



Creating a Master Plan for Greenhouse Operations

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Introduction

You have heard the expression “*Change is inevitable*”. Unfortunately, sometimes people are unhappy after a change, such as renovating an existing greenhouse, because they ended up spending as much money as they would have by building an entirely new facility, but without gaining the full benefits of a new facility. Creating a business master plan may help prevent such disappointments.

Changes in the greenhouse industry during the past decades have increased greenhouse construction and operation costs significantly. This makes it necessary to carefully plan the overall design of the facilities in order to avoid costly retrofits at a later stage. A comprehensive master plan is required that reflects how the owner/operator intends the completed facility to function. A key component of the plan is the careful integration of all the systems and buildings comprising the entire greenhouse operation.

For financial reasons, it is often not possible to include all the desired systems and installations in the initial construction of the facility. However, the overall plan should provide for these systems and installations so that they can be added at a later date without trouble or unnecessary additional costs (e.g., from the onset, install a sufficiently large water supply line that can accommodate the planned future expansion of the greenhouse facility).

It is generally a good idea to establish priorities and not to compromise when implementing a design plan. The priorities and systems selected to be included in the first installation should always be options that provide the greatest returns. Additional systems can be added at a later date.

There are many items to consider when formulating a facility’s master plan, especially because it is part of an organizational master plan. It is generally easier to add a greenhouse than to develop an overall business goal and a plan to achieve it. Technical, horticultural, and business management skills are required for the successful operation of greenhouse facilities. Excellence in only one area cannot guarantee overall business success.

The Business Plan

A business plan is an important part of an overall master plan. Expansion or improvement of facilities always implies added costs and the expansion must be considered with the profitability and overall organizational plan in mind.

A business plan usually contains several components including plans addressing human resources (labor), marketing, production, and finances. The following list may serve as a guideline for developing a successful business plan. Developing a business plan is an iterative process that may have to be repeated on an annual basis to adjust for unforeseen circumstances.



- Look at the past (what worked, what didn't).
- List your goals (e.g., more or new crops, expansion).
- Get specific (fill in the details).
- Develop steps (what steps are required?).
- Estimate costs involved.
- Estimate time commitments.
- Estimate labor requirements.
- Prioritize (rate in order of importance).
- Write an action plan (make a schedule for your plan).
- Reality check (is your plan too ambitious?).
- Get consensus (talk to co-workers, family, etc.).

Greenhouse Design

There are many items to consider when contemplating the location and design of a greenhouse. These include, but are not limited to, the following:

- Site selection and access.
- Greenhouse orientation for optimum light utilization.
- Structural strength to handle weather conditions, including wind and snow.
- Suitable greenhouse glazing materials, including plastic film, rigid plastic panels, glass.
- Energy conservation considerations, e.g., double-layer glazing, curtain systems.
- Environmental control systems, e.g., heating, ventilation, lighting, CO₂ enrichment.

- Irrigation and fertigation systems, e.g., drip irrigation, ebb and flood floors.
- Availability of utilities, including water, electricity, and heating fuel.
- Plant production systems, e.g., rolling benches, hanging baskets.
- Materials handling systems, e.g., soil mixing, pot fillers, conveyor belts.
- Labor (availability and salary structure).

Requirements for a Greenhouse Production System

There are many components of a greenhouse production system. Table 1 shows some of the inputs and outputs that need to be considered when planning a greenhouse production system. Each of the items mentioned needs to be considered. Evaluating the greenhouse as an integrated system can help prevent potential problems.

Table 1. Greenhouse inputs and outputs important for facility design.

Inputs	Outputs
Seeds, cuttings, plugs, etc.	Finished plant material
Growing media	(Plant) Waste
Energy (heating fuel and electricity)	Heat (loss to air and conduction to subsoil)
Light	Stray light from supplemental lighting
Carbon dioxide	Oxygen
Water	Runoff
Fertilizer	Leachate
Labor	
Disease and pest management	

A site survey that includes a topographical map is important so that there are no surprises with runoff, quantities of required back fill, road access, or local zoning regulations. The elevations shown on the map should have a minimum of 1-foot contour intervals. The site plan should accurately show the property and indicate current buildings, roads, and locations of all utilities. Locations of streams, ponds, and dedicated wetlands are important for runoff considerations as well as the permitting process. If a retail operation is part of the design plan, then more care is needed in planning to satisfy building code, public safety, and zoning regulations. NRAES 51, *Produce Handling for Direct Marketing* and NRAES 52, *Facilities for Roadside Markets*, contain good planning information for retail operations. Key to good planning is to arrange the sales area so that employee and plant material movement do not intersect and interrupt normal customer movement and traffic patterns. When considering sales areas within greenhouse structures, building code and zoning regulations will have an effect on the design of the facility. A prudent check by the engineer involved in the construction of the facility with the local building code and zoning officials is advised. Retail operations allowing public access are often subject to particular scrutiny by local building code officials.

Key Components of the Greenhouse Facility

Foundation

Permanent greenhouse facilities are often constructed with a solid concrete foundation. Structural foundation footers and/or walls must extend below the frost line and perimeter walls should be insulated to prevent unnecessary heat loss to the outside environment bordering the greenhouse perimeter. Main interior concrete walkways should be at least 4 inches thick and 10 feet wide to accommodate vehicular traffic.

Structure

The type of greenhouse structure should be based on the crops to be grown, the growing system used, the level of automation, the amount and location of

equipment used, and the overall physical arrangement possible on the site. These variables determine bay width and length, gutter height, type of glazing, type of ventilation, etc. Use of supplemental lighting, shade/energy curtains, and production of hanging baskets can determine gutter height. In addition, irrigation booms may require additional vertical clearances.

Ventilation and Cooling System

Ventilation systems can be either mechanical or natural (i.e., without the use of fans to move air through the greenhouse). The use of natural ventilation is mostly determined by the average wind conditions at the site. When there is virtually no wind, air circulation depends primarily on the buoyancy of hotter air in the greenhouse rising out of the ventilation outlets (roof vents) and drawing air in through the ventilation inlets (side vents). Natural ventilation using side and roof vents is a popular choice, as is the novel open-roof greenhouse design, but their appropriateness depends on the crops being grown, local weather conditions, and grower preferences.

Heating System

The heating system should be selected based on the crops being grown, heating uniformity criteria, fuel availability and cost, and grower preferences. The initial installation cost is important but should not be the most important consideration. Uniform crop growth is very important for most production systems, and the heating and ventilation systems have a major impact on producing uniform crops. Heating systems that give good temperature uniformity are preferred (e.g., circulating hot-water heating systems, floor and bench heating systems). Forced hot air systems generally have lower initial costs but decreased heating efficiency and less satisfactory uniformity will generally reduce long-term profitability.

Thermal Screens or Curtain Systems

A thermal screen that doubles as a shade screen is often one of the best investments a grower can make. The design of the greenhouse structure must be able to accommodate a thermal screen (i.e., enough

space is needed between the top of the plant canopy and the greenhouse roof to accommodate the operation of a thermal/shade screen). If the installation cannot be included at the start of a greenhouse construction project, the design must include provisions for it to be added without expensive modification or alteration to the greenhouse at a later date. It is important to also consider the possible future addition of supplemental lighting and/or movable irrigation systems when deciding on the initial greenhouse height. Some greenhouse operations had to be reconstructed one or more times over their life to accommodate improvements and the marginal cost of several extra feet of height in initial construction is modest.

Growing Systems

Efficient use of greenhouse space is a major consideration for growers. Being able to fill and empty the greenhouse efficiently and quickly is very important. Here, mechanization can help. The bedding plant industry is a good example of the importance of mechanization. Each piece of equipment is part of a system used to achieve the desired goal of efficient movement at reduced time commitment, effort, and cost. Figure 1 illustrates different greenhouse layouts, each realizing different space and labor efficiencies. Speedy removal of the crop from the greenhouse may require the use of an overhead conveyance to bring the plant material to a main walkway.

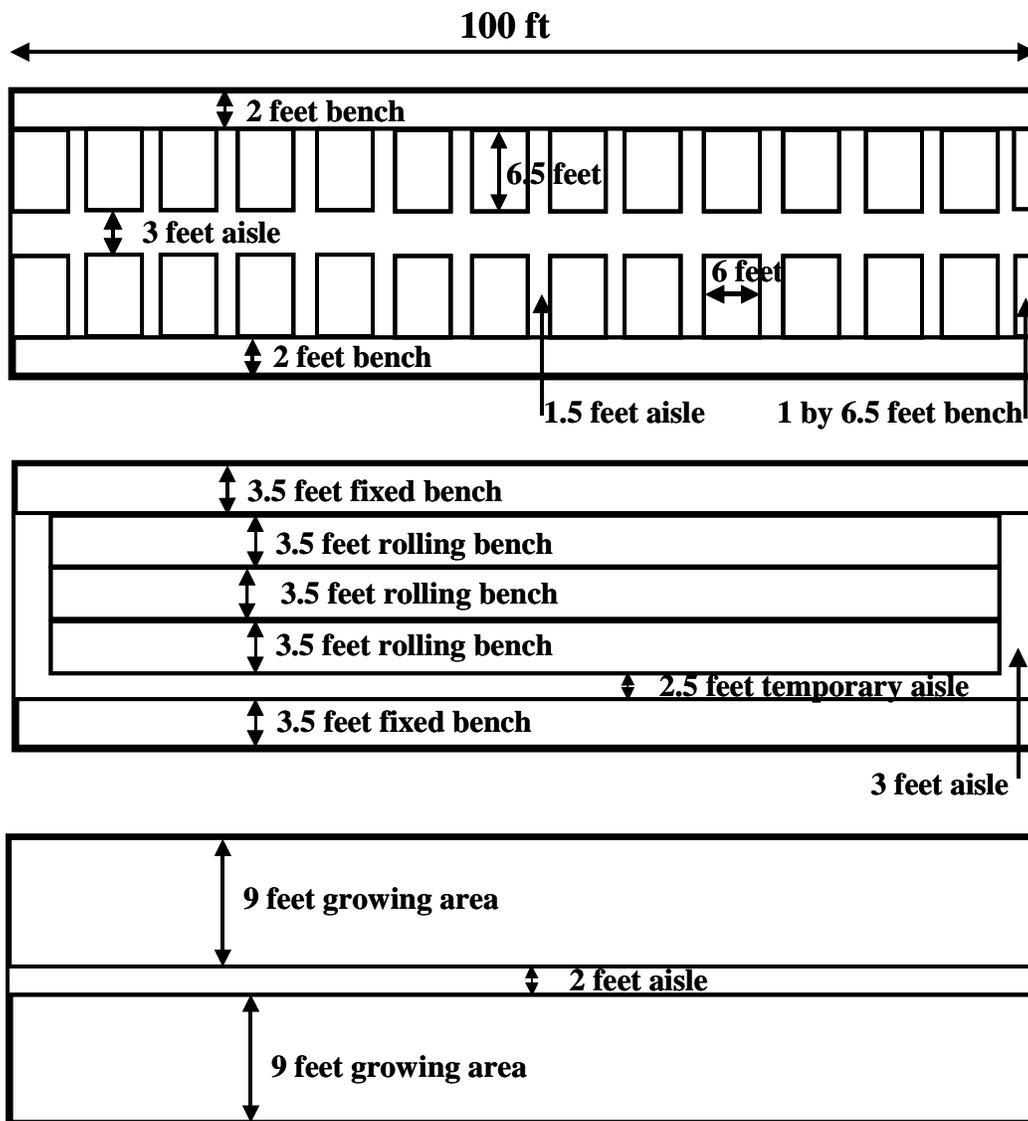


Figure 1. Examples of different space utilizations for three different growing system designs in a 20 by 100 foot greenhouse. From top to bottom: peninsular benches (71% efficient), rolling longitudinal benches (84% efficient), and growing on the floor (90% efficient).

Environmental Control System

Quality analog and digital (computer) systems are available that accurately sense and control both aerial and media (soil) conditions. Common measurements include air, canopy, and root-zone temperatures, sunlight (often measured as photosynthetically active radiation), relative humidity of the greenhouse air, aerial carbon dioxide concentration, electrical conductivity and pH of the nutrient solution and/or media. In addition, measurements such as ventilation window position, ventilation fan runtime, operation of pumps, position of mixing valves, nutrient solution volume, etc., are used to keep track of equipment operation. Computerized control systems have the advantage of recording data for subsequent use in evaluating plant performance or identifying problems with the mechanical aspects of the growing system.

Adequate Water Supply

In siting a greenhouse, consideration must be given to the availability of water. Is there an adequate water supply? And what is the water quality? Does it make sense to capture the runoff from the roof and store it for irrigation? In some areas of New Jersey water availability may be a limiting factor for greenhouse establishment and production. All users of agricultural or horticultural water that exceed a usage of 100,000 gallons per day must obtain an agricultural certification for the privilege of diverting water from ground or surface sources. The Rutgers Cooperative Research and Extension agricultural agent in your county can assist in determining water use requirements for your operation and the application process for certification.

Irrigation Systems

Irrigation systems vary in design and layout. Automation is a major consideration. Thus, a greenhouse design should be chosen that allows for (future) installations of automated control and autonomously operated equipment. The fertilizer injection system must be compatible with the installed irrigation system and backflow prevention devices need to be installed to comply with the law. NRAES 56, *Water and*

Nutrient Management for Greenhouses, provides additional useful information.

Utilities Installations

The installation and availability of common utilities (water, electricity, natural gas) is of utmost importance, particularly when considering adequate capacity for future expansion. Following appropriate electrical installation practices (i.e., adhere to electrical codes, hire licensed electricians, have all work properly inspected) throughout the greenhouse operation can prevent future safety and operational problems as well as maintenance and breakdown situations. Each critical electrical component should have provision for a connection to an emergency generation system, preferably to be installed when the greenhouse is constructed. The emergency system should have enough capacity to operate all control systems, boilers and circulators in the heating system, and at least the first stage of fan ventilation systems.

A Suggested Master Plan for the Construction of a 4-Acre Greenhouse Facility

Figure 2 illustrates a possible four-phase approach to constructing a 4-acre greenhouse facility. The selection of equipment and facilities to operate the greenhouse is a major and sometimes challenging decision. For instance, should one consider a transportable bench system be installed first before a superior heating system? Consider the situation that would occur with a greenhouse with transportable benches, but a non-uniform heating system. The produced crop will then not be uniform throughout the greenhouse at harvest time. The result is the challenge of moving transportable benches to the headhouse while some of the crop is ready, some almost ready, and the remainder at various other stages. How do you handle the crop? Several paths of product travel will have to be established. This situation will result in extra labor, eliminating the anticipated advantage of the transportable bench system. A transportable bench system must deliver 90–95% uniformity to the headhouse for the materials handling system to

function optimally. The answer to the hypothetical questions raised above is, of course, that first there has to be an excellent heating system installed before

a transportable bench system should be considered. Uniform environmental control is a prerequisite to mechanization.

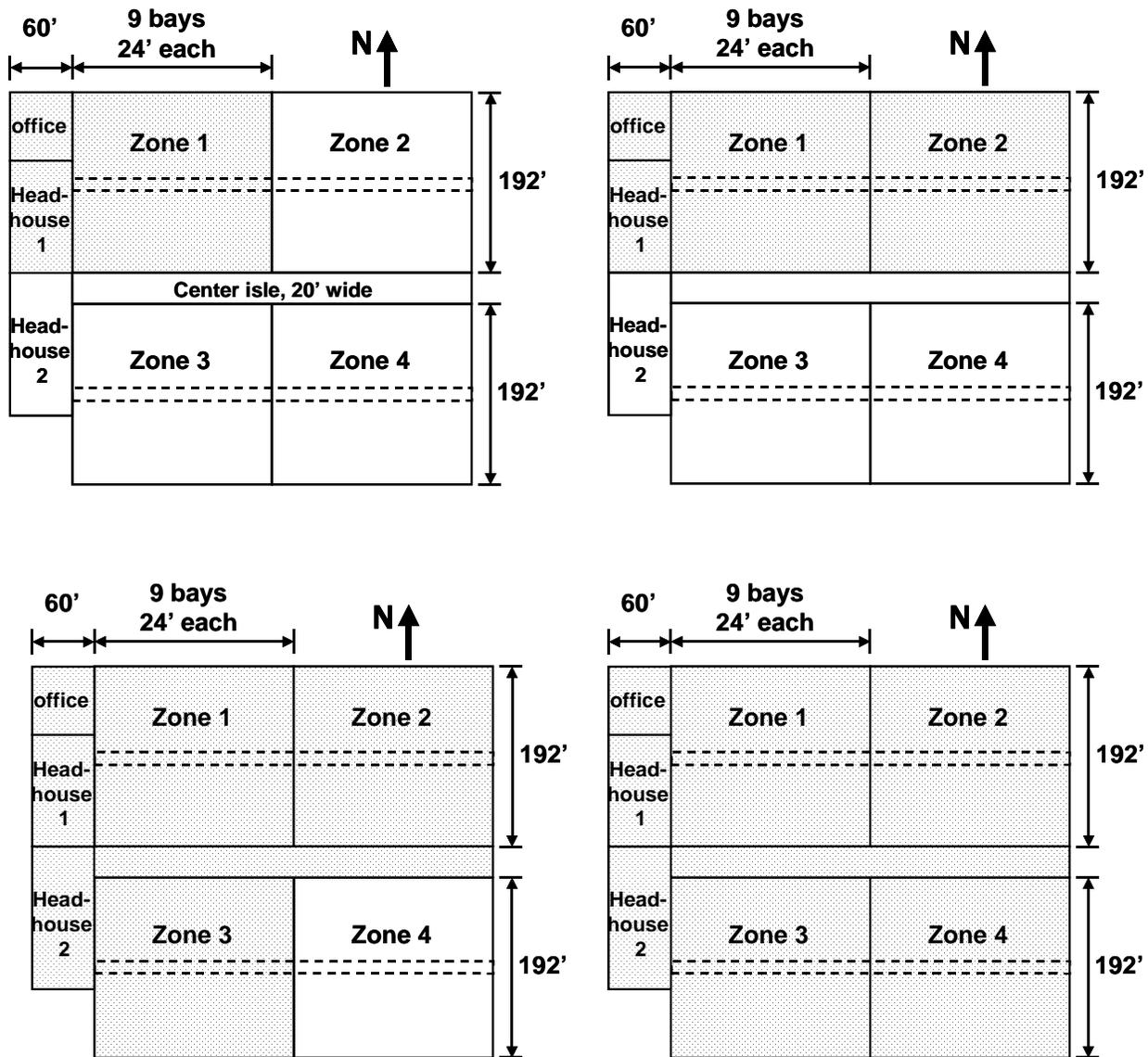


Figure 2. Phased construction of a 4-acre greenhouse facility. Phase 1: Office, Headhouse 1 and Zone 1, Phase 2: Zone 2, Phase 3: Central walkway, Headhouse 2, and Zone 3, Phase 4: Zone 4.

Summary

A good master plan has many components. Considerable thought and evaluation has to be made before the plan is completed and before the intended program of growth and expansion is undertaken. The important issues include a business plan, a site evaluation, an evaluation of the desired

type of growing structures, necessary and desired equipment, and the impact the expansion might have on neighbors bordering your property. The checklist (Table 2) and the included references contain additional information helpful in preparing a master plan for greenhouse operators who are considering erecting new facilities or renovating current ones.

Table 2. Greenhouse design and construction checklist.

Permits

Site Preparation

Leveling
Drainage (from roof and interior drains, including sewage drains)
Digging holes for foundation posts

Utilities

Electricity
Potable water
Irrigation water
Telephone
Natural gas
Propane storage tank
Fuel oil storage tank
Sewage system

Greenhouse Foundation

Soil-bearing capacity
Posts
Perimeter (knee) wall
Concrete floors/walkways
Roof drainage

Greenhouse Structure (includes glazing)

Roof
Sidewalls
End walls

Ventilation and Cooling Systems

Mechanical ventilation
Natural ventilation
Exhaust fans
Evaporative cooling pad
Fog cooling system
Horizontal airflow fans
Roof sprinkler system

Curtain Systems

White wash
External curtains
Internal curtains
Energy retention

Shading
Blackout system (photoperiod control)

Heating Systems

Hot air unit heater
Hot air furnace
Hot water unit heater
Poly-tube distribution system
Hot water boiler
Perimeter hot water distribution system
Overhead hot water distribution system
Bench heating system (hot water)
Floor heating system (hot water)
Radiant heating
Steam heating

Irrigation Systems

Hand watering
Overhead sprinkler system
Irrigation boom (movable)
Flood floor
Drip irrigation
Capillary mat
Hydroponics

Fertigation

Proportioners
Liquid fertilizer injection system
Slow release fertilizer

CO₂ Injection Units

Pure (vaporized liquid) CO₂ distribution system
CO₂ burners
Flue gas CO₂ extraction system

Greenhouse Lighting

Supplemental lighting system
Photoperiod lighting system
Walkway and security lighting

Growing Systems

Greenhouse floor
Fixed tables or benches
Rolling tables
Mobile or transportable tables
Hanging basket systems
Hydroponics

Environmental Control Systems

Analog control
Computer control
Alarm systems

Electrical Installations

Service entrance equipment
Distribution panels
Control panels
Interface panels
Main operating voltage
Low voltage lines (for equipment control)
Stand-by power generator

Miscellaneous Equipment Installations

Site Finishing (including landscaping)

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