BASIC GREENHOUSE CONSTRUCTION AND OPERATION

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Floriculture

The cultivation and management
of ornamental & especially flowering plants

- Categories
  - ✓ Bedding & Garden Plants
  - ✓Potted Flowering Plants
  - ✓Herbaceous Perennials
  - ✓Foliage Plants
  - ✓Cut Flowers
  - ✓Cut Cultivated Greens

Source: USDA, 2016

Industry Trends

- Floriculture
  - $31.3 Billion Retail Sales in 2015
  - $4.37 Billion Wholesale Value in 2015
- Top Producers
  - California
  - Florida

Source: USDA, 2016

What is a Greenhouse?

- Structure Covered With Transparent Material
- Artificially Heated
- Sufficient Height For Workers And Plants

What Will A Greenhouse Cost?

- Costs Vary Depending On
  - Location, Terrain, Distance From Utilities Etc.
- Simple Construction With No Winter Heating
  - $1.25 per square foot
- Quonset Style With Heating Capabilities
  - $4.00 per square foot

Source: Dr. James Robbins, University of Arkansas

Approximate Square Foot Costs

Greenhouse Style	Cost Per Square Foot
Quonset – Polyethylene with no Heating or Cooling	$1.25
Quonset – Polyethylene with Heating	$2.00
Quonset – Polyethylene with Heating & Cooling	$4.00
Quonset – Gutter Connected with Heating & Cooling	$4.50
High Sidewall, Gutter Connected Polyethylene with Heating	$6.00
Open-Roof Type	$8.00
Retractable Roof with Drop Sidewall	$10.00
Aluminum Frame, Glass or Polycarbonate Panels	$20.00

Source: Dr. James Robbins, University of Arkansas

Estimated Cost for a 30' x 96' Quonset Polyethylene Greenhouse

Component	Estimated Cost
Structure & Covering	$4146
Flooring	$505
Heating & Cooling Equipment	$6239
Frame Assembly	$1480
Benches	$2800
Grand Total	**$15,170**

Source: Dr. James Robbins, University of Arkansas

Things to Consider

- Site Selection & Layout
- Greenhouse Cost
- Greenhouse Structure
- Environmental Controls
- Crops?
- Wholesale or Retail?

SITE SELECTION

Site Selection

- Location
- Adequate Land
- Topography
- Orientation
- Water
- Accessibility
- Utilities
- Regulations

Location

- Primary Consideration
- Estimate Size Range Needed
- Purchase 2x Initial Need for Expansion
- Drives, Parking, Holding Ponds
- Service Buildings and Storage – 10% of Space

Adequate Land

- 2 Acres Minimum
  - ✓ Facilities
  - ✓ Outdoor Growing Area
  - ✓ Parking
  - ✓ Buffers
- Adjacent Vacant Land For Expansion

Topography

- Level Site 0-5% Slope
- Well Drained Site
- Natural Windbreaks
- Avoid Trees within 100 feet
  - Prevents Drafts
  - Reduces Shading
- Avoid Frost Pockets

Orientation

- North to South Always Provides More Light
- Greenhouse Structure Casts Shadows
- Consider Type of Greenhouse
- Location

Single Greenhouse

- Above 40 ° N Latitude
  Ridge Run East to West
- Below 40° N Latitude
  Ridge Run North to South

Gutter-Connected or Ridge & Furrow

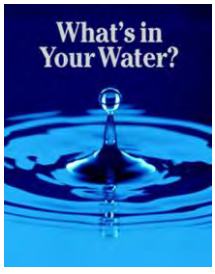
Ridge Run North to South

Photo Credit: Atlas Greenhouse

Photo Credit: Rough Brothers Inc.

Water

- Quality and Quantity
- Test Water BEFORE Purchasing Site
- Recharge Rates for Well Water
- Water Rights or Limits?



Accessibility

- Most Important Factor if Retail Operation
- Highly Populated Area
- Easy Access For Shipping and Receiving Products

Utilities

- Consider Availability and Cost of Acquiring Electricity, Telephone & Internet service.

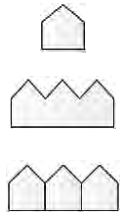
Regulations

- Local, State & Federal Regulations May Apply
- Zoning Laws
- Building Codes & Permits
- Parking & Signage Specifications
- Frontage and Side Yard Distance Requirements

GREENHOUSE STRUCTURE

Structure Classification

- **Free-Standing or Even Span**
  - Most Common Type
  - Self Supporting Commercial Greenhouse
- **Gutter Connected or Ridge and Furrow**
  - 2 or more even span greenhouses connected together at the eaves
- **Contiguous**
  - 2 or more even span greenhouses with inner walls separating each greenhouse



Structure Types

- Free-standing
  - Quonset (hoop)
  - Gable
  - Gothic
- Gutter Connected
  - Series of Quonset, Gable or Gothic
  - Ridge & Furrow

Quonset

- Rounded Roof
- Solid End Walls
- Greatest Amount of Sunlight Penetration
- Width - 12-30 ft.
- Length – 48, 96 and 144 ft.
- Hoop Spacing - 4-5 ft.
- Flexible Covering Required
- Least Expensive to Set Up

Source: Clydette Alsup-Egbers, Missouri State University

Gable

- Free-Standing
- Truss Frame
- Solid End Walls
- Width - 60 ft.
- Length – 48, 96 and 144 ft.
- Any Frame Spacing
- Covering - Flexible or Glass
- Higher Snow Load Capacity

Photo Credit: BWI Grower Technical Sales

Source: Clydette Alsup-Egbers, Missouri State University

Gothic

- Free Standing
- Trussed Frame
- Solid End Walls
- Max Width - 50 feet
- Increased Side Wall Height
- Snow Slides Off Easily

Photo Credits: Gothic Arch Greenhouses

Source: Clydette Alsup-Egbers, Missouri State University

Gutter Connected or Ridge & Furrow

- Series of Houses Connected at The Gutter-level
- 30 % Additional Growing Space
- Width
  Each Bay - 12, 24, 30 and 36 feet With Trusses to Support Larger Widths
- Length
  can be any, if > 200 feet it is difficult to cool with fan ventilation

Source: Clydette Alsup-Egbers, Missouri State University

- Most economical if 20,000+ sq. feet
- Centralized Utilities Easier and Less Expensive to Install and Maintain
- Heating Cost Reduction of 25%, due to Cover : Floor Ratio decrease
- Labor Efficient

Photo Credit: GGS Structures Inc.

Structural Components

- Frame Material
- Side Post
- Curtain Wall
- Truss
- Purlin
- Ridge
- Sash Bar
- Gutter
- Doors
- Glazing

Components of a Greenhouse

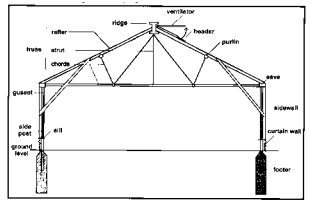


Photo Credit: Kirkwood Community College, Cedar Rapids, Iowa

Frame

Consider
- Type and Cost of Material
- Strength and Weight of Materials
- The amount of shade cast by the frame

Frame Materials

- Aluminum
  - Alloy: Aluminum combined with other materials to increase strength and flexibility with rust and rot resistance
- Plastic Pipe
- Wood
- Combination

Glazing

- Life Expectancy
- Heat Retention
- Ultraviolet Degradation
- Thermal Contraction
- Flammability
- Flexibility
- Light Transmission
- Cost

Glazing Materials

Polyethylene

- Glass
- Polyethylene
- Polycarbonate

Polycarbonate

Photo Credits: International Greenhouse Company

Glass Covering

- High Light Transmission – Up to 90%
- Low Heat Retention
- Not Flexible
- Heat, UV & Wind Resistant
- Expensive
- Easily Broken

Polyethylene

- Flexible
- Inexpensive
- Less Light Transmission
  - 87% Single Layer
  - 78% Double Layer
- High Thermal Contraction
- Fan Needed for Double Layer
- Damaged By Wind/Snow
- Heat Retention
  - Low Single Layers
  - Excellent for Double Layer
- Needs Replacement After 4-6 Years

Polycarbonate

- Not Flexible
- High Heat Retention
- High Light Transmission 81%
- UV Light Protection
- Can Yellow or Weaken
- Less Damage From Weather

Flooring

- Soil
- Gravel
- Concrete
- Flood Floor




HEATING & COOLING

Heating Basics

- Must Add Heat At The Rate It Is Lost
- Lost By Conduction, Infiltration, Radiation
- Consider:
  - Location
  - Frame Material & Glazing
  - Size of GH
  - Crops Grown
- Ensure that Exhaust DOES NOT Contact Crops

Source: Steven E. Newman, Ph.D., Colorado State University

Heating Systems

- Unit Heater
- Central Heat
- Radiant Heat
- Passive Solar Heat

Unit Heaters

- Forced Air Heaters
- Located throughout the Greenhouse
- Heat Floor Area of 2,000 to 6,000 square feet
- Need Constant Supply of Oxygen
- Relatively Inexpensive
  - $1.00-1.50 square foot

Source: Clydette Alsup-Egbers, Missouri State University and Steven E. Newman, Colorado State University

Central Heat

- One or More Boilers In a Central Location
- Pipes Move Steam or Hot Water
- Longer Life Expectancy
- More Expensive $4.50-6.00 square foot
- Less Maintenance

Source: Clydette Alsup-Egbers, Missouri State University and Steven E. Newman, Colorado State University

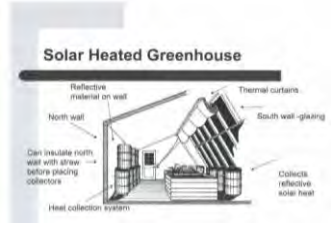
Radiant Heating

- Emits Infrared Radiation to Warm Plants & Objects
- 30-50% Savings Over Conventional Heating Systems
- Costs $2.50-$4.50 per square foot
- Placement Can Be Ceiling or Floor
  - 5 ft. Away From Plants
  - 4 ft. From Roof
  - 10 ft. From Walls
  - 20-30 Ft. Apart
- Heats an area 2 times the height

Source: Clydette Alsup-Egbers, Missouri State University and Steven E. Newman, Colorado State University

Passive Solar Heat

- 55 Gallon Barrels Filled With Water
- 2.5 Gallons/Square foot of glazing for season extension
- 5 gallons/Square foot for year round



Source: University of Missouri Bradford Research Center

University of Missouri Bradford Research Center

http://bradford.cafnr.org/passive-solar-greenhouse/

Cooling Systems

Passive Cooling

- Vents at Top & Side Wall
- Roll Up Side Walls
- Retractable Roofs
- Shade Cloth

Active Cooling

- Pad & Fan
- Fog Cooling
- Mechanical Air Conditioning
  - Small Facilities Only
  - Hobby/Lean-to

Evaporative Pad & Fan Cooling

- Ambient Air Passes Through Cellulose Material
- Water Flows Down Pad & Cools Air
- Exhaust Fan On Opposite Wall Pulls Cooler Air

IRRIGATION SYSTEMS

Irrigation Systems

- Closed or Open System
  - Closed
    - Nutrient Solution Is Recirculated And Not Allowed To Enter Back Into The Environment
  - Open
    - Nutrient Solution Is Allowed To Pass Through The Root System And Back Into The Environment

Common Types of Irrigation

- Hand Watering
- Sprinklers
- Drip Irrigation
- Booms
- Ebb and Flow Bench

Hand Watering

- Labor Intensive
- Hoses Can Damage Plants
- Improper Watering

Photo Credit: UMass Amherst

Overhead Sprinklers

- Misting
  - Fine mist emitted from overhead sprinklers
  - Ideal for Plant Propagation and Seed Germination
  - Minimizes Plant Stress
  - Helps control environment

Photo Credit: Curbstone Valley Farm
Source: Gothic Arch Greenhouses

Drip Irrigation

- Tubes With Emitters Or Spray Stakes
- Individual Containers Are Watered
- Regulated and Timed
- Low Energy Costs
- Conserves Water
- Customizable/Expandable
- Best For Containerized Production

Source: Gothic Arch Greenhouses

Boom Irrigation

- Durable
- Customized
- Saves Time and Labor
- Simple To Operate
- Programmable Within Bays
- Reduce Over Spray
- Increase Growing Space by 15%

Source: UMass Amherst & Cherry Creek Systems

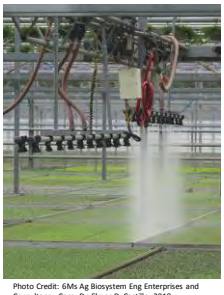


Photo Credit: 6Ms Ag Biosystem Eng Enterprises and Consultancy Corp. Dr. Elmer D. Castillo. 2010.

Ebb and Flow Bench Irrigation

- Flood And Drain Process Hydrates From Below
- Flooding Forces Stale Air Out And Fresh Air Back Into The Media
- Water or Weak Nutrient Solution Pumped On Several Times A Day
- Uniform Moisture Levels

Photo Credit: Pure Hydroponics
Source: Gothic Arch Greenhouses

GREENHOUSE LAYOUT

Types of Benches and Beds

- Benches
  Stationary or Rolling
- Raised Beds
  Beds Raised off the floor, usually 24-36 inches
- Ground Beds
  Constructed directly on the floor and filled with media
- Ebb and flow bench
  Raised bench approximately 3-6 inches deep and capable of holding water

Bench Size & Spacing

- Bench
  24-36" High
  ≤ 3' Wide – Against Wall
  ≥ 6' Wide – If Accessible From Both Sides
- Aisle
  3-4' Center Allows For Use of Carts
  8' Center if Large GH for Equipment

Source: Clydette Alsup-Egbers, Missouri State University

Bench Efficiency

- Calculate % Greenhouse Space Production
  (Usable Bench Area ÷ Area of GH Floor) x 100= Bench Efficiency
- Bench Arrangement Affects Efficiency
- Increase Space
  Multi Tier Benches, Hanging Baskets, Stagger Containers

Source: Clydette Alsup-Egbers, Missouri State University




Photo Credit: Gothic Arch Greenhouses

Crop Scheduling

- Crop Rotation Plan for 1 Year
- Select Species or Cultivars to Grow
- Determine Space Needed
- Quantity Needed of Each
- Time Needed
- What Size Container to Sell In
- MOST IMPORTANT – KEEP RECORDS

Sometimes The Best Teacher is Experience

- Visit with other Growers
- Extension and Outreach Centers
- Classes/Workshops
- Tour Facilities
- Good Luck and Have FUN!

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Questions?