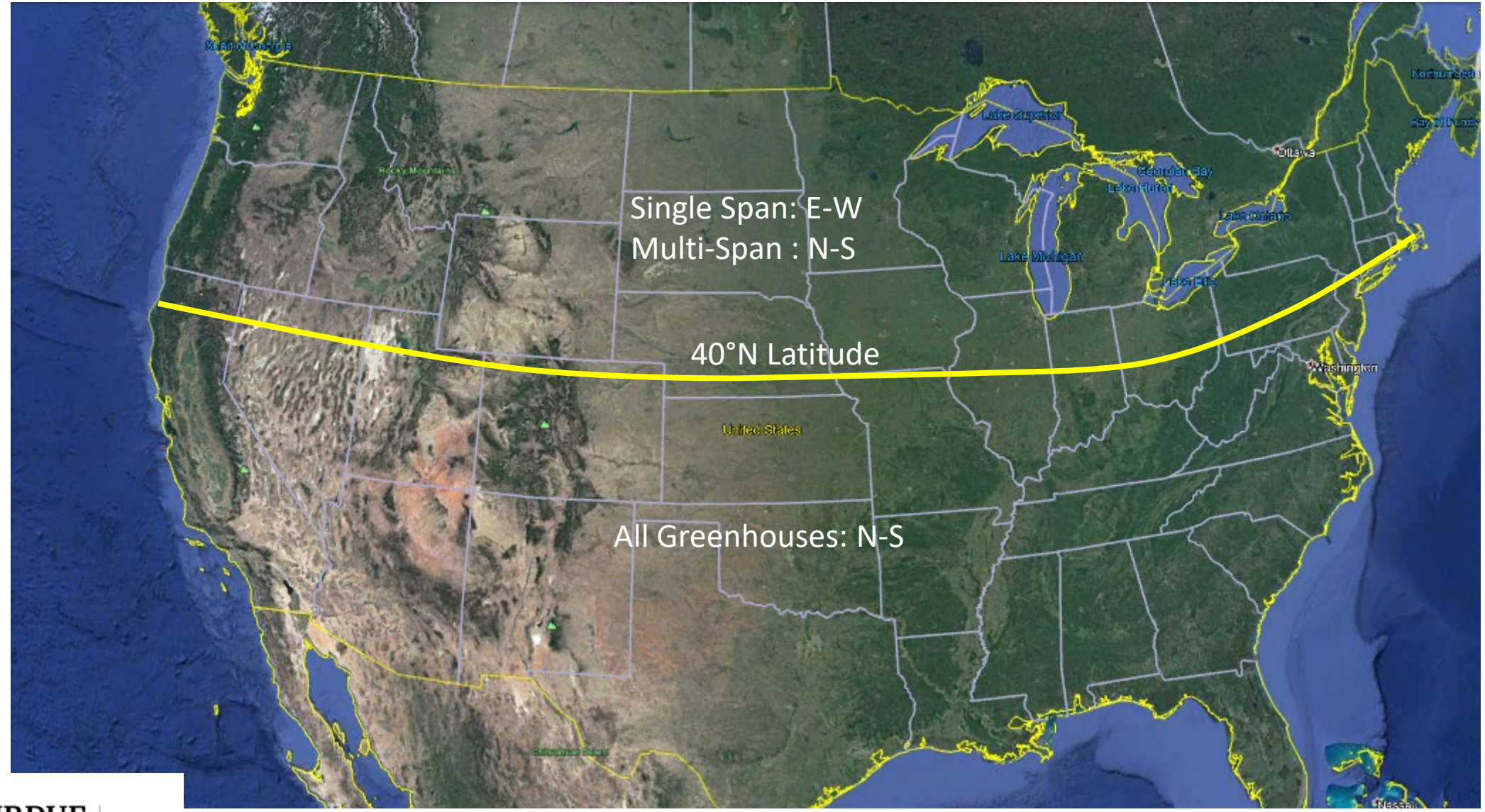
Single-span



Multi-span



Greenhouse Orientation



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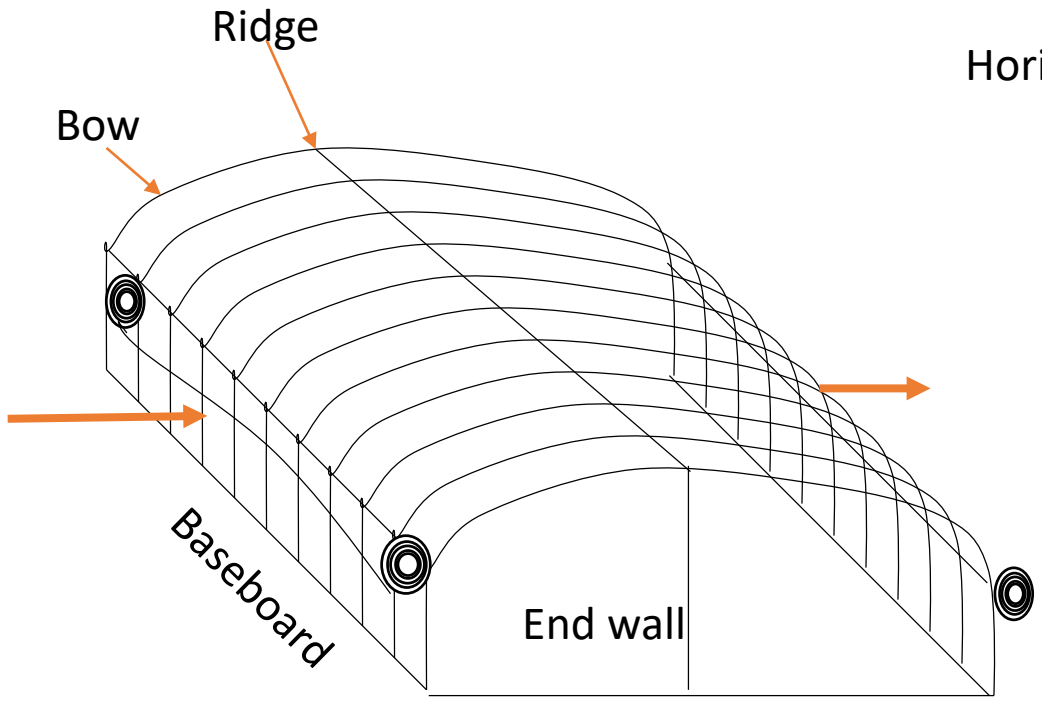
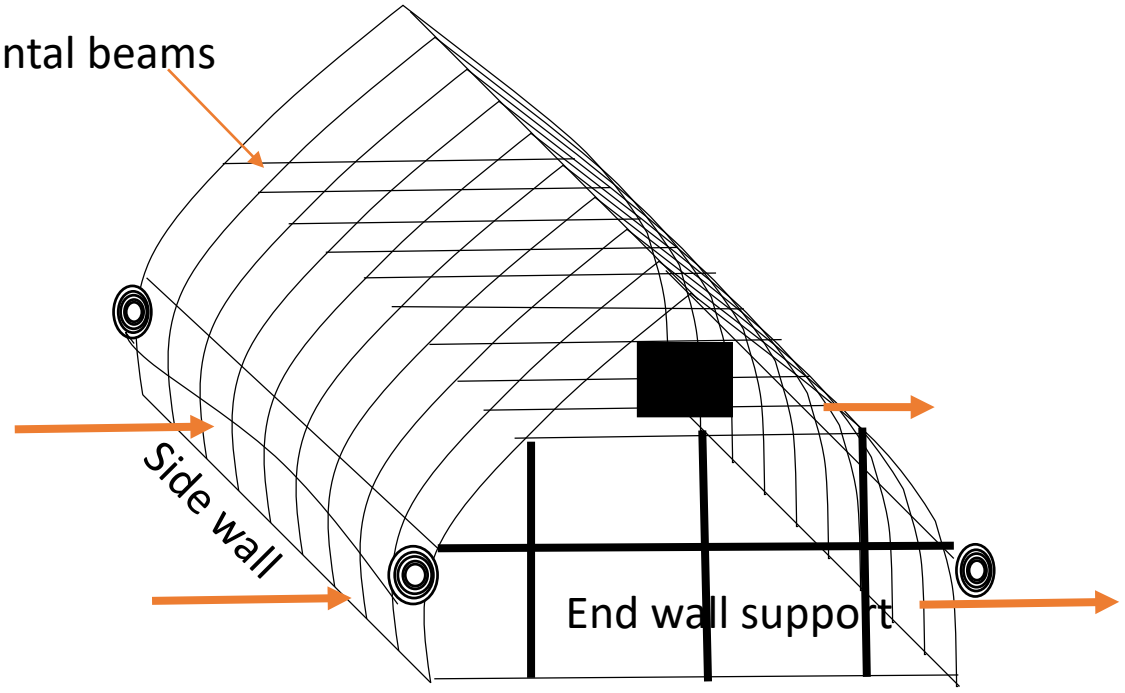
Greenhouse Designs: High Tunnels



Arch style



Gothic Arch style

- Ventilation through side wall
- Additional support through horizontal beams and end wall support in gothic arch design
- Polyethylene glazing

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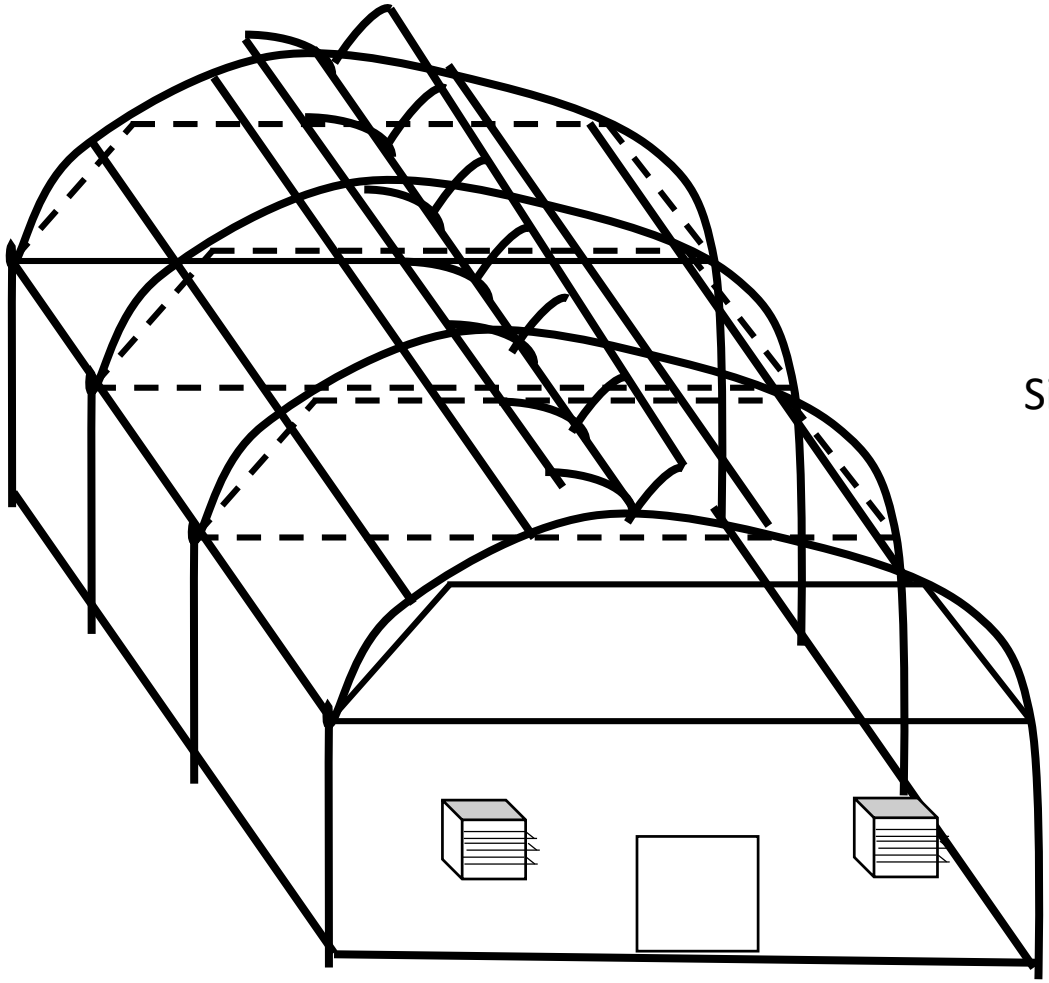
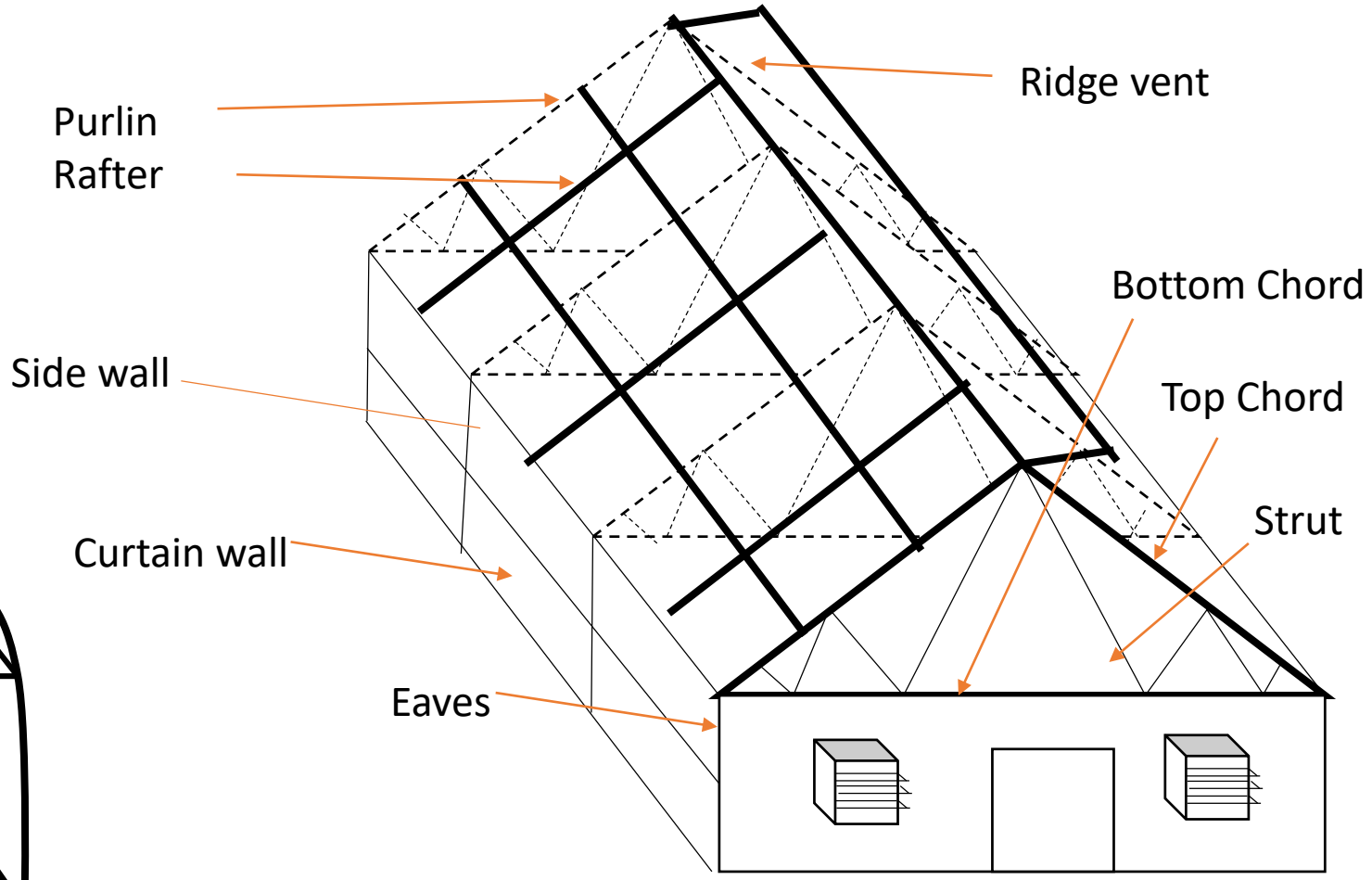
Greenhouse Designs: Single-span



Arch-style

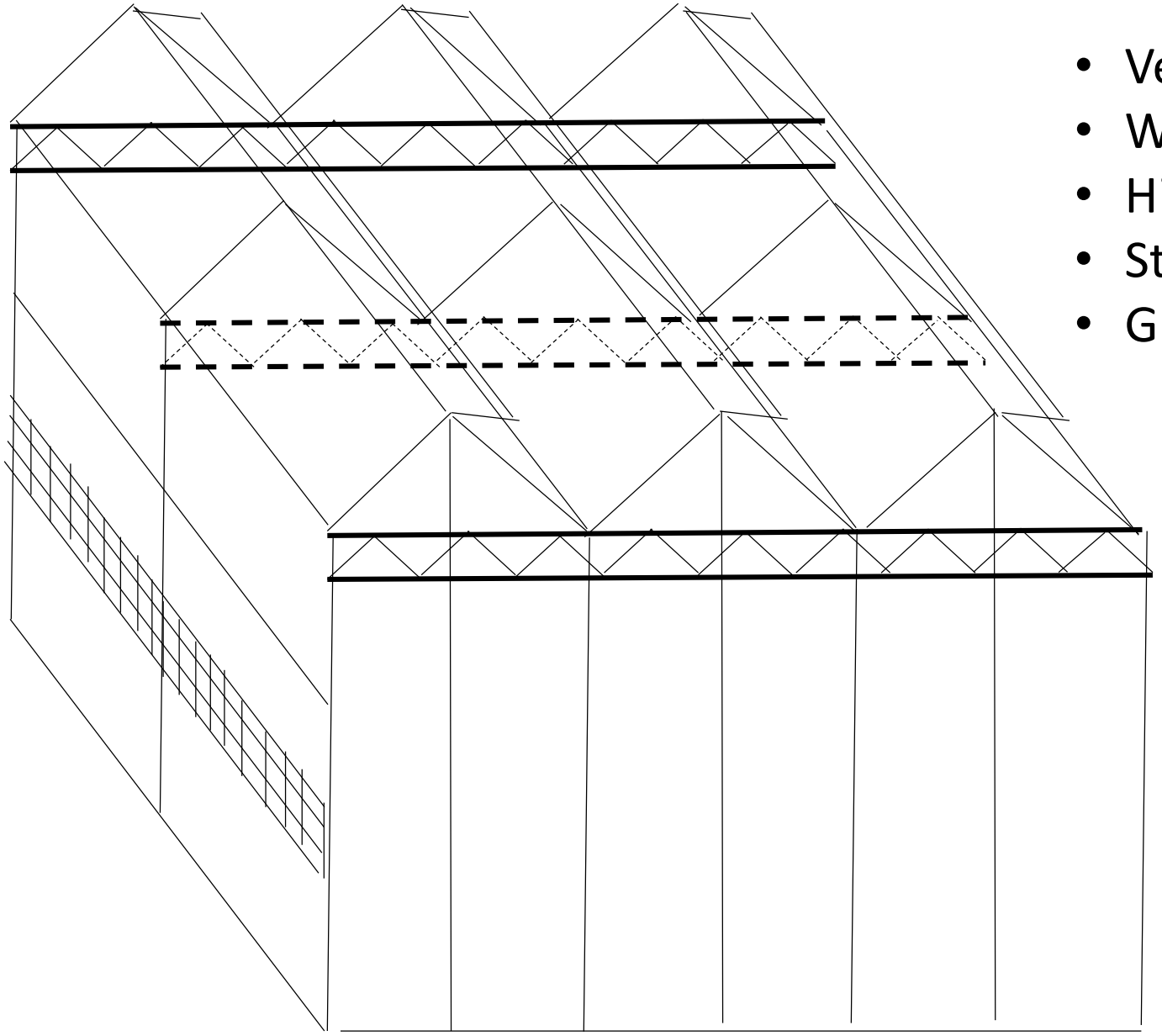
- High profile and polyethylene roof
- Simpler truss structure



Gable-style

- Glass roofing
- Fink Truss, even load distribution
- Roof ventilation

Greenhouse Designs: Multi-span



- Venlo-style, tall greenhouse
- Warren truss, suitable for spanned loads
- High light, low humidity
- Structure suitable for high-wire vegetables
- Glass roof, low profile

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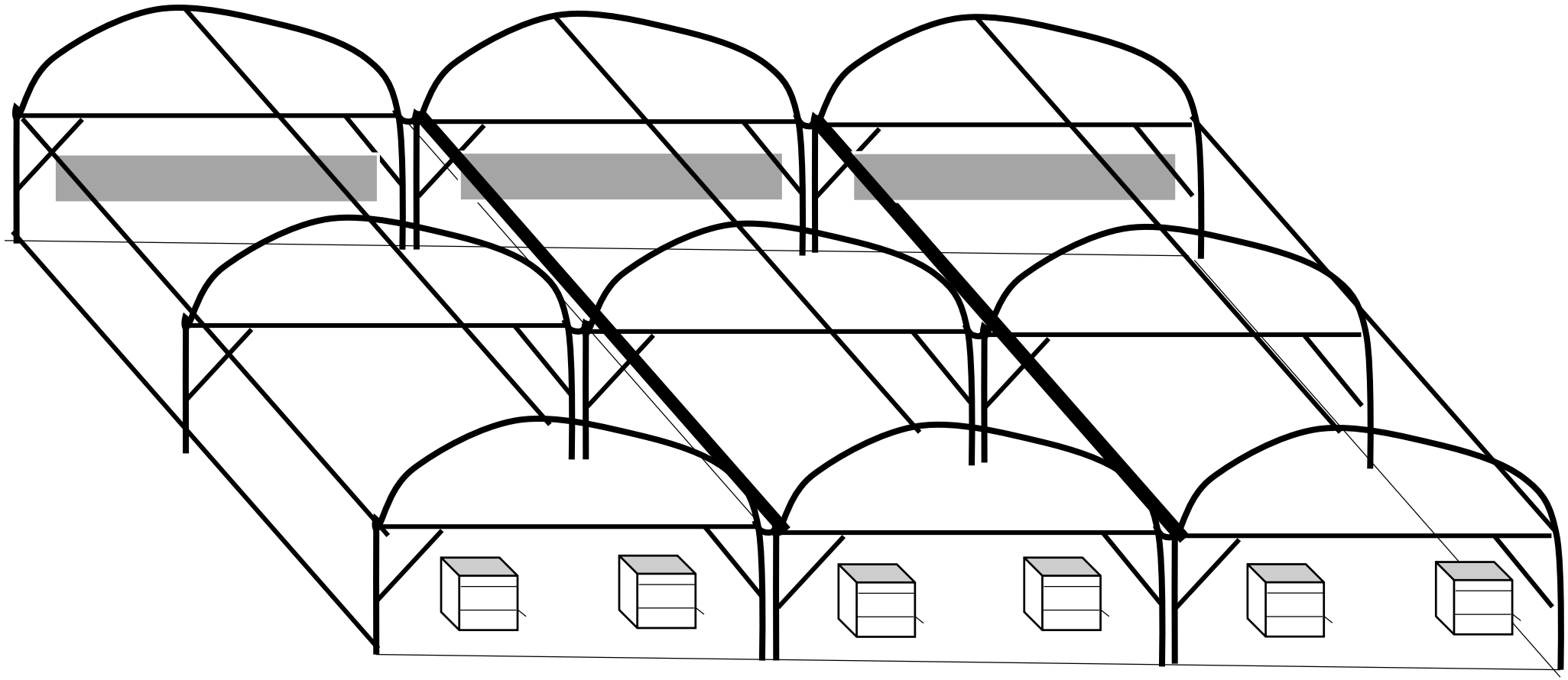
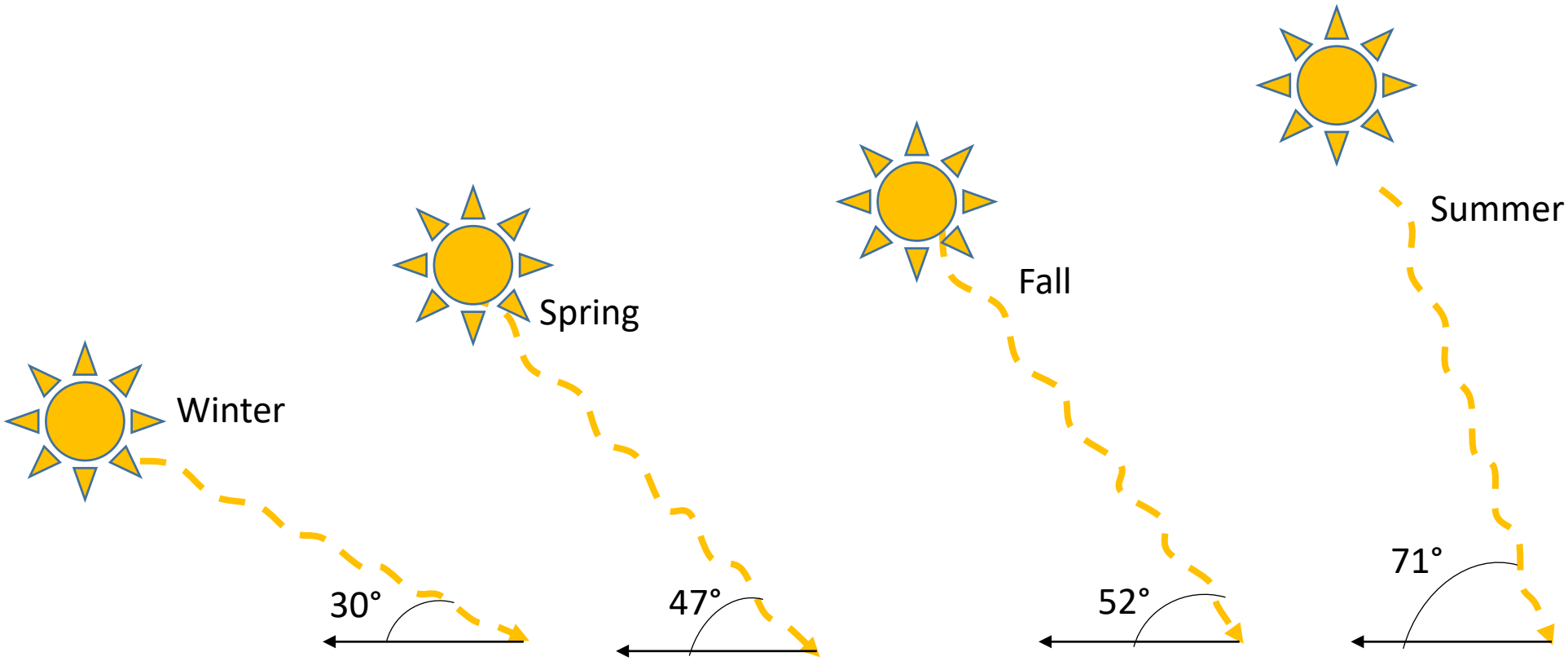
Greenhouse Designs: Multi-span



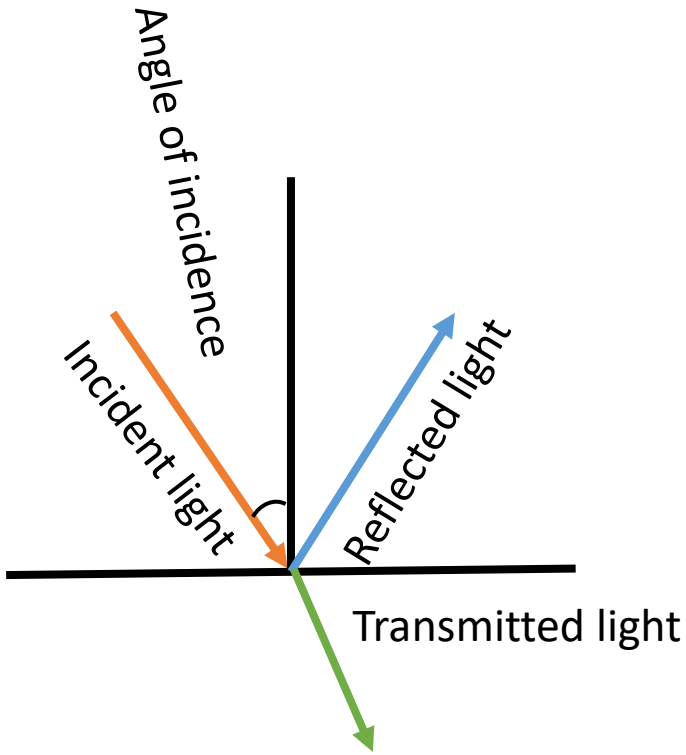
Gutter connected with arch style roof
Polyethylene glazing
Simple structure; diagonals support horizontal bar

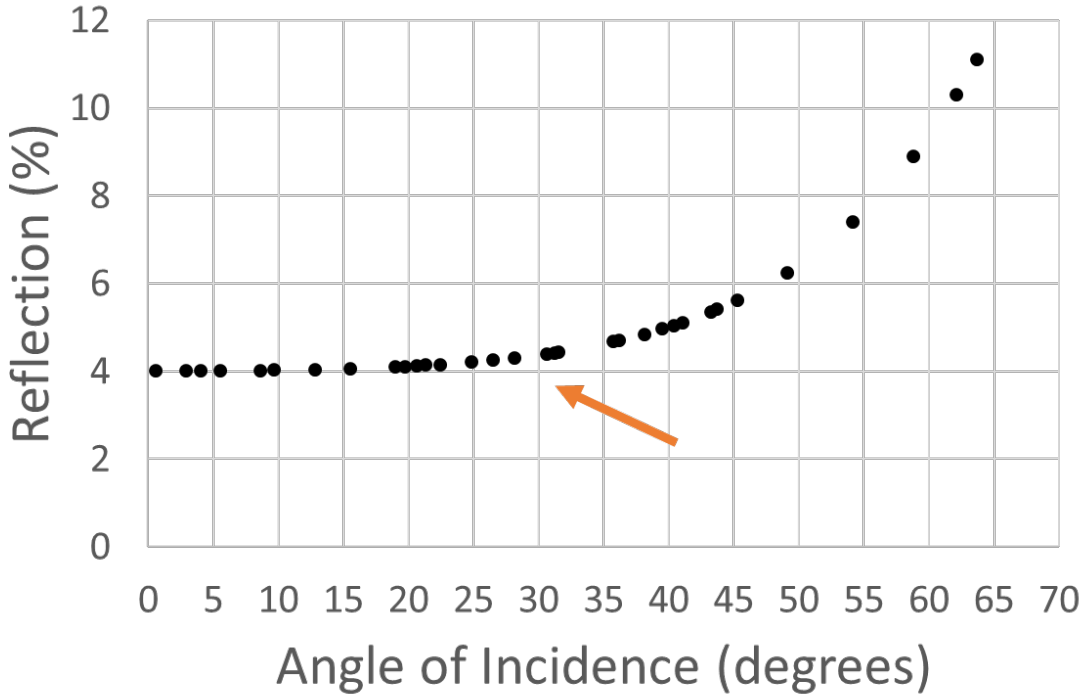
Solar Elevation



Angle of incidence (AOI)

- Angle between incident light and imaginary line perpendicular to the surface
- Less angle of incidence is better, increases light transmission





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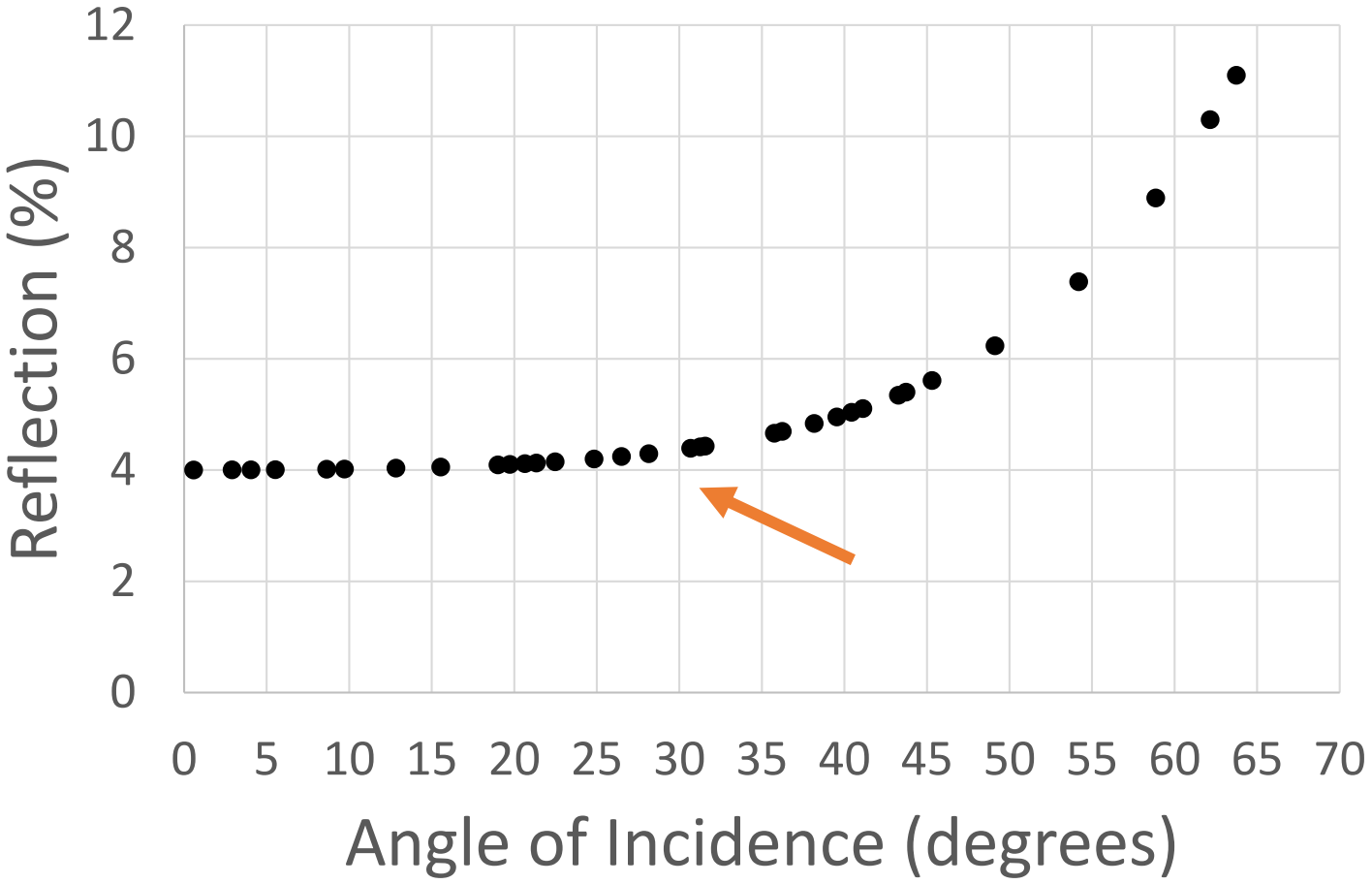
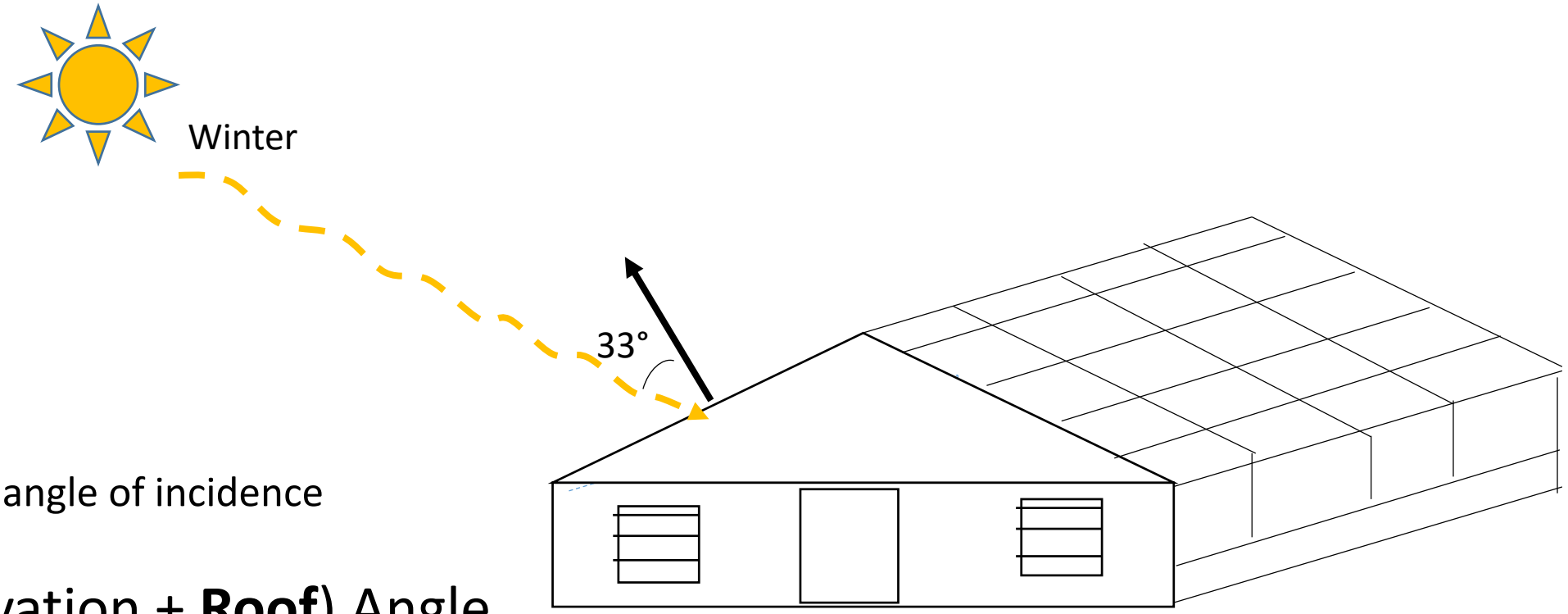
Reflection Losses



No significant difference in reflection (%) up to an angle of incidence of 30 degrees

Roof Pitch or Roof Angle

- Roof pitch is vertical rise for half span; usually expressed for every 12 feet of length
- 4: 12 (18.4°), 5: 12 (22.6°) and 6: 12 (26.6°) are common roof pitches for greenhouses

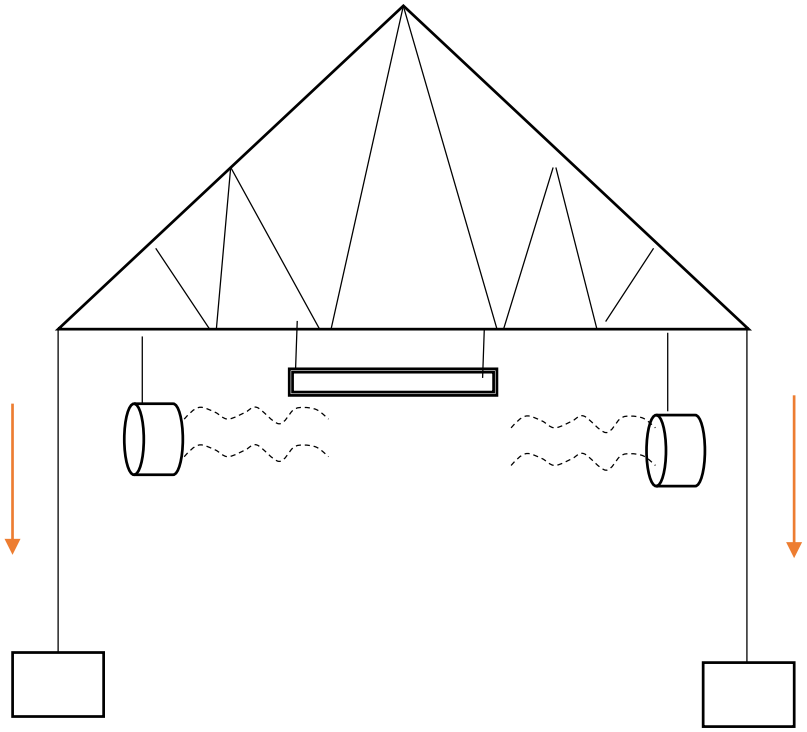


- Roof pitch decreases angle of incidence
- AOI = 90 – (Elevation + **Roof**) Angle
- With a roof pitch of 6: 12, AOI= 90- (30 + 27) = 33°

Greenhouse Structural Loads

1. **Dead load (D):**

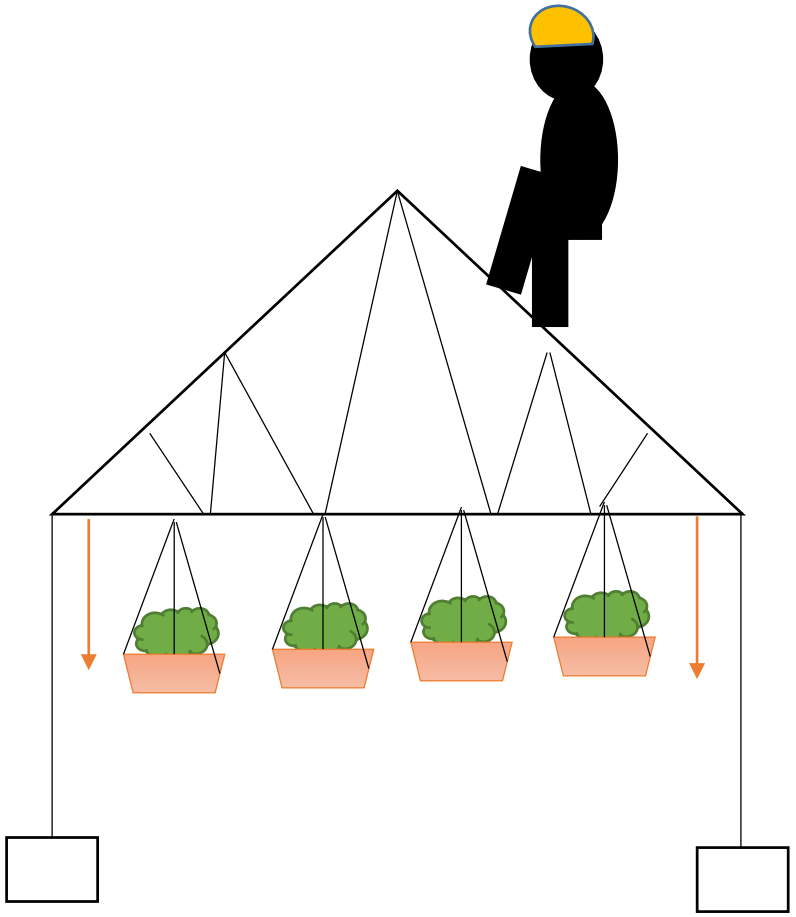
- Constant in magnitude throughout life
- e.g. glazing, walls, fixed equipment, hanging fans
- Structural elements weigh less than the load they can bear
- Assume a value of 5 pounds per square feet (psf) if weights are unknown
- If wind lift > dead load, the structure will be carried away by wind



Greenhouse Structural Loads

2. **Live load (L):**

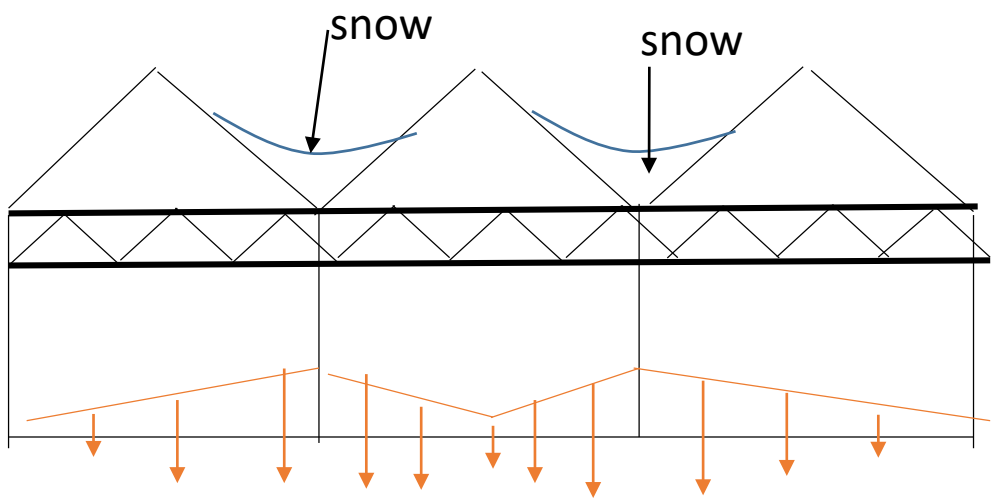
- Short-term loads
- e.g. hanging baskets, maintenance crew on the roof
- Recommendation is 15 psf, hanging baskets can add up to 5 psf
- Concentrated load of 100 pounds to be supported by roof members, purlins, rafters



Greenhouse Structural Loads

3. Snow load (S):

- Ground snow load is 15-30 psf for Indiana
- Three inches of wet and heavy snow can add a load of 5 psf on the roof; this can add 6-8 tons weight on a 30’ x 100’ greenhouse
- Sloped roof snow load calculated from ground snow load using factors like exposure to wind, terrain, heated or unheated greenhouse, roof pitch
- Snow will not slide below 30 degree roof angle
- A higher of either snow load or live load is considered in designing overall load



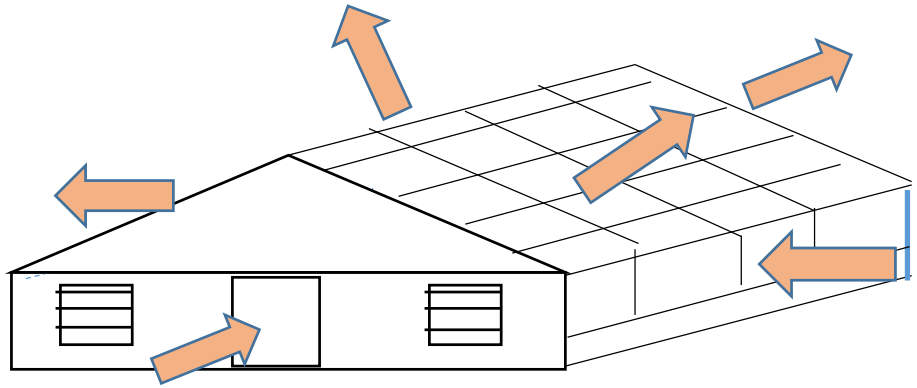
Source: greenhousegrower.com

Greenhouse Structural Loads

4. Wind load (W):

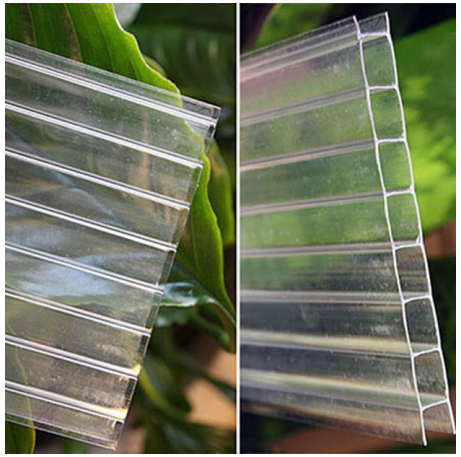
- A min of 10 psf to be considered
- Basic wind speed used for Indiana is between 70 and 80 mph
- It is adjusted for gusts, exposure, height, usage to calculate minimum design wind load
- Wind lift should not be more than 2/3rd of dead load

For Indiana, a combination of D + S + W is appropriate for designing overall load on the structure



Greenhouse Glazing Materials

Characteristic	Polyethylene	Polycarbonate	Glass
Classification (NGMA)	I	II	III
Price (per sq. feet)	$0.10 to $0.30	$1.50	$ 6 to 8
Durability	3-5 yrs	10-15 yrs	25 yrs
Light Transmission	0.9	0.8	0.9
Thermal Transmission	0.18	0	0.02
Thickness	0.15 mm	4 mm	4 mm
Structures	light	medium	heavy
Other Considerations	IR and UV blockers, and anti-condensation additives are available; double poly	Rigid plastic, double-layer; lowest energy loss	Floated/tempered glass; glass has higher infiltration rate, thus thermal conductivity is high, RH low for same reason



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Thank You!