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## Greenhouse Structures

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### **Introduction** [\(top\)](#)

Selection of the greenhouse design is determined by the expectations, needs and experience of the grower. Consider what crop(s) will be grown, how they will be managed, and the grower experiences in the type of growing system. With this initial information, a workable design can be completed, and then modified by the financial realities of the required investment.

### **Basic Design Requirements** [\(top\)](#)

Assume a greenhouse layout, that efficiently uses the land space available. Begin with a small, but complete, free-standing greenhouse unit, which readily fits within a plan for future additions to this initial unit, or with modular blocks of separate, larger greenhouses. Consider the location and size of a headhouse work area, storage space and office space. Select a greenhouse design with structural integrity sufficient for the weather conditions (winds, snow) of the site. The greenhouse structure must not only be of sufficient overall size, but also be proportioned to fit the modular size (row spacing or bench width) of the crop production system, such that use of interior space is maximized.

The land should be well-drained and level, with access to roads for transport of materials and products. Utilities such as fuel, electrical power and telephone should be readily available. Sufficient quantity of good quality water is a necessity. Consider pH, hardness, salinity, and dissolved minerals when determining water quality. Have a lab test completed!

An important consideration for future expansion is whether a ground-to-ground (Quonset style), or gutter-connected structure should be initially selected. The Quonset can initially be less expensive. However, its maximum width is limited to approximately 9 m (30 ft), and for expansion, additional and separate units must be built. The gutter-connected design allows for future expansion by moving its sidewall and adding more bays. The entire module is under one roof, which provides for common access, and the capability of sharing environmental control systems, and other mechanical systems.

Multiple, separate structures can potentially offer isolation for disease and insect control measures, which seems less possible within gutter-connected facilities. However, pest control practices are more difficult and time consuming in the separated, smaller structures.

### **Greenhouse Orientation** ([top](#))

Orientation is determined by the direction of the greenhouse roof ridge or gutters, relative to the line of movement of the sun. There is no optimal orientation, but there are costs/benefits to be considered for either choice. The primary concern is for the maximum quantity, duration and uniform availability of solar radiation for plant growth. At geographic locations greater than 30° from the equator, the seasonal reduction of solar radiation is the most limiting plant growth and development factor.

The free-standing, Quonset greenhouse will provide more solar radiation than a gutter-connected greenhouse, with a similar orientation. The total yearly light received will be greatest for the Quonset or gutter-connected greenhouses if oriented with a N-S (North to South) roof ridge. Much of this total, however, is received in the summer season when light is not limiting.

Considering only the winter season, that is, the lowest light intensity and shortest daylength period of the year, an E-W ridge orientation will gain more total light than a N-S orientation.

For uniformity of light distribution to the plant canopy, the N-S oriented greenhouse is always better than the E-W. The shadow patterns caused by the overhead greenhouse supporting structures continually move across the crops (from west to east), as the sun travels from sunrise in the east to sunset in the west. This is especially important during the light-limiting season.

### **Glazings and Coverings** ([top](#))

The types of greenhouse coverings range from traditional glass to the polymer plastics, such as thin films or multi-layer rigid plastic panels. Enhancements to covering materials include: ultra-violet radiation (UV) degradation inhibitors, infrared radiation (IR) absorbency, and anti-condensation drip surfaces, as well as, other unique radiation transmission properties.

Plastic glazing includes: rigid plastic structured panels, such as fiberglass reinforced polyester (FRP), polycarbonate (PC), acrylic (PMMA, polymethylmethacrylate), and polyvinyl chloride (PVC) panels.

Thin film coverings include low-density polyethylene (LDPE), polyvinylchloride (PVC), and ethylene vinyl acetate copolymer (EVA). These materials have been used in single, double and even triple layers to cover the greenhouse.

Glass is quite inert, in contrast to plastic, and it can function for 40 to 50 years without failure. It is non-combustible, resistant to UV radiation and air pollutant degradation, and it maintains its initial radiation transmission if regularly cleaned. The greatest drawback of glass is its vulnerability to catastrophic losses caused by hail.

Polyethylene film covered greenhouses have been developed so that they are reliable, and usually have a lower initial cost than most other greenhouse glazing systems. All plastic coverings are affected by weathering and have useful lives of 3-5 years for films, and 10-15 years for rigid panels. Low air infiltration rates resulting from the continuous film cover have improved energy savings, but contribute to high greenhouse air humidity conditions. Moisture condensation, especially on flattened arch-shaped roofs, promotes dripping on the crop below. The open-roof greenhouse structures, where the entire roof can be mechanically opened and closed, have resolved some of these problems.

Selection of the type of covering material to use on new construction or on renovation projects requires many practical considerations. The flexible and forming properties of the film simplify the covering process compared to rigid plastics or glass. The attachment procedures for plastic film range from the simplicity of wooden nailer strips to the reusable aluminum extrusion inter-locking strips. The need for replacing the film every three to four years requires that the recovering process be rapid and easy. A means of recycling or disposing of spent film must also be considered.

Glass or rigid structured plastic panels require the more elaborate aluminum extrusions for their attachment to

the greenhouse structure. These must be designed for the longer life of these covering materials.

Rigid plastic structured panels made of acrylic, polycarbonate, PVC and FRP, are initially more expensive as a cover than polyethylene film, but they require less maintenance and provide a longer useful life. Re-glazing systems for acrylic and polycarbonate panels use fewer, stronger support elements which are spaced wider apart. This has effectively reduced the amount of structural shading typically associated with glass.

Ultraviolet radiation promotes photochemical degradation processes in all plastics and is generally the major reason for their replacement. Temperature extremes and their duration can weaken film coverings, and this is especially a problem where the film contacts the greenhouse metal structure. Air pollutants also reduce the usable life of plastic coverings. These may be from sources external to the greenhouse which are attracted to the outer plastic layers and reduce radiation transmission. They may also come from internal sources such as chemicals used for pest control, which can cause premature failure of the plastic.

### **Environmental Control** ([top](#))

Environmental control for heating and cooling uniformity is a very important design consideration to maintain desired environmental setpoint conditions. However, the distribution of heat is difficult, and a uniformly heated environment may not result. Non-uniform environments cause differential plant growth rates, potential disease problems, unpredictable results with nutrition or hormonal application, and generally a more difficult plant production system to manage.

For the most effective and uniform cooling and heating, the rows of plants should be arranged in the direction parallel with the ridge or gutters of the greenhouse structure. For ventilation, this assumes that the ventilation system (fans and air inlets) would be located on the endwalls (perpendicular to the direction of the gutters). Should airflow be restricted and non-uniform, then the ventilation system cannot effectively cool the plant, nor provide for sufficient air exchange for humidity reduction (disease control) and replenishing carbon dioxide.

Evaporative cooling systems, whether pad and fan, or high-pressure fog, are highly dependent upon effective and uniform ventilation, as well. Similarly, row orientation can improve air movement and more effective heating of each plant.

The capability of a hot water heating system for distributing the heat the plants is less affected by plant row direction within the greenhouse than a hot air system. The heating pipe network is uniformly spaced throughout the entire greenhouse area, and typically distributes the heat more uniformly. The hot water pipes may be placed at the perimeter walls, overhead, at the base of the plant, or in a combination of each. Heating pipes near the base of the plant provide warmed air near the floor which rises through the plant canopy, providing a desirable plant microclimate.

A taller greenhouse is better for improved climate uniformity. In gutter-connected greenhouses, a minimum of 3 m (10 ft) from floor surface to gutter, plus an additional 1.2 m (4 ft) from the gutter up to the ridge, is desirable. Tall greenhouses provide a large internal air volume, which reduces rapid changes of the greenhouse climate caused by the natural daily fluctuations of the outside environmental conditions.

In addition, a tall greenhouse provides sufficient space required for other greenhouse systems such as: an energy blanket or shade cloth, supplemental lights, raised benches (reducing usable height to overhead systems), irrigation boom, overhead misting systems, tall crops such as tomatoes, or hanging basket plants.

The most common energy conservation technique related directly to the design of the structure is the internal energy blanket. This system could also be used as a shading system with proper selection of blanket material. In all greenhouse structure designs, a space for the energy blanket should be provided, whether the systems is initially installed or not. Within a gutter-connected greenhouse, the blanket can be located at the height of the gutter. When not in use it can be tightly packed beneath the gutter to minimize shading to the plants below.

### **Management, Labor, Internal Transport, Space Utilization, and Materials Flow** ([top](#))

Greenhouse crop production has work conditions that can be modified and improved as a result of the mechanization, automation, or environmental control systems. The labor demand is nearly continuous, which helps to maintain a skilled, dependable workforce. The regularity and repetitiveness of the work tasks allows for improvement of work conditions, work procedures, and mechanization, which ultimately lead to increased productivity and safety for the worker.

Management and labor for crop production is a major expense for a greenhouse operation, thus any means to increase labor productivity or improve labor management is beneficial. Generally, a larger facility under one roof, such as with gutter-connected greenhouse, can improve the labor management situation. The preparation and work areas for specific tasks can be centralized for more efficient labor productivity. Supplies and raw materials can be readily available from central storage. The layout or relative locations of preparation area, growing area, storage, and shipping (input/output), directly affects the production capacity, flow of materials, and labor productivity of the greenhouse. The plant production space within the greenhouse bays, accounts for the largest of these locations.

The type of growing system, its physical layout, and its environment and plant culture systems (water, nutrients, heat) directly affect labor efficiency and flow of materials. Within the plant production area, the greenhouse bays consists of crop rows which are typically organized in a repetitive fashion. The bays have aisles for worker access to the plants. It is desirable to minimize both the number and the size of the aisles, in order to increase the greenhouse floor space for plant production.

The limitations on these minimum sizes are based on the light availability to the plant canopy, and the need for sufficient access to the plants to complete the tasks associated with plant care, maintenance, and most importantly, harvest.

The crop rows within the bay must be inter-connected to each other for easy access by the workers, as well as, to the input/output location (typically a shed) of the greenhouse. The number and size of pathways which make this connection need to be minimized, however, they must be of sufficient capacity to prevent labor or transport bottlenecks. They should be sized for the required machinery that must be transported.

#### **Automation, Mechanization and Labor Aids** [\(top\)](#)

The importance of mechanization and automation is directly proportional to the amount of handling and maintenance operations required for the crop. Handling is determined whether the crop requires regular (daily) handling/transport to complete an operation (pinch, prune) during its growth period, and whether these operations can remain within the greenhouse growing area, or must be transported to a work area outside the growing area. A general rule of internal transport to make the most efficient use of labor is, to move the largest unit size of materials or crop over the shortest possible distance within each labor transport cycle.

There are several options for locating the work area (i.e. the area where hands-on maintenance operations will be performed on the crop) for efficient crop transportation. It could be near by but removed from the production area, for example, within an adjacent shed building. There is also the option for a mobile work station, which is moved to the plants in the growing area.

Machinery and hand equipment which can improve the capability of the workers to perform their tasks, or improve the working conditions should be considered in the design. Automation and mechanization have an investment cost which must outweigh the costs of a manual operation. Automated machinery or manual labor aids increase the uniformity and consistency of the product, and the work force. Mechanization of an operation can provide mechanical power, speed, repetition, safety and a greater potential for consistency and quality control. Automation includes these attributes but with greater flexibility, and potentially, some automated decision-making.

#### **Questions?** [\(top\)](#)

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