Stage 1 – Desired Results

ESTABLISHED GOALS

- To address the food equity crisis in underserved Chicago neighborhoods
- To sustainably develop greenhouses drawing minimal resources from the existing energy grid.
- To equip these greenhouses with passive energy channels to sustain their operations (solar, wind, rainwater capture).
- To design operational processes to optimize the quantity and quality of fresh fruits and vegetables while minimizing maintenance and labor.
- To ensure repeatability of greenhouse construction to propagate multiple greenhouses feasibly and economically.

Transfer

Students will be able to independently use their learning to…

- Articulate the benefits of greenhouses to stakeholders, neighborhood residents, and consumers.
- Knowledgeably develop greenhouses and deploy them into environments having varied characteristics
- Work effectively with suppliers and vendors of recycled/repurposed materials to acquire these inputs at the appropriate levels of quality, quantity, and price.
- Develop managerial capabilities to effectively coordinate construction initiatives beyond the greenhouse project.

Meaning

UNDERSTANDINGS

Students will understand that…

- Greenhouses were used in ancient times and evolved into a wide variety of uses today.
- Greenhouses can have a variety of structure types and the advantages and disadvantages for each.
- Laying the foundation, the type of foundation to use and the basic components of a simple greenhouse, with their functions.
- Greenhouse coverings are comprised of major types, and each has advantages and disadvantages.
- Orienting a greenhouse range and the different types of bench orientations in the greenhouse are crucial design decisions.
- The active and passive methods for heating and ventilating a greenhouse have four basic types, and that each has advantages and disadvantages.
- Hydration is an important aspect of greenhouse viability, and that passive and active methods have advantages and disadvantages.

ESSENTIAL QUESTIONS

1. Experts believe that greenhouses will probably assume an important role in the future global food supply. Climate change phenomena, including temperature increases, wind shifts, and storm activity (producing excess rainfall) favor increased global food production in greenhouses. Heating and cooling technologies, necessary components of greenhouses, available at higher efficiencies and lower costs, will continue to become available.
2. Greenhouse automation is accelerating, with greater capabilities and use of AI, to maximize yield, quality, and nutritional value without human involvement. Systems using Internet of Things (IoT) sensors are already capable of monitoring plant growth, analyzing plant biochemistry, and adjusting soil characteristics, thus making localized intelligent decisions, to adjust the growth environment.
3. Future greenhouses will strongly emphasize their contribution to the whole-life-cycle carbon footprint, particularly through bypassing the traditional energy grid in favor of localized renewable energy sources.
4. Future greenhouses will utilize water reclamation increasing efficiency to compensate for the challenges in tapping freshwater resources.
5. To promote food safety, greenhouse production technologies can minimize the use of pesticides, herbicides, and rely upon nonchemical methods (e.g., ultraviolet sterilization) to control insects and diseases.

Acquisition

Students will know…	*Students will be skilled at…*

	• Provide background on when greenhouses were first used and their wide variety of uses today. • Discuss different basic greenhouse structure types and the advantages and disadvantages for each. • Discuss steps prior to laying the foundation, the type of foundation to use and the basic components of a simple greenhouse, with their functions. • Provide the four major classes of greenhouse coverings used today and give their advantages and disadvantages. • Discuss the criteria for selecting a greenhouse range. • Discuss the proper ways to orient a greenhouse range and the different types of bench orientations in the greenhouse. • Discuss the four major methods for heating greenhouses and provide the advantages and disadvantages of each. • Discuss the different types of ventilation and cooling systems commonly used in greenhouses today.	• Identifying the sequence of activities in planning and building a greenhouse. • Designing a greenhouse based upon the site considerations (i.e., availability of sunlight, slope, drainage, etc.) and the availability of materials (frame, covering, etc.). • Estimate the duration and effort for building a greenhouse based upon its design. • Know which tools, fasteners, and implements to use when building greenhouses of various types. • Apply the principles of sustainable construction to a greenhouse design. • Estimate the energy needs for a particular greenhouse design and determine whether active or passive energy is feasible. • Understand how to evaluate a greenhouse design for LEED credits for certification. • Navigating the permitting and regulatory processes when necessary.

Stage 2 – Evidence and Assessment

Evaluative Criteria	Assessment Evidence
Learners will have formative assessments (short quizzes) to gauge progressive understanding, and a summative assessment based upon the modeling exercise in the final lesson.	PERFORMANCE TASK(S): The learners will maintain a journal containing notes from lessons as well as findings from research points. It will also contain the lab notes from the modeling exercise, comprising static and dynamic analysis, evaluation of light, heat, and water availability, and assessment of LEED credits for their design and model.
	OTHER EVIDENCE: Any external resources that the learner uses to evaluate the efficacy or practicality of their model should be assessed for validity and completeness.

Stage 3 – Learning Plan

Summary of Key Learning Events and Instruction (22 hours)

Lesson 1: Introduction to Greenhouses (1 hour)
Greenhouses are structures covered with a transparent material that allows sufficient sunlight to enter for the purpose of growing and maintaining plants. Greenhouse range refers to two or more greenhouses located together. A headhouse is a central building used for offices, storage and workspace with attached greenhouses. Different basic greenhouse structures (their components and functions), their major components, and the advantages and disadvantages of each will be reviewed. Also, we will discuss the advantages and disadvantages of four major classes of greenhouse coverings.

The criteria for selecting a greenhouse range location, with the proper ways to orient the range and the different type of bench arrangements within the greenhouse, will be presented. Finally, the light and temperature characteristics of each greenhouse design will be analyzed.

Lesson 2: Basic Greenhouse Structure Types (2 hours)

Greenhouse design types depend upon the following constraints:

- Space available
- Type of plants to be grown
- Geographical location since latitude determines the angle of sunlight impacting the greenhouse
- Cost of construction materials, with a strong preference for recycled/repurposed materials

Certain greenhouse types may meet the constraints more efficiently. Three main types are:

1. Attached greenhouse – this type is connected to a building. There are three basic styles:
   - Lean-to greenhouse
   - Attached even-span greenhouse
   - Window-mounted greenhouse
2. Freestanding greenhouse – this type stands separate from other buildings or greenhouses. There are various styles including:
   - Even span
   - Uneven span
   - Gothic arch
   - Quonset
3. Connected greenhouse
   - Gutter-connected
   - Dutch houses
   - Barrel vault
   - Sawtooth

Lesson 3: Structural Elements of a Greenhouse (1 hour)

Regardless of the type or style, every greenhouse has basic structural components. These include:

- Ridge (top of the greenhouse)
- Anchor support posts (main structural support)
- Trusses (structural strength)
- Purlins (structural strength)
- Ventilators (cooling)
- Cooling fans (cooling)

Lesson 4: Greenhouse Coverings (2 hours)

The greenhouse covering spans the structural elements of the greenhouse. Its two key functions are to allow the maximum amount of light into the greenhouse, and to protect the plants within from climate events.

1. Glass
   The main advantage of glass is that it provides the best light transmission of any greenhouse covering. However, there are some disadvantages:
   - Cost of glass is very high
   - Cost of heating the greenhouse is higher
   - Problems with vandalism
2. Polyethylene
   Advantages are:
   - The initial cost is cheaper
   - Fuel costs are lower

   Disadvantages are:
   - Polyethylene has a short life span; UV light causes breakdown of polyethylene. When UV inhibitors are applied to polyethylene the average life is three years.

- Condensation on the inside surface of the greenhouse can lead to disease occurrence and a reduction in the amount of sunlight entering the greenhouse.

3. Fiberglass-Reinforced Plastic
   The biggest advantage of fiberglass-reinforced plastic is that it allows the same amount of sunlight through as glass. However, in recent years fiberglass-reinforced plastic has decreased in popularity because of the following disadvantages:
   - Very susceptible to UV light, dust and pollution degradation.
   - Flammable and thus insurance rates may be higher.
4. Acrylic and polycarbonate
   Acrylic and polycarbonate types of greenhouse coverings have almost completely replaced the use of fiberglass-reinforced plastic because of the following advantages:
   - Lightweight and easy to install
   - Excellent heat insulating ability
   - Good light transmission
   - A disadvantage is that it is flammable.
5. PET polyethylene terephthalate, the chemical name for polyester. It is widely used globally as an inexpensive solution for food and beverage packaging. Some advantages include:
   - PET is approved as safe for contact with foods and beverages by the FDA
   - PET is completely recyclable and is the most recycled plastic in the U.S and worldwide.
   - PET is a very energy-efficient packaging material. Although its raw materials are derived from crude oil and natural gas, it enjoys a very favorable sustainability profile in comparison to glass, aluminum and other container materials.
   - The high strength of PET in comparison to its light weight is a major key to its energy efficiency, allowing for more product to be delivered in less packaging and using less fuel for transport.

Lesson 5: Locating a Greenhouse Range (2 hours)

The main considerations for selecting a greenhouse range (a single greenhouse, or a headhouse + greenhouses, if applicable)

1. Market – adequate commercial and retail demand for produce
2. Accessibility – proximity to local streets/alleys is good for market traffic but is also nearer to pollution (such as ozone and ethylene), as well as increasing the threat of vandalism.
3. Climatic conditions – open access to sunlight, temperature (highs and lows), protection from snowfall and high winds.
4. Topography and drainage – slope of range and absorbability of ground
5. Water and other utilities - source of good quality water and other utilities such as electricity, fuel and waste disposal, unless low energy footprint is desired.
6. Zoning regulations
7. Labor supply - Both paid and volunteer labor are needed for construction and operations tasks.
8. Expansion - adequate space for future expansion is a minor consideration.

Lesson 6: Layout of the Greenhouse Range (2 hours)

This applies both to a single greenhouse, or multiple greenhouses connected to a headhouse.

Range Orientation

1. Orient the range to allow for maximum light intensity to enter the greenhouse.
2. Know the direction of the prevailing winds to orient the greenhouse to minimize heat loss.
3. Entrances and drives should be accessible to large trucks, customers and employees.

Bench Orientation in the Greenhouse

1. Common bench arrangements are:
   a. Longitudinal - Typically used for fresh flower production. This type of arrangement allows for mechanization, but it is difficult for employees to move across the greenhouse.
   b. Cross benching - Provides for easy accessibility to all benches but does not maximize growing space.
   c. Peninsular - Provides accessibility by employees, while maximizing the growing area.

Lesson 7: Controlling Greenhouse Temperatures (2 hours)

Good temperature control is a major factor for producing a high-quality crop. Commonly used greenhouse heating systems include:

1. Steam heating systems - typically used in large greenhouses.
2. Hot water heating systems - typically used in smaller greenhouses.
3. Forced-air heaters - commonly used in commercial greenhouse ranges. Problems with the dryness of the heat occur with this type of heating.

Each of the above use oil or propane to fuel the boiler, which may cause problems with pollutants such as propylene and ethylene.

4. Infrared radiant heaters - The major advantage of this type of heater is that it conserves energy and has no problems with pollutants. The disadvantages associated with this heating system are:
    - Cost
    - It may be difficult to monitor the actual temperature received by the plant since air temperature is not a good indicator. Infrared heaters warm plants and other objects in the greenhouse but not the air temperature to the same extent.

Greenhouses must have ventilation and cooling capabilities throughout the year. During the summer and even the winter months the air temperature in the greenhouse may become too high and inhibit plant growth. In addition to cooling, ventilation of a greenhouse provides the following:

1. Renews the supply of carbon dioxide needed for photosynthesis.
2. Circulates the air to reduce the chance of diseases.
3. Prevents ethylene buildup.

Lesson 8: Ventilation and Cooling Systems (2 hours)

1. Natural ventilation system - The air is exchanged through open ridge and side vents. This is one of the oldest methods of cooling. Note that injury to plants located near the side vents may occur.
2. Fan-tube ventilation system - The air is distributed through a plastic tube with holes that run the length of the greenhouse. This system is used in conjunction with the heating system.
3. Fan and pad cooling system - This type of system is used for summer cooling.
4. Fog evaporative cooling system - This system utilizes a fog generation system inside the greenhouse, which is similar to what you see when football players are cooled down on the sideline.

An alternative way to cool greenhouses is to use shading materials. Liquid shading compounds are often applied to glass as well as polyethylene covered greenhouses to reduce the light intensity as well as the temperature. This is typically done in the spring and summer. During times of the year when heat buildup is not a problem, this material is washed off to allow more light into the greenhouse.

Lesson 9: Greenhouse Modeling Activity (8 hours)

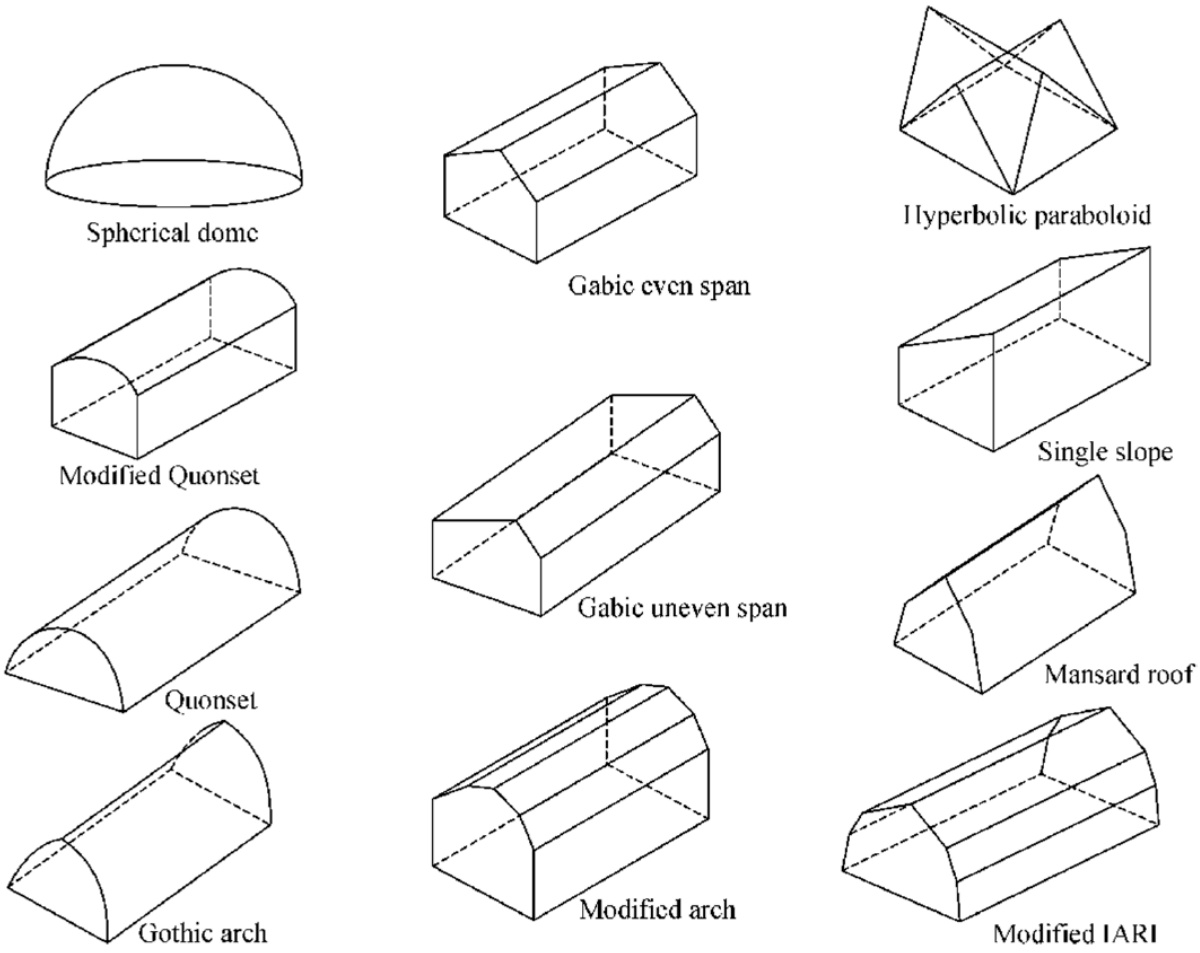
In this module, we discussed different greenhouse structures, including their structural components and functions. Now we will take what we learned and apply building greenhouse models and test their structural characteristics and gain deeper understanding on supplying utilities to greenhouses.

The motivation for the project becomes greater as it converges upon a tangible result. The idea underlying the opening activity is to offer a graduated approach, starting with the examination of the many concepts for greenhouse design, presenting criteria for evaluating and prioritizing designs, selecting the most promising designs, then building and testing models representative of those designs.

In this way, the participants will get hands-on experience with design thinking, as well as assessing the strengths and weaknesses of each design, to select a candidate for the construction of a prototype.

The steps for this workshop involve:

1) Present several types of greenhouse design. Some examples include:



2) The learners can select the designs deemed most or promising for the project.
3) The models should be of manageable size – large enough to experiment on, small enough to fit onto a working surface.
4) Perform stress tests on each design. This involves downward force (as with snowfall), shear force, (as with steady winds or rain), and spiral force (as with high velocity or shifting winds). Weights will provide downward force, while tension (e.g., rubber bands) provide shear and spiral forces.
5) Estimate the heat and light required for each design. This means the lumens of light needed, and the BTUs of heat. This is a function of surface area and volume of the structure. The formulas will be provided to the learners.
6) Estimate the amount of electrical power needed to sustain each design to provide:
    - Water and nutrients for the plants
    - Light (during periods of low sunlight)
    - Heat (during periods of cold temperatures)
    - Ventilation (to create an equilibrium air pressure and flow)

    As before, formulas will be provided to the learners.
7) Write a report noting the key findings and make recommendations based upon the discoveries made.