N·E·X·U·S
GREENHOUSE SYSTEMS
SYSTEM 420 HYBRID GREENHOUSES

# White Paper

## Cannabis Greenhouse Environmental Factors

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## Background

Building a cannabis greenhouse is a major investment. Overall costs range from $20 to $100 per square foot depending on the greenhouse size, type of environmental equipment, and geographic location. Additional factors include: growing climate, production goals, and the overall capital budget. Making the best decisions possible during the planning process will substantially increase the probability for long-term success once the greenhouse is in cannabis production.

An area with a substantial impact on the financial cost structure is the system of environmental equipment and controls. Taking the time to understand the local weather patterns and necessary cultivation methods to effectively grow crops in a specific geographic environment is crucial to cost-effective cannabis greenhouse operations. With this knowledge in place, the best environmental equipment decisions can be made.

As a greenhouse manufacturer, Nexus designs high quality, commercial greenhouses for the traditional horticulture and the emerging cannabis markets. The company partners with environmental equipment and control providers, and manages the development of integrated greenhouses. This white paper outlines the various options for optimal greenhouse cultivation.

## Heat

The main purpose of a greenhouse heating system is to replace energy lost when outside temperatures are below the desired greenhouse temperatures. This lost heat is based upon four factors:

1. Surface area
2. Geographic location
3. Type of crops
4. Heat loss rate

## Overhead Heating

One common method is overhead forced air unit heaters, which run from hot water, natural gas, propane, or oil. These heaters blow hot air into the cannabis greenhouse to maintain environmental air temperature set points. This effort ensures the entire plant canopy receives an equal amount of heat. In addition to providing ideal temperatures for good plant growth and yield, the heaters contribute to dehumidification in combination with controlled venting.

Unit heaters are popular due to low capital and installation costs, high reliability, and the ease of staging multiple heaters. Multiple heaters provide backup ability in case of equipment failure, which is essential in cold climates to prevent crop damage. These heaters are usually mounted directly within the greenhouse zone where they will provide the heat. Exhaust gases from the heaters are expelled through the roof or end walls. Gas heating is one of the most economical heating options and provides considerable efficiency when operating.

## Horizontal Air Flow

Working in combination with overhead heaters, horizontal airflow fans provide a consistent distribution of carbon dioxide, humidity, and temperature especially during the winter months. Horizontal air movement is created by the strategic placement of HAF fans at a height of approximately eight feet from the floor or above the plant canopy. The fans also ensure that cold air brought in by ventilation systems mix uniformly with the warm air inside the cannabis greenhouse.

Fans are located along the length of the greenhouse. The direction of air flow alternates among adjacent growing areas. Each fan should be placed approximately 50 ft. apart inside the growing space or at intervals of 25% of the total length. For cannabis, there can be up to one-third more fans than in traditional growing. With continuous air movement, these fans significantly improve the plant microclimate and overall plant quality.

Cannabis crops with horizontal air fans above

## Root Zone Heating

Heating plant root zones with overhead heating is often challenging since pushing heat to the floor area can be difficult (heat naturally rises). One solution to this concern is floor or benching systems with radiant heat. Floor heating consists of plastic pipes embedded into concrete or sand beneath the floor surface.

Warm water flows through the pipes and emits heat into the floor areas. This heat covers multiple growing zones with uniform temperatures. However, floor heat cannot be used to warm air temperatures without raising root temperatures to excessively high levels.

Benching heat systems involve water pipes above the floor and under the bench systems. The heat pipes are closer to the growing containers and provide the shortest route of heat flow to reach the soil. For most crops, soil temperature is more important than air temperature.

Root zone cannabis heating benefits include better germination of seed, faster rooting of cuttings, and increased plant growth and disease control in potted plants. Regardless of the type of root zone heating system, the greenhouse needs to have a boiler system to heat water to the 120-200 degree F temperature level depending on the type of boiler.

### Infrared Heating

This type of heater is usually hung in the peak of a cannabis greenhouse with heat directed towards the objects to be heated. While heated air that is surrounded by cold air rises, infrared energy does not convert to heat until it is absorbed by the object. With this concept in mind, growers can design heating systems to heat the plants and soil in a uniform manner without heating the overall greenhouse air climate.

Since these gas-fired, low-intensity heating systems warm plants naturally and consistently, then most plants will positively respond. Some plants may even grow faster. Rooted cutting or seedlings often take hold quicker from the warmer soil. The growing zone expands due to the small temperature variance.

## Cooling

Ventilation is important all-year long and not just in the summer months. Heat stress can occur even on days when outside temperatures are 30 degrees or more below the desired inside temperature. On a clear day of 60 degrees, the temperatures inside a greenhouse can exceed 100 degrees. Without proper ventilation, greenhouses can easily become hot enough to damage cannabis crops.

By replacing the warm, moist air inside with cooler, dry air from outside, then the growing environment becomes better suited for cultivation. In additional to cooling the cannabis greenhouse, ventilation reduces the internal humidity levels and replenishes the carbon dioxide that plants consume during photosynthesis. Ventilation occurs from either natural or mechanical systems.

### Natural Ventilation

This type of ventilation is driven by temperature differences inside and outside the cannabis greenhouse or wind conditions that create small air pressure differences. Vents are opened to get the warm air to leave and cooler air to enter. The specific type of natural ventilation method used is largely dependent upon the geographic location. Naturally occurring wind breeze along with proper greenhouse orientation can be an especially effective combination in some geographic areas. Understanding the meteorological environmental in specific geographies is crucial to designing natural ventilation systems.

Ridge vents are an economical way to release the hotter attic air in a greenhouse. The release of this air allows for cooler temperatures at the plant level. Plant health is improved by the leaf movement caused by the upward air current to the ridge vent.

System designs include roll-up sides (manual or automatically operated), side vents, roof vents or ridge vents. Adjustment for the roll-up sides can be several inches or feet as well as the entire side wall depending upon the amount of necessary air. The curtains, which compose the roll-up sides, can be lowered from the top or raised from the bottom according to each system's design and operation methods.

The amount of cooling that occurs depends upon the wind velocity and direction, greenhouse directional orientation, structural width and length, outside air temperature, and any wind obstruction from nearby trees, buildings, or other greenhouses. Vent openings (3-4 ft. wide) along the length of the greenhouse will allow for cross ventilation from prevailing wind patterns. The greenhouse directional orientation needs to account for wind patterns that blow across the structure rather than along the length.

### Evaporative Cooling

Reducing air temperature by evaporating water into the air is a common method of greenhouse cooling. As water evaporates, heat energy is lost to the air, which reduces the temperature. A fan and pad system is the preferred evaporative cooling method for many greenhouse cannabis growers. Exhaust fans are placed in one end wall and pads on the opposite end wall. Water consistently moves over and through the pad while operating.

The fans exhaust air from the greenhouse and pull fresh air in through the moist pads. The air loses heat and the temperature drops. This drop in temperature depends on the air's capacity to absorb water. Evaporative cooling is more effective when humidity in the outside air is low. When the outside air temperature is 95 degrees with 50 percent relative humidity, the drop in cooling is approximately 13 degrees. Yet, if the relative humidity is 70 percent, then the expected cooling would be 8 degrees. If the relative humidity rises to 90 percent, then only a 2 degree temperature drop is likely to occur. Due to solar radiation, the air will gradually heat up from pad wall to the exhaust fans.

Evaporate pad cooler on a greenhouse end wall

### Positive Pressure Cooling

High volume jet-fans pull air through an evaporative cooling system and push this air into the cannabis greenhouse with special convection tubes. This process increases static pressure inside the greenhouse. Ridge vents maintain normal pressure inside, which allows the heat to escape. Another benefit of a positive pressure system is insect exclusion. When positive air flow from inside the greenhouse reaches the roof vents, then the pressure substantially reduces insect entry. Adding insect screening to the roof vents increases the potential for nearly full insect exclusion even more. The need for pesticide use will decrease.

### Fog

High pressure fog systems are another greenhouse cooling method, which can be a supplemental alternative to other systems. Fog nozzles are placed all through the greenhouse as well as at the air inlet. Water evaporates throughout the greenhouse instead of only along one wall with a wet pad system. These systems can be expensive due to the large number of necessary nozzles and high pressure pumps required to make small water droplets. Good water treatment and filtration is essential to produce actual fog rather than mist. Consistent maintenance is important to prevent chemical and biological buildup in the nozzles. A benefit of a fog system over a pad wall is a more uniform temperature from inlet to exhaust.

### Humidity

A secondary role of a ventilation system is to reduce or eliminate excessive humidity. When there is not adequate ventilation, extra humidity condenses on leaf surfaces, which increase disease

potential. Condensation contributes to deterioration of the greenhouse components. Light transmission is reduced as well. When the moist air around the cannabis is replaced with the cooler and drier outside air, then internal humidity levels substantially fall. Consistent equipment operation, reasonable plant spacing, and early daily watering are best practices for reducing relative humidity and preventing cannabis plant diseases.

### Ventilation/Airflow

Proper ventilation and sufficient airflow are vital to managing relative humidity inside a greenhouse. Warm air has a higher capacity for moisture than cool air. On a warm, sunny day, the air within a greenhouse accumulates moisture. As evening approaches, outside temperatures cool, the internal air temperatures drop, which reduces the water-holding capacity until water condenses on the plant and greenhouse surfaces at the dew point.

To reduce this type of condensation, air exchanges will remove the moisture-filled greenhouse air and replace it with drier, outside air. If the new air is cool, the fresh air needs to be heated to reduce internal relative humidity levels. Horizontal airflow blends cool and warm air together within a cannabis greenhouse to buffer the air from falling below the dew point.

### Insect Exclusion

Since cannabis is a consumer product, a minimal number of pesticides are available for commercial use. Using an insect screen is a common method for reducing pests. While screening does not guarantee a complete pest-free greenhouse, it makes a major difference. Screens create resistance, which limits the ability of the pest to enter the greenhouse. Appropriately matching the mesh type to the pests you are trying to exclude is important.

Another method is positive pressure cooling. Air is pushed through an evaporative cooling system, which forces the air into the greenhouse. Exhaust vents must be designed to allow air pressure to stabilize while still creating higher air pressure inside the greenhouse than outside. Due to this internal air pressure, insect infiltration through greenhouse openings is further restricted.

### CO2

Enriching cannabis with additional CO2 is an option to increase plant growth and crop yields. The ideal quantity depends upon the type of cannabis, light intensity, temperature, and crop growth stage. Many growers do not monitor CO2 levels. As long as crop yields are sufficient, growers may be satisfied with the overall production effort. However, monitoring can occur with infrared CO2 gas monitors at a reasonable cost. If these monitors show that CO2 levels are insufficient for expected cannabis yields, then a CO2 enrichment system can be implemented.

There are many ways to enrich CO2 levels. A natural approach can be initially considered. Approximately, one to two hours after sunrise, CO2 build-up from the night is at a high level. Horizontal airflow improvements can be made to distribute CO2 evenly throughout the greenhouse. An optimal CO2 level is 1,000 to 1,200 ppm.

If natural CO2 enrichment does not achieve the desired results, then other options may be considered. When outside air conditions are too extreme for proper ventilation, then extra CO2 from liquid or bottled CO2 gas may be needed. Careful handling processes are necessary for safe

implementation from these sources. In addition, specialized equipment, which are designed and certified for CO2 application, is another option.

## Fertigation

Maintaining adequate plant nutrition is one of the most important factors in cultivating greenhouse cannabis. Most growers utilize a liquid feed program as their main method of supplying plant nutrients. The frequency of these liquid applications can vary with some growers supplying the nutrients at the peak periods of vegetative or reproductive growth. However, a constant feed (soluble fertilizer at each irrigation) is often the preferred method for producing the best plant growth.

By injecting soluble fertilizers into the irrigation system, the following benefits can be obtained:

1. Precise control of nutrient concentration and supplemental minerals
2. Customization of nutrient solutions to fit the requirements of any plant stage or species
3. When properly applied, there is a low potential for over-fertilization or crop salt injury
4. Fertilization solutions are easy to monitor and apply to crops

Fertigation provides an accurate and consistent application of nutrients to the wetted plant area, where the active roots exist. This effort is a highly efficient process since the plant roots absorb the nutrients, which increases plant growth and reduces wasted fertilizer. However, fertilizer recommendations aren't available due to a lack of federal regulations.

## Environmental Controls

Cannabis greenhouse environments have unique challenges for effective environmental control. Temperature fluxuations may occur rapidly and widely vary depending on solar radiation levels, ambient temperatures, humidity, wind velocity and direction, amount of plant material inside the greenhouse, and watering practices. Proper control of the cannabis greenhouse environment is challenging, yet the benefits of good control far exceed the costs.

The overall objective of any greenhouse system is to reduce the input cost per unit of production and maintain or increase the quality of production. While some enhancements improve the input cost and/or functions of a few specific tasks, such as heating or cooling, an integrated environment system will have a positive impact on nearly every greenhouse component. Even an incremental performance improvement in several areas will lead to much better overall results.

According to the National Greenhouse Manufacturers Association, specific benefits include:

- **Higher Energy Efficiency:** Better equipment coordination and more accurate control can reduce heating, fuel, and electrical costs
- **Better Labor Efficiency:** Automated controls increase the productivity of workers by enabling them to focus on more essential tasks
- **Improved Management Effectiveness:** Additional information is available to managers and growers to help them make better management decisions and spend more time managing the operation
- **Reduced Water Use:** Growers report reduced overall water use of up to 70% with the most effective irrigation controls

- **Reduced Fertilizer Use:** When combined with lower water use, fertilizer application and improved efficiency can occur
- **Reduced Chemical Use:** More precise control of temperatures and effective use of growth regulating temperature practices, which reduces the need for growth regulators
- **Reduced Pesticide Use:** Greenhouses with better climate control and precise irrigation produce healthier plants
- **Improved Plant Quality & Uniformity:** Less disease, more effective irrigation and fertilization, improved grower information, and management all combine to increase the health and uniformity of plants
- **Reduced Equipment Wear & Tear:** Continuous monitoring and alarms alert growers to pending breakdowns and other problems prior to more serious consequences
- **Less Plant Loss from Failures**: Good data logging and graphing of greenhouse conditions and sophisticated early warning alarm systems help reduce losses from catastrophic failures


Environmental control panels

## About Nexus

Nexus Corporation has served the greenhouse industry as a top US manufacturer since 1967. With a corporate office and production facility in Northglenn, CO along with an advanced manufacturing plant in Pana, IL, the company brings innovative designs, high quality products, and exceptional customer service to its System 420™ hybrid greenhouse systems.

Nexus has a team of engineers (licensed in 49 states), sales, project management, customer service, and operations professionals dedicated to managing a greenhouse development project

from start to finish. The team has expertise regarding the customized design components, efficiency features, and cost management strategies necessary to maximize crop yields and return-on-investment.

**For more information on greenhouses from Nexus Corporation, click here.**

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