Effective natural ventilation of a greenhouse barn uses properly positioned openings with unobstructed air flow inside the building.

Greenhouse barns in the northeastern United States are typically used to house replacement heifer calves on dairy farms but can provide a comfortable, protective indoor environment for many types of farm animals when care is given to providing adequate fresh air exchange. Greenhouse barn structures are usually simple, double-polyethylene covered hoop houses with gravel floors that employ natural ventilation using manually adjusted sidewall openings. Several economic advantages have been noted mainly related to lower construction, tax, and insurance costs of the structures. Calf caretakers enjoy the light, bright airy nature of the greenhouse barn versus the dark, dank interior of many retired dairy facilities (where calves have often been kept). On other farms, caretakers spend more time with the calves while protected from severe winter weather inside greenhouse barns versus time spent attending calves in individual, outdoor hutches. There is opportunity for improved animal health with increased attention to calf care, protection from severe weather while providing good indoor air quality with dry bedding conditions.

A little extra attention is needed to control temperature and ventilation aspects of greenhouse barns. Conventional livestock barns of wood frame construction have not had to accommodate the tremendous solar load that a greenhouse structure presents. Two major designs are common in greenhouse barns. One is a simple free-standing arch while the other has the "arches" in a gutter-connected configuration (figure 1).

![Figure 1. Greenhouse barn dimensions in relation to effective ventilation openings.](image)

This article recommends design features to use for proper ventilation for good air quality within a greenhouse barn. Effective natural ventilation design uses openings positioned both high and low in the structure, large openings for summer heat removal, unobstructed air flow inside the building, and location at a breezy site.

**Location, location, location**

Wind exposure is needed for air movement into, through, and out of the structure. Greenhouse barns are naturally ventilated buildings that need to adhere to all the proven features that make naturally ventilated buildings work. Most natural ventilation is provided by wind.

Orientation in the northeastern United States is generally with the long openings of the sidewall of the building facing the west to south-west where prevailing summer breezes originate. Locate the building at least 50-feet away from nearby one-story farmstead structures; farther away from taller structures that block wind.

Place the greenhouse barn in a breezy location that is not in the "wind shadow" of another building, trees, etc. Orient it so that summer breezes blow through the structure.
Breathable

Without some careful thought, a greenhouse barn can become a big plastic bag with animals inside. Heat, condensation, and manure gases will be trapped. The structure needs to be breathable. Most often greenhouse shade cloth is used on endwalls and sidewalls to provide air exchange year round.

The mesh shade cloth sidewall concept has been the major innovation that converted the greenhouse for plants into the greenhouse barn for livestock. Shade cloth dampens the effect of a strong wind blowing on the housed animals while providing a breathable sidewall. It comes in many shade cloth densities from 5% to over 90%. These percentages relate to the amount of sunlight blocked from going through the woven or knitted polypropylene material but would also relate to the amount of air flow blocked. Use no greater than 80% shade cloth on the ventilation openings with 50-60% shade cloth a good compromise for airflow, shade and tempering strong wind.

Provide shade cloth as endwall material on all greenhouse barns with additional shade cloth on sidewalls of wide (>40-feet) or multi-span greenhouse barns. Shade cloth end wall air exchange can be improved by leaving the top 1 to 2-feet of the gable peak completely open.

Some tips on shade cloth walls:

- Dust will reduce air flow through the shade cloth material so plan on periodic cleaning; annual at the minimum.
- Often the top 1- to 2-foot portion of the gable endwall is left completely uncovered, with no shade cloth, for even better air exchange.
- Sliding doors on the gable endwalls may be covered with mesh. On large gutter-connected barns, the shade cloth walls should be removed to allow enhanced hot weather ventilation.
- Managers can leave sidewall curtains (plastic or mesh) open a few inches at the top even during cold weather.
- For calf greenhouse barns, side wall height can be as low as 3 to 4 feet with consideration given to avoiding rain entry onto the bedded calf pen area. Mature dairy cows, by contrast, are typically housed in 12- to 14-foot eave height greenhouse barns with mesh openings on all walls.
- Top-opening curtains, designed similar to those used on poultry or dairy barns, are preferred as they remove moist air near the roof and decrease the potential for drafts on the animals. Bottom-opening sidewall curtains usually roll up on an attached pipe.
- On buildings with tall sidewalls (14 feet and higher), double curtains may be used that open from both the top and bottom.
- Field experience indicates that shade cloth material in livestock barn environments has about a six-year lifespan and that the material is usually a fixed installation as opposed to a moveable curtain.

Heat buildup!

Greenhouses get real hot in the summer. Greenhouse barns use translucent roof coverings and big ventilation openings to overcome the natural heat buildup. Shade cloth and light-reducing coverings are the first line of defense as once the radiation heats up the building interior this heat is harder to remove versus not allowing the heat buildup to begin. Even the best ventilation does not reduce the solar radiant heat load.

Shade cloth of 90 to 95% is used on the greenhouse barn roof to block excessive sunlight (80% is not enough). Shade cloth is added to the roof when warm spring weather starts without fear of snow. Snow slides off the plastic roof easily but shade cloth discourages snow slide. Some tarps and opaque plastics have been used successfully as roof coverings. A milky-white 70% opaque film has been found to reduce light entry enough to be used instead of shade cloth with regular transparent greenhouse film.

Provide openings for hot, moist, or stale air to get out

Provide sufficient openings for warm, moist air to escape. Openings positioned high in the structure are particularly important as this is where warm, moist air accumulates. Warm moisture-laden air is not likely to move downward to get out of the building. Open gable ends with 1 to 2 feet of mesh removed, are common on small free-standing greenhouses. Ridge vents are common on larger and gutter-connected greenhouse barns.

Provide some high openings

Thermal buoyancy, which is simply hot air rising, provides air exchange during windless times or when a large difference exists between the inside and outside temperatures. This is usually a cold weather ventilation strategy. In conventional “cold” animal housing (barns without supplemental heat) the indoor temperature is kept within 5 to 10°F of outdoor temperature so ventilation by thermal buoyancy is seldom a strong ventilation force. But for greenhouse barns in the winter, this temperature difference between outdoors and indoors can be significantly greater (40°F or more) due to the “greenhouse effect” of trapped solar energy. This warm air will hold a lot more moisture than cooler air. As the barn cools with decreasing sunlight, it is especially important that this warm moist air has been exhausted from the building before condensation begins to release all the air’s moisture back into the greenhouse barn. Animals will tolerate cold well when combined with dry air and dry bedding. Cold with damp air and a wet haircoat is stressful.
How far to expect air to move to get out of the structure

For stale air stuck in the middle of a barn, how far does it have to travel to get out? This relates to the workable length and width of a greenhouse barn. The further it has to travel, the less likely the building will maintain fresh air quality.

What works in similar naturally-ventilated buildings? Many 40-foot wide poultry houses with sidewalk openings but no ridge opening have ventilated effectively most of the time. This means stale air stuck in the middle of the barn had to move about 20-feet to get out of the building through an open sidewalk vent. Free-standing horticultural greenhouses are typically up to 35-feet wide using sidewalk vents and no ridge vent; but they are not often used during hot summer weather.

Making sure stale air does not have to travel farther than 20-feet to exit the building through an opening (sidewall, endwall, or ridge opening) will assist good ventilation. Simple arch greenhouse barns are often managed with closed sidewalk vents during cold weather. Air exchange instead relies on gable endwall openings to provide cold weather air exchange. This means limiting the simple freestanding arch building length to about 40-feet. It also means limiting building width to 40-feet when only sidewalk openings (no ridge vent) are used.

Gutter-connected greenhouse barns will need more openings in order to accommodate the 20-foot stale air travel recommendation.

| Limit the distance stale air has to travel to exhaust from the barn to less than 20 feet. Higher sidewalls and ridge vents allow wider building width and length. The simple naturally ventilated barn and greenhouse, discussed above, would have an 8-foot sidewall height. Modern naturally-ventilated dairy freestall barns (of conventional post frame construction) have a 14-foot sidewall height and are often 100 feet wide with a large (2-feet wide) ridge vent opening. The full 14-foot sidewall is open during warm and hot weather. Higher sidewalls allow more wind-driven air to enter the structure for better air exchange. The ridge vent, in addition to providing a high outlet for any thermal buoyancy driven air exchange, also allows hot air at the roof peak to escape. More importantly, a ridge vent offers a high opening upon which the wind can act to draw more air out of the structure. The wind blows faster higher off the ground so the ridge is an effective hot, stale air release point, similar to a chimney on a fireplace. | Greenhouse barns that are wider or longer than 40-feet should have sidewalk openings of 10 to 14-foot height and/or ridge vents. Buildings both wider and longer than 40-feet should have ridge vents and 14-foot sidewalk height. |

Ridge vent or not?

Is a ridge vent worth the additional construction cost? It depends. On wider buildings at full capacity with mature animals? Yes, it would be worth the additional cost. At a site where wind is limited? Yes, a ridge vent would be worth it. On a simple, small calf shelter in a windy location it would not likely be worth the additional cost. Consider the principles presented above about location at a windy site, breathability of the structure, and distance that stale air has to move to get out of the building to determine if a ridge vent(s) will significantly improve ventilation performance. In gutter-connected greenhouse barns, not all ridges need a vent if the stale air can travel less than 20-feet to a neighboring ridge vent or side/end wall opening to exit the building. Remember that moisture and warmer air rises and is unlikely to travel downward to escape out an adjoining section of the building.

A naturally ventilated building with a ridge vent will ventilate better than one without the ridge vent.

Concluding Remarks

Greenhouse barns have evolved to adequately address the different environment livestock require versus greenhouses’ original plant occupants. Most of the modifications have focused on aspects of environmental control such as reduction of solar load and addition of improved endwall and sidewall ventilation openings. The application of shade cloth material as a breathable wall construction for greenhouse barns has been the best single advance in environmental control.

Inclusion of ridge vents continues to prompt debate. Ridge vents are awkward to construct on the simple hoop house design versus installing them on the gable roof used in conventional livestock housing. Awkward construction leads to more costly construction so ridge vents have been avoided even though they improve air exchange.

Many people will continue to be attracted to the extra bright interior and working conditions within a greenhouse barn. A site specific evaluation of the merits of greenhouse barn construction versus more conventional construction is important. Design features that ensure animal comfort, such as roof shade, mesh walls, ridge vent, and automated sidewalk curtains, can bring construction cost near that of a conventional pole building. Consider that a simple pole-frame building with shade cloth sides all around may offer similar or improved animal and worker benefit versus the greenhouse-type barn. Fresh, dry air without drafts, rain, and snow entry is the goal as cold alone can be managed with additional bedding and more feed for dairy animals. Moderate swings in indoor temperature are acceptable for animal comfort as long as fresh, dry air conditions are constantly maintained.