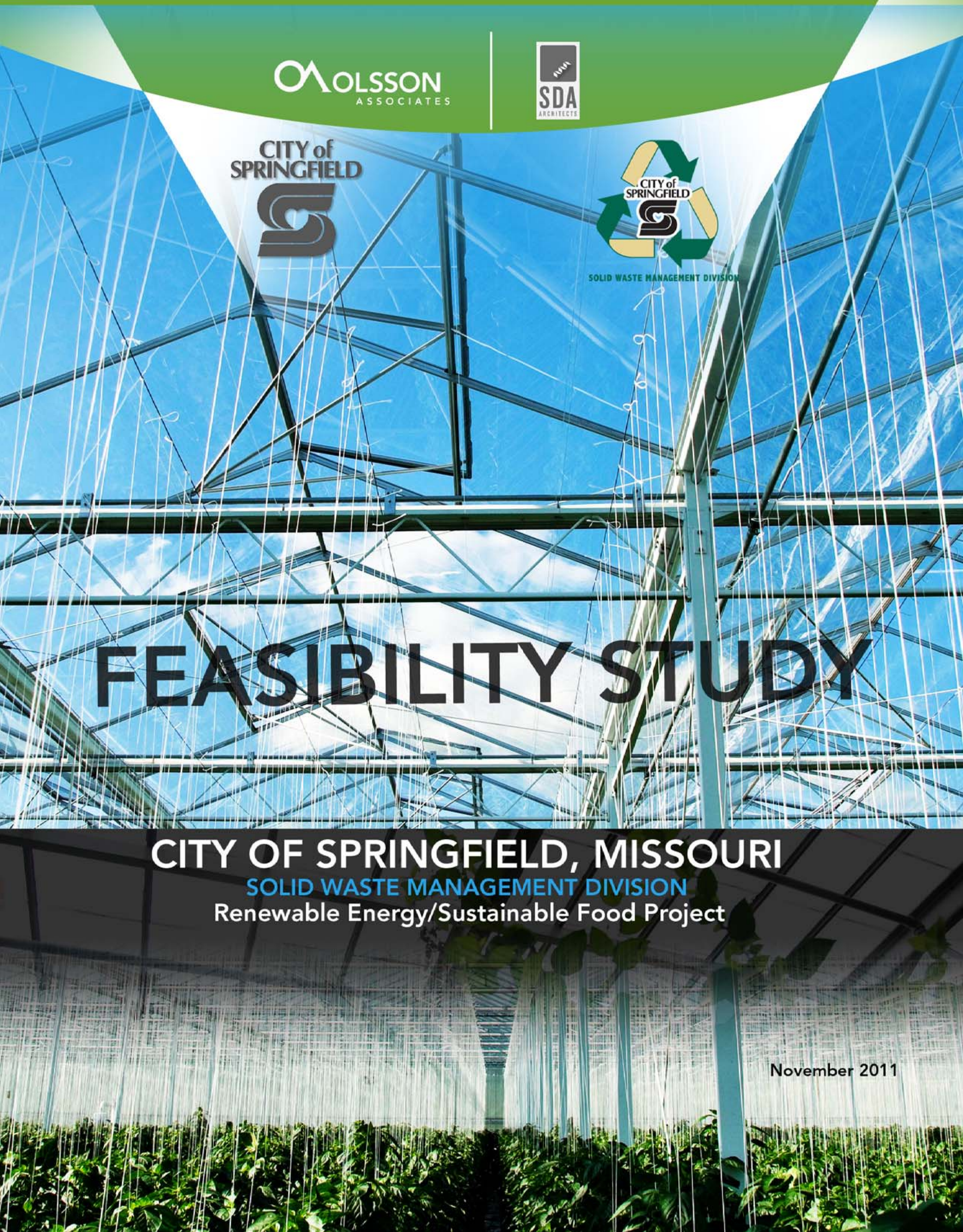

OLSSON ASSOCIATES

SDA ARCHITECTS

CITY of SPRINGFIELD

CITY of SPRINGFIELD SOLID WASTE MANAGEMENT DIVISION

FEASIBILITY STUDY

CITY OF SPRINGFIELD, MISSOURI

SOLID WASTE MANAGEMENT DIVISION

Renewable Energy/Sustainable Food Project

November 2011

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1.0 EXECUTIVE SUMMARY

The feasibility study for the Renewable Energy/Sustainable Food (RE/SF) Greenhouse Project was conducted to examine the potential for building a sustainable greenhouse operation that will produce fresh vegetables for sale and distribution in the Springfield region. This feasibility study was funded in part from a grant from the Missouri Department of Natural Resources (MDNR) under the "Energize Missouri Renewable Energy Study Subgrant" program. This study focused on the technical, environmental and economic feasibility of greenhouse operations, supported by using a portion of the waste heat and electric power from the Nobile Hill Landfill Renewable Energy Center (NHLREC).

The primary goal of the feasibility study is to provide the City with information that can be used to establish a clear vision of what the greenhouse operation will look like through a conceptual design, which includes the following tasks:

1. Conduct an economic evaluation of the costs necessary for greenhouse construction and operation, as well as the market available to support crop production.
2. Identify potential funding sources that can provide potential capital to initiate and support the greenhouse operation for the City of Springfield.
3. Determine how the greenhouse operation will feasibly operate, as either a public or private sector entity.
4. Identify equipment and systems that can be used for establishing a successful greenhouse operation.
5. Develop a conceptual design for the greenhouse that includes sizing, structure type, equipment needs, growing systems, and energy, water, and personnel needs.
6. Develop a recommendation regarding the construction and operation of a sustainable greenhouse facility for the City of Springfield.

Results of the feasibility study show that the funding, construction and operation of a sustainable greenhouse can be successfully achieved. This conclusion is supported by the following findings:

1. A market study was conducted by Missouri State University (MSU) that shows the market for fresh vegetables continues to rise. The MSU study shows that total expenditures for fresh vegetables in the Springfield metropolitan area are expected to increase from approximately $59 Million in 2010 to an estimated $67 Million in 2015. It's anticipated that this demand will be met by both imported vegetables as well as supply from local growers. Most of the demand, however, is met by vegetables grown in distant locations such as Mexico and then imported into the U.S. and Springfield markets. These imports often lack freshness and quality.

The MSU study found that fresh produce grown locally near Springfield is highly favored by grocers and their customers, with approximately 87 percent favoring locally-grown produce. If a marketing plan can be established that develops a steady client base, then a greenhouse operation capturing as little as two percent of the Springfield market for vegetables can generate as much or more than $1,000,000 in gross revenue per year.

Design and construction of the greenhouse, assuming an initial size of approximately 35,000 square feet of production space with additional Headhouse or management and handing areas, is estimated to be between $2,000,000 and $2,700,000. Operating costs are estimated to be approximately $41,000 to $44,000 per month, or approximately $500,000 per year, assuming that costs will be reduced from use of heat produced by electric generators at the landfill. The operation's cost includes payment of loans or bonds that may be used for initial financing of the greenhouse, and *it includes conservative estimates of all costs*. Revenue projections (provided successful operations and management of the greenhouse, and selection of the most profitable, desired vegetables to be grown) are estimated to range from approximately $950,000 - $1,500,000 per year. The beginning range of $950,000 is projected, if conventional growing methods are used, with tomatoes typically being the most profitable crop. The upper range of $1,500,000 is projected, if crops are grown organically and a market premium is achieved, as realized in the performance of a similar greenhouse operation in Iowa. In short, potential revenue projections well exceed probable costs for greenhouse operations.

2. There are several potential grant sources that can provide revenue for this project. Potential funding sources include municipal financing through bonds, Federal support either through grants or Federally-insured loans, or through private financing. Some examples include:

   – Municipal Bonds. If the City of Springfield desires, it is possible to develop a special bond for financing construction of the greenhouse structure.

   – Federal State Marketing Improvement Program (FSMIP) -- This matching grant program provides matching funds to State Departments of Agriculture and other appropriate State agencies to assist in exploring new market opportunities for food and agricultural products, and to encourage research and innovation aimed at improving the efficiency and performance of the marketing system.

   – Specialty Crop Block Grant Program - Specialty crop block grant funds can be requested to enhance the competitiveness of specialty crops.

   – Small Business Administration (SBA) Programs – SBA programs include loans to small businesses to facilitate initial start-up, as well as long-term operations. A specific example of an SBA loan includes the CDC/504 Loan Program.

Proceeds from 504 loans are typically used for fixed asset projects, such as the City's greenhouse project.

- Private sector loans – with a good business plan, loans can be obtained from local financers at favorable interest rates. A typical business loan with associated terms was used in the economic analysis completed for this report.

3. Ownership and operation of the greenhouse must be considered in context of complete public (City of Springfield) ownership and operation, the development of a public-private partnership, or complete private ownership and operation. All ownership and operation options have benefits as well as concerns. However, in the evaluation of the factors affecting ownership and operation, ***it is apparent that a public-private partnership may provide the most benefits to the City.*** As for the private-sector operator and to the region as a whole, providing a sustainable greenhouse operation, that achieves the City's goals and meets market demands, is critical to provide long-term success.

4. Greenhouse models developed in this study included two structural approaches, as well as growing systems that are technically as well as economically feasible in achieving the goals of the City. The structures include light frame, arched roof style structures covered with dual-layered polyethylene plastic sheeting, and a more rigid apex roof frame structure with polycarbonate sides and roofing. Growing systems evaluated include hydroponic systems that are efficient and economical, as well as soil-based systems that are conducive for growing potentially more profitable organic vegetable crops. The models show that any of these structures and growing systems have a high potential for success in Springfield.

5. Based on the findings of the feasibility study and discussions with City staff, a conceptual design for a successful greenhouse operation has been developed that includes an approximate 35,000 square food-growing house. This house is built using either the arched roof or the apex roof style structure and a 3,500 square foot Headhouse that includes management areas as well as vegetable packing and shipping areas. The conceptual design includes provisions for heat transfer from the electrical generators at the landfill, and consideration of both soil-based and hydroponic growing systems. The conceptual design at this time is based on a soil-based system for growing organic vegetables.

6. The feasibility study presents substantial information that provides the City with information from which to determine their preferred approach for a greenhouse operation at the Noble Hill Landfill. Starting "small" with an approximate one-acre greenhouse is the best approach, giving the City (and whoever operates the greenhouse) the opportunity to maximize inputs within potential budgetary limits. This approach also allows the market for locally-grown vegetables to be tested, the development and training of a strong greenhouse operations team, as well as time to plan for greenhouse operations.

A public-private partnership will enable the City to foster the establishment and growth of the greenhouse operations with the expertise of an experienced and effective professional greenhouse management team offered by the private sector. This will keep the focus of the greenhouse oriented to the goals of the City in achieving a sustainable, profitable greenhouse operation that provides locally-grown vegetables for the region.

2.0 INTRODUCTION

2.1 PROJECT PURPOSE

The purpose of this study is to determine the economic, technical, and logistical feasibility of using a portion of the waste heat and electric power from the NHLREC for the sustainable operation of a greenhouse operation that will produce, sell, and distribute vegetable crops in the Springfield region. This study also considers the possibility of operating the greenhouse as a public/private partnership, contributing to our region's locally-grown food supply, and creating new, year-round jobs for our community.

2.2 GOALS AND OBJECTIVES

The primary goal of this feasibility study is an evaluation of the factors that provides the City of Springfield with the information necessary to determine if a sustainable greenhouse using heat generated by electric power generators at the Noble Hill Landfill can be built and successfully operated for the production of vegetables that can be sold in the Springfield area market. The objectives include:

1. Information that can be used by the City of Springfield to establish clear direction of what the greenhouse operation will look like through a conceptual design,
2. How the greenhouse operation will feasibly operate as either a public or private sector entity,
3. Identify equipment and systems that can be used for establishing a successful greenhouse operation.
4. Develop a conceptual design for the greenhouse that includes sizing, structure type, equipment needs, growing systems, and energy, water, and personnel needs.
5. Conduct an economic evaluation of the costs necessary for greenhouse construction and operation, and the market available to support crop production.
6. Identify potential funding sources that can provide potential capital to initiate and support the greenhouse operation for the City of Springfield.
7. Develop a recommendation of the efficacy of a sustainable greenhouse operation for the City of Springfield.

2.3 PROJECT BACKGROUND

The project is titled the Renewable Energy/Sustainable Food Project (RE/SF). The City of Springfield applied and received a grant from the Missouri Department of Natural

Resources (MDNR) under the "Energize Missouri Renewable Energy Study Subgrant" program.

Landfill gas is captured from the Springfield Sanitary Landfill and is piped to the City Utilities owned NHLREC. The gas collected provides a fuel source that runs two 1.6 Megawatt Caterpillar 3520 electric generators producing a total of 3.2 Megawatts of renewable energy. These generators have been in operation since May 2006. In generating the electric power, approximately 65% of the fuel energy used is lost as waste heat through the generators cooling and exhaust system. As an alternative to the loss of a valuable resource, the waste heat and electric power produced from electric generation station will be utilized to provide heating, cooling, and power for a proposed greenhouse that will be located on adjacent City owned property.

2.4 EXISTING SITE OVERVIEW

The site of the proposed greenhouse operation consists of approximately 40.0 acres including the Generation Station (approximately 3.0 acres) and is owned by the City of Springfield. The Generation Station tract of land is located in the northwest corner and is the Nobile Hill Landfill Renewable Energy Center. The focus of this study is for development and operation of the greenhouse on the approximate 37.0 remaining acres.

The property and surrounding area is situated in a primarily rural agriculture environment, zoned A-1 Agriculture District. The property is located south of the City's Springfield Sanitary Landfill, and on the west side of State Highway Route 13. The property is bordered to the west and south by Farm Road 34, and separated from State Highway Route 13 on the east by a parcel of City-owned land. The property consists primarily of open pasture with a few scattered trees. There are two existing ponds and an existing farm building structure. Current use of the property is farming and haying. Existing information indicates that the site has never been disturbed due to mass grading and native soils remain a primary feature of the site.

An existing ground water monitoring well (Monitoring Well OPZ-10 of the Ozark Aquifer in Cotter Dolomite) is located on the property. The coordinate location of the well is N 564187.8687 and E 253095.0806 and it was installed October 14, 1997. The top of well casing elevation is 1237.73' and the ground surface elevation around the well is 1232.49'. Groundwater at this location is 192.05 feet below the surface with a water surface elevation of 1040.44'. The total depth of the well is 218.8' at elevation 1013.69'. Routine monitoring inspections occur twice a year, typically in May and November.

2.5 CONTENT OF THE FEASIBILITY STUDY

This feasibility study report is presented to provide the results of the evaluation of factors that are necessary for the establishment of a successful greenhouse operation. These factors include:

- An overview of greenhouse operations and food production (Chapter 3)
- An analysis of the market conditions that will support a greenhouse operation for vegetable production in the Springfield area, highlighting a market study conducted by Missouri State University (Chapter 4).
- An economic analysis of the costs and potential revenues that will affect the potential for building and sustaining the greenhouse operation (Chapter 5).
- An energy assessment of the amount of energy needed to support the greenhouse, and the mechanisms for capturing and conveying it to the greenhouse (Chapter 6).
- An assessment of the factors affecting sizing of the greenhouse operation, including those that ultimately determine the maximum or most optimum size the greenhouse should be to remain a profitable, sustainable operation (Chapter 7).
- A description of systems that have been evaluated and are commonly used in greenhouse operations (Chapter 8).
- Following the assessment of the factors that contribute to determining the potential for a successful, sustainable greenhouse operation, recommendations and a concept design for the greenhouse (Section 9).
- Figures illustrating the site, site conditions, and the conceptual greenhouse (Section 10).
- Appendix of probable cost for the two test models (Section 11).

2.6 PROJECT TEAM AND RESPONSIBILITIES

The City of Springfield selected Olsson Associates and Sapp Design Associates to conduct the feasibility study. The project team consists of the following personnel:

1. City of Springfield

   Steve Meyer – Project direction and oversight

   Ted O'Neill – Technical assistance and quality assurance

   Erick Roberts – Technical Assistance with Landfill Operations

   Doug Durrington – Technical Assistance

   Barbara Lucks – Technical Assistance

   Karen Stewart – Technical Assistance

2. Olsson Associates

    Kevin Lowe, P.E. – Project Manager

    Cameron Smith, ASLA – Technical lead and feasibility study direction

    Shawn Cochran, P.E. – Energy analysis and greenhouse mechanical systems

    Ted Hartsig, CPSS – Technical assistance for greenhouse operations and crop production

3. Sapp Design Associates

    Jim Stufflebeam, AIA – Project Design Architect

    Lisa Drew-Alton, AIA – Sustainable Project Architect

3.0 GREENHOUSE OPERATIONS AND FOOD PRODUCTION

This section provides a general overview of typical greenhouse operations for commercial vegetable production. More detailed information of the design specifics are provided in Sections 8 and 9.

3.1 TYPICAL GREENHOUSE OPERATIONS

There are probably no "typical" greenhouse operations, as managing and operating a greenhouse is contingent on a high number of variables that affect crop production outcomes and successful greenhouse function. This feasibility study focuses on commercial greenhouse operations, and more specifically on greenhouse operations for vegetable production. Even in commercial greenhouses, management and operation are dependent on the size and structure of the greenhouse, crops produced, production goals, plant growing methods and systems, plant densities, and management of the greenhouse environment, including temperature, humidity, nutrients, and pest management. Management is also contingent on resources available, such as labor, water and heat sources, and the ability to market and deliver product. Variables affecting the design, construction, and operations of a greenhouse that will be discussed in this section include:

1. Greenhouse size and structure
2. Crop growing techniques
3. Typical greenhouse vegetable crops
4. Vegetable crop production and operation considerations

3.2 GREENHOUSE SIZE AND STRUCTURE

Commercial greenhouse operations often range in size from less than one-half acre of greenhouse space to greenhouses covering several acres (often between 6 and 10 acres for large production operations). According to North Carolina State University (www.ces.ncsu.edu/depts/hort/greenhouse_veg), a 1-acre greenhouse is a good starting point. A comparison of greenhouse coverings that constitute most greenhouses is provided in Table 3-1 (next page).

Traditionally, glass greenhouses have been the mainstay of commercial operations. The technology is evolving, however, that is allowing greenhouse structures to be inexpensively built and managed using plastic coverings. The more rigid glass structures allow more mechanical means of managing airflow and humidity, and are easier to maintain. They are also more expensive to build, requiring heavier structural frames and tempered glass panels to reduce the potential for breaking. Rigid plastic panels can be used instead of glass that are more energy efficient (insulating), and allow for less framework. Because of their insulating properties, however, the plastic panels are prone to snow accumulating on them, blocking light and potentially accumulating too heavy a load for the greenhouse structure to support.

Many greenhouses are built with an arched frame with no sidewalls, often made of light aluminum, and covered with polyethylene or similar plastic. The arched roof style of greenhouse, with sidewalls from 4 to 8 feet supporting the arched roof, will often have similar construction. A dual-layer plastic covering is often installed that improves insulating qualities of the materials. Past problems with these types of greenhouses have been control of the internal environment, particularly maintaining consistent temperatures and humidity. In fact, humidity control was listed as a primary problem, particularly in southern climates. Advancing technology is providing solutions to these issues, providing vent openings in the plastic-covered greenhouses that provide greater air exchange to control temperature and humidity.

Table 3-1: Comparison of Greenhouse Types

Greenhouse Type	Benefits	Disadvantages
Traditional Glass Structure	• Relatively low maintenance, primarily for cleaning glass, caulking seams • Maximizes light transmission • Typically lasts for more 25 years • Resilient against weather (wind and snow) • Better control of environmental conditions.	• Requires a strong, rigid structure or frame • Expensive to build and to replace broken panes • Difficult to build • Poor insulation properties – loses heat too fast, transmits heat in summer
Polycarbonate Plastic Panels	• Less expensive than glass [1] (up to 40% less expensive) • Typically stronger and lighter than glass and requires less framework • Less structure = less shade • Typically lasts 10+ years • Better insulation qualities	• Less light transmission than glass • Potential fire hazard • Can collapse under the weight of snow
Plastic Film Greenhouses	• Least expensive and easier to construct • Good insulation properties • Very common and easy to acquire	• Polyethylene film must be replaced every 2- to 4 years • Less structurally sound than glass or rigid plastic • Less air exchange and requires more environmental controls • If curved walls there is less space for plants • Condensate that collects on plastic can drip onto plants and foster disease

1. http://EzineArticles.com/?expert=Gary_Bunn

3.3 CROP GROWING TECHNIQUES

Greenhouse vegetable crop growing techniques have and continue to advance rapidly. Many commercial greenhouse operations utilize hydroponic growing systems to maximize vegetable production and to automate environmental controls, but greenhouses with soil beds or soil in pots on benches are also commonly seen, depending on the type of crop being grown. The two systems are compared below.

3.3.1 Hydroponics

Hydroponic growing systems essentially involve growing the crop without soil, instead bathing the plant roots in a solution that delivers moisture and nutrients as needed. Often, an artificial substrate provides a structural media in which the roots can grow into, but that water will readily pass through. Such substrates include rockwool and perlite, If substrates are not used, then typically a system called Nutrient Film Technique (NTF) is used in which roots grow in a water-filled trough. There are many advantages and some disadvantages to hydroponic systems, as described in Table 3-2.

Table 3-2: Advantages and Disadvantages of Hydroponic Growing Systems

Advantages	Disadvantages
• Can produce more crop per square foot of greenhouse space • High water use efficiency if recirculating systems are used • The watering/nutrient delivery system is most often automated and can be adjusted • Reduced potential for disease • Substrate media can last for multiple crops and is easily replaced • Typically lower labor requirement and cost	• High initial cost • Typically requires more maintenance • Must calculate and plan nutrient additions to solution • The potential for errors is higher and with greater impact on plants • Generally, the entire system must be devoted to a single crop type • Not conducive to organic vegetable production

Hydroponic systems are operated in either closed or open systems. Closed hydroponic systems provide a continuous flow of fluids to the plants, with the solution recaptured and recycled to the plants. This is the most efficient water-saving system, and the nutrient level as well as the pH and electrical conductivity of the solution must be continually monitored to prevent imbalances and damages to the crops. Automated systems are available to continuously monitor the solutions. Open systems typically drip water and nutrients into troughs in which crops are planted, and the water is allowed to either evaporate or escape to outside systems. Nutrient additions must be calculated for each water application.

Hydroponic systems can be implemented in troughs, on benches, or using vertical stands depending on the crop. Trellises are required to support the plants. Examples of such systems include:

1. Vertical growing systems (www.hydrostacker.com, www.vertigro.com) allows potted plants to be stacked, with a production capacity of about 3 plants per square foot. Pots are filled with artificial growing media.

Examples of vertical hydroponic systems

2. Trough Systems: trough systems typically use artificial media, but also will use a steady stream on nutrient liquids. The plants are positioned in lateral troughs or trays through which a constant stream of moisture and nutrients flow, either by nutrient film systems or drip irrigation. These systems are optimal for taller growing plants, and require less structure.

www.smart-fertilizer.com

3.3.2 Soil-Based Systems

Soil-based crop production systems in greenhouses simply use soil as their base media on which to grow their plants. This soil can consist of a natural base soil or a man-made growing media. There are many advantages and disadvantages of using the soil, whether the bed are on the natural ground, in raised beds on platforms, or in pots. Using soil-based systems, there are more opportunities to grow a large variety of crops, including larger plants. In all cases, the soil needs to be well-drained and provide sufficient rooting depth and nutrient-holding capacity.

Table 3-3: Advantages and Disadvantages of Soil-Based Growing Systems

Advantages	Disadvantages
• Less initial cost • Cost of production of some vegetables is less • Greater tolerance for varying nutrient levels, with less potential for accidental high or low nutrient additions that could be harmful to crops • Typically requires less maintenance that hydroponic systems • Allows for bedding crops to be grown	• Higher potential for plant disease • Soils must be closely managed, including periodically rejuvenated (labor intensive) • Soil moisture must be carefully monitored, both for poor drainage or overwatering, or for excessive drying • Chemical condition of soil must be carefully monitored (especially in pots)

Crop quality and consistency is more difficult to maintain in soil-based systems, and the potential for disease and insect infestations is higher. Initial costs and overall operations and maintenance on a daily basis may be less for soil-based growing systems, as the soil provides the nutrient and moisture-supplying needs of the plants, but monitoring for plant health and pests, labor for harvest, and potential for greater loss are higher.

3.4 ORGANIC vs. STANDARD PRODUCTION

Organic growing systems produce crops without the input of synthetic fertilizers, pesticides or growth regulators (USDA, 1980). Organically-grown crops have gained substantial favor in the U.S. during the last 20 years and are often preferred in greenhouse production because the premium price they bring (National Sustainable Agriculture Information Service, 2011). Organic production of vegetables can be certified through the USDA's National Organic Program (NOP), a rigorous process that often takes a few years to achieve. If organically-grown crops are not certified, or prior to certification, they can at least be said to be “organically-grown” without the certification.

Typically, organically-grown crops are produced in soil-based systems because most organic nutrient sources are poorly soluble and feeding in a water-based system, such as hydroponics can be difficult. Recent developments in organic fertilizers, however, are providing more water-soluble or suspension fertilizer materials. Certification and use of these fertilizer materials, however, is reviewed and approved by the USDA NOP. Therefore, the prospect of producing organically-grown vegetables can be achieved through hydroponic systems, but with remaining challenges related to nutrient management and control, and a higher cost for these fertilizers.

Organically-grown vegetables can also be produced in “soilless cultures. Soilless cultures rely on non-soil, organic substrates to support the plants. Soilless cultures include Bag Culture, in which crops are grown in upright bags filled with substrates such as peat/vermiculite, rice hulls, peanut hulls, or even pine bark. The plants are fed with solubilized organic fertilizers, and have the benefits of better control of plant growth and disease management, and often high levels of production.

Soil-based production systems remain preferred for organically-grown crops, probably because of the familiarity of such practices by farmers (National Sustainable Agriculture Information Service, 2011). The methods used for soil-based systems, or ground culture, are similar to those used in the field. Management of soil amendments in preparation of crops, and nutrient management requires less intensive management. Crop production can be quite high with soil-based systems, with as much as 70 pounds of organically-grown tomatoes per plant produced at a greenhouse facility for Perfect Circle in Iowa (Perfect Circle interview, May 11, 2011).

Standard crop growing systems in greenhouse operations don’t have the limits of fertilizer, pesticides, or growth regulators to manage plant production. Growing systems accordingly can include methods that maximize management and production of the crop through the means necessary to reduce crop loss. Because many available nutrients are water soluble, hydroponic systems are often favored in standard crop production methods.

3.5 TYPICAL GREENHOUSE VEGETABLE CROPS

Commercial greenhouse vegetable production includes produce that is most highly demanded by the public, whether in individual consumption, or by restaurants, grocery stores, or institutions, as well as those vegetables that may be more regionally-specific for optimal growth conditions. These vegetables primarily include tomatoes, lettuce, cucumbers, bell peppers, peas, eggplant, herbs, and strawberries (New Mexico State University Circular 556, July 2001). According to Dr. Arbindra Rimal (Missouri State University), the most commonly consumed vegetables in the Springfield area are potatoes, onions, tomatoes, romaine lettuce, and head lettuce. Potatoes and onions are field-grown vegetables, however, and so the most popular greenhouse grown vegetables would include tomatoes, romaine lettuce, and head lettuce.

Generally, the type of vegetable crop grown is a matter of consideration regarding the available space and production potential of a vegetable per square foot of space, how the crop is most optimally grown (hydroponically or in a soil bed), and such factors as greenhouse capacity for temperature and humidity controls, disease management and pest control, and water and fertilizer needs. In addition, the skill and experience of the greenhouse manager also factors into the type of vegetable crop grown, their ability to understand and control the variables affecting crop production, and the amount of time and resources available for managing and nurturing the crop.

3.6 FOOD PRODUCTION AND OPERATION CONSIDERATIONS

Several considerations must be given to successful operation of a greenhouse for production of vegetables that contribute to the efficacy of its long-term sustainability. In evaluation of the operational needs of the greenhouse, we considered that the water, nutrient, health management, and growing systems of any vegetable produced would be the same. There are many economic impacts that result from these operations, including labor requirements (including the need for well-trained labor), daily maintenance and monitoring, nurturing and handling of plants, and harvesting and packaging of crop products.

3.6.1 Water Needs and Availability

Vegetable crops typically have very sensitive water needs: too little or too much water can dramatically affect fruit production as well as contribute to the overall health of the plant. Therefore, making sure that there is an adequate, reliable source of water available for the greenhouse, and that it is managed correctly is vitally important.

Depending on the growing system selected for greenhouse operations, the amount of water necessary for optimal crop production varies. Generally, 25 to 30 inches of water is necessary for most vegetable production, whether it is received by rain or irrigation. In a greenhouse, of course, it will be by irrigation. If it is assumed that each vegetable plant requires approximately 2.5 square feet of space for growth (this can range from as little as 1 square foot to as many as 4 square feet per plant), this would be approximately 45 gallons of water needed during the season for the growth and fruiting of each plant.

By recirculation water and nutrients, hydroponic growing systems are much more efficient in water use than soil-based growing systems. Water use for vegetable production using hydroponics may be as little as 1/20 or 5 percent of the water needed for field production of vegetable crops. If we conservatively assume that the water efficiency of hydroponic growing systems is 25 percent, then we may estimate that approximately 11 to 12 gallons of water will be necessary for each vegetable plant grown during a season. This is the amount of water that will be used by the plant, and not lost to evaporation or leakage. If we estimate approximately 15,000 plants per acre of greenhouse space, the water need for the crop is approximately 180,000 gallons through the season. Further assuming the growing/fruit production season to be 6 months (typical of such crops as tomatoes), this is approximately equal to 1,000 gallons of water needed every day, delivered to the entire crop through low-flow irrigation at a rate of approximately 0.7 gallons per minute (assuming a continuous flow is necessary). Details of water distribution and delivery methods are specific to different hydroponic systems.

3.6.2 Nutrient and Pest / Disease Management

Among the most challenging of greenhouse operations may be proper nutrient management and minimizing disease and pest stresses to vegetable crops. Too little nutrient addition, or in the wrong forms, could limit crop production. Too much nutrient addition can be toxic to the plant and ruin the crop. Several publications exist that provide guidance for nutrient and pH requirements for vegetable production, including optimal timing of nutrient applications, and concentrations. Many hydroponic growing systems have an electronically controlled automated nutrient management system and pH monitoring programs that can make adjustments to the solutions to minimize errant nutrient levels and optimize plant growth.

Similarly, without proper precautions, vegetable crops are susceptible to diseases that may result from too high of humidity in the greenhouse, importing of disease pathogens from people entering the greenhouse, or simply from windblown pathogen entry. Key to success for disease control is recognizing symptoms in plants and treating accordingly. Pests enter the greenhouse through inadequate entry controls (doorways, vents), or they may be soil borne. In recent years, advances in pest control and management has aided greenhouse management significantly. Typical disease and pest management practices include:

- Plant varieties that resist disease and pest infestations
- Pest monitoring and control programs
- Environmental controls that maintain conditions favorable to plants but unfavorable to pests and disease
- Greenhouse sanitation

3.6.3 Climate Control

The greenhouse environment related to temperature and humidity can have significant impacts on crop production. This is particularly important in the

Southern Missouri Region where winter can be particularly cold, but summers can be quite hot and humid. Temperature is the first consideration, as most plants grow and produce fruit optimally at temperatures between 75 to 90 degrees. Some crops require slightly varying temperatures during their lifecycles; for example hotter temperatures for germination of cucumbers, but maintenance of slightly cooler temperatures during the growth and fruiting stages. The opposite is appropriate for tomatoes. Therefore, the ability of the facility to supply uniform temperatures throughout the growing area (minimize temperature gradients) is dependent upon the available heat and heat distribution system in winter, and the ability of the building to be cooled in the summer. Insulation qualities of the greenhouse roof and walls are important in helping to maintain consistent and uniform temperatures. In addition, it may be important to consider a backup heating system if the primary heat source fails, even for a short time.

Humidity is another important operations feature to be considered. Greenhouses are by their nature humid because of the transpiration of water by the plants. Humidity levels in the greenhouse must be kept at appropriate levels to reduce (or minimize) the incidence of disease on the plants. Depending on the season, humidity may condensate on the roof of the structure and drip onto the plants. Such occurrences must be avoided as this most often leads to invasive diseases colonizing on plant leaves or stems. Many modern greenhouse covers are treated to prevent condensate from either forming or dripping onto the plants.

3.6.4 Waste Management

Waste management of solids and liquids will be an important facet of greenhouse operations to reduce the potential for disease and pest incidence. The waste materials should be removed and disposed of as quickly as possible. Most solid wastes are anticipated to be green plant material of harvested crops, including crops that have reached the end of their life cycle. The waste materials become breeding material for potential pests as well as disease, and therefore should be managed as quickly as possible. For a greenhouse operation, the vegetative material may be optimal for composting that can be used as a nutrient and soil amendment for outdoor or indoor soil plots utilized for crop production, or made available to other compost users.

Liquid wastes will typically be nutrient-amended solutions used for irrigating crops in the greenhouse that are either collected for disposal by design, or that may leak from the system. If nutrient solutions are allowed to stand or persist within the greenhouse, disease, mold, and algae may grow in the pools, potentially threatening vegetable crops. In addition, salt accumulations from the nutrient solutions may cause damage to the greenhouse foundation, or if it flows outside of the greenhouse, impact ground- and surface water supplies.

Waste water collected from the greenhouse can be used for irrigating outdoor crop growing plots in the summer and fall, or the waste water can be used for irrigating compost piles, or treated in on-site treatment wetlands that will remove excess nutrients. Treated water can then be recycled, possibly for re-use in irrigation systems, or as grey water for use with on site sanitary facilities.

3.6.5 Harvest, Packing and Distribution

The value of the crop is limited if it is not harvested at the appropriate time, handled and packaged correctly, and delivered to customers on time. In fact, substantial value is placed on the freshness of locally-grown vegetables because they can be harvested and delivered to market so quickly (as discussed in Section 4). The harvest, packing, and distribution of locally grown vegetables must often occur within a 24-hour period. Considerations for harvest, packing, and distribution of the greenhouse crops include:

- Planning the production of the crop for timing and sequencing of harvest to meet market needs. This includes understanding and managing the timing of crop fruit production and ripening, harvest methods (usually by hand), and care of handling, as well as labor and resource requirements for harvesting.
- Preservation of the crop. This will include maintaining an optimal environment (usually cool) for packing, storing, and delivering the crop to its final destination.
- Wrapping and packing crop produce for delivery. This may require wrapping of individual fruits (tomatoes, cucumbers, head lettuce), or proper containers for packaging of the crop for delivery. Wrapping and containers must be available when the crop is ready.
- When the crop has been harvest and packaged, it must be distributed within an appropriate time period to the market to minimize loss. This may require the coordination and/or operation of a distribution or transportation system, have an adequate climate controlled short-term storage space, or have space available for customers to purchase crop from the greenhouse.

4.0 MARKET ANALYSIS

The construction and operation of a greenhouse for vegetable production is not feasible unless there is a market demand for the vegetables produced. The City of Springfield contracted with the Missouri State University (MSU), Darr School of Agriculture to research and prepares a market analysis for fresh vegetables consumption and use in the Springfield area. The MSU study provides a detailed overview of the Springfield market for vegetables; other market factors can affect the sale and subsequent revenue that will support the greenhouse operation. The MSU study covered the five-county Springfield metro area of Christian, Dallas, Green, Polk and Webster Counties.

4.1 SUMMARY OF MSU MARKET STUDY

The MSU study of the market potential for fresh vegetables was conducted by faculty and students in the fall of 2010, with a report prepared in 2011. The objective of the study was to develop an estimate of the market for fresh vegetables in the metropolitan Springfield area, including identification of probable customers that would provide a steady base of revenue from vegetable sales. An additional purpose of the study was to assess potential produce purchase volumes, prices paid, and seasonality in the market.

The results of the market study show that the per capita consumption of fresh vegetables is driven both by consumer demand and the availability of vegetables. According to the study, vegetable consumption is increasing per person in the U.S. and the Springfield Metropolitan area, and more than 345 varieties of fresh vegetable items are available to consumers. Per capita consumption of some vegetables such as Romaine and leaf lettuce, dry yellow onions, bell peppers, and cucumbers are increasing in consumption, while tomatoes, cabbage, and carrots have maintained a consistently level rate of consumption. Potatoes and head lettuce appear to be decreasing in consumption. While potatoes are decreasing in consumption, they have been and are projected to remain the most consumed vegetable demanded in the market, including Springfield. Onions and tomatoes are the next most popular vegetables for the projected future, and head lettuce will decline and be overtaken by Romaine and leaf lettuce in consumer demand.

4.1.1 Market for Local Crops

The market for fresh vegetables continues to rise. The MSU study shows that total expenditures for fresh vegetables in the Springfield metropolitan area are expected to increase from approximately $59 Million in 2010 to an estimated $67 Million in 2015. It's anticipated that this demand will be met by both imported vegetables as well as supply from local growers. Most of the demand, however, is met by vegetables grown in distant locations such as Mexico and imported to the U.S. and Springfield markets. Locally, Springfield markets include Farmer's Markets, retail stores, food service establishments (restaurants and dining halls), and other direct markets. Most of the fresh vegetable market lies with restaurants where more than 80 percent of the vegetables used are fresh. Farmer's markets accounted for a small portion of the fresh vegetable sales, approximately $600,000 total.

Farmers markets have become very popular in Springfield for purchasing fresh vegetables typically grown on small farms.
Source: http://www.ky3.com/news/ky3inc-photo-gallery-friday-night-farmers-market,0,2780627

The study demonstrates a comparison of in season vs. off season prices paid by metro area restaurants and grocery stores for the most common locally consumed fresh vegetables. The comparison shows that the off season price for all of the vegetables increases, from approximately 21 percent higher for cabbage to as much as 228 percent for tomatoes. This information provides important guidance to a greenhouse manager to determine costs of production and timing vs. the price they will be able to get.

In a survey conducted as part of the MSU study, local grocery stores were more responsive to survey questions, indicating a positive impression of locally grown produce. The locally-owned grocers service an average of approximately 13,000 to 15,000 customers a week, with some reporting as many as 20,000 customers a week. The stores responding to the survey indicated that they typically dedicate as much as 16 percent of their floor space to fresh produce. The study further reports that nearly three quarters of the stores sell fresh vegetables provided by local growers, with as much as 28 percent of their fresh vegetable sales coming from local growers during the growing season, and 11 percent of the vegetables sold during the off season or winter months. Of these vegetables, tomatoes are purchased in the greatest quantity, accounting for 18 percent of total fresh produce sales. Strong sales of other produce include squash, berries, lettuce, salad mixtures, cabbage and yellow onions. Results of the survey indicated that an average of 400 pounds of tomatoes per day is sold per store, and as much as 2,500 pounds of tomatoes in total per week.

4.1.2 Food Marketing and Distribution

The majority of fresh vegetables purchased and consumed in the Springfield region come from food distributors or wholesalers (such as Sysco Food, Associated Grocers, etc.),with only about one-fourth of the independent restaurants in the region purchasing fresh vegetables locally. The study found that chain restaurants purchased their fresh vegetables through distributors and have no interest in purchasing vegetables locally. Independent restaurants, however, seemed more inclined to purchase fresh vegetables locally, with more than 60 percent indicating that they are willing to purchase their vegetables from a local source. There is not such a willingness to purchase “organic” vegetables. Instead, the preference is for freshness and high quality of the vegetables, and having a larger variety to choose from. Other reasons cited for preferring local vegetables by independent restaurants was promotion of the local economy and farmers, that they are safer to eat, and that vegetables grown locally generally taste better.

The perception of fresh produce grown locally near Springfield is highly favored by grocers and their customers, with approximately 87 percent favoring locally grown produce. The stores like to support the local economy, and state that quality and taste of the product is also strongly supported. Their main concern is the ability of local growers to provide a consistent supply of fresh vegetables at a competitive price.

4.2 LOCAL PRODUCERS

There are several vegetable growers in Southwest and Southcentral Missouri, with as many as 38 growers identified on the University of Missouri Extension database. It is likely that there are other growers who are not registered. According to the database, most vegetable growers in the region market largely through wholesalers and via roadside stands, and farmer’s markets are also a popular marketing venue in Southwest Missouri.

Nearly all of the growers identified on the University of Missouri database grow vegetables in the field, with only one greenhouse identified in Springfield, but has since closed. The one greenhouse operation, however, has been reported to have closed, leaving no greenhouse operations in the region that produce fresh vegetables. Table 4-1 shows the typical crops that are produced by these farms, although the amounts of each type of vegetable or fruit were not available. The information indicates that fruit and squash vegetables (including squash, pumpkins, gourds, and similar) are most commonly grown, and tomatoes, cucumbers, and peppers are also commonly grown. The information also indicates that most of the growers in Southwest Missouri sell their crops to wholesalers, an indication of the demand for local fresh produce.

Table 4-1 Vegetable Growers in Southwest and Southcentral Missouri (source: University of Missouri Extension)

Market Region	Total Growers	Marketing Approach				Crops grown									
		Farmer's Market	Wholesale	U-Pick	Roadside	tomatoes	cucumbers	peppers	Beans Peas	Corn	Lettuce	Spinach	Squash Gourds	Fruit	Other
SW Mo	18	12	14	6	10	7	5	8	6	5	4	3	8	8	3
SC Mo	20	5	9	8	11	5	6	7	3	4	3	1	10	13	9

- Other markets not listed include coop and mail order
- There is one greenhouse operation identified in Springfield
- Other crops include potatoes, asparagus, nuts, herbs, onions, turnips

4.3 ADDITIONAL MARKET DATA AND INFORMATION

A past study of market forces affecting greenhouse vegetable production was completed by Joseph Pena of Texas A &M University in 1985 and updated in 2005 (Greenhouse Vegetable Production Economic Considerations, Marketing, and Financing, *Dr. Jose Peña, Texas Cooperative Extension, May, 2005*). Dr. Pena's study focused on tomato production, but could be interpolated to other vegetables produced in greenhouses in the south-central U.S. This study actually includes and addresses greenhouse construction and operations costs in addition to the market for vegetables produced and revenue that would be generated. Pena's study essentially concluded that greenhouse production of tomatoes is dramatically impacted by the market, with the cost of greenhouse production offset by the ability of the greenhouse operator's ability to market the crop. If the crop (in this case, tomatoes) can be marketed as superior to field-grown crops, the return will enable successful operations. In addition, Pena states that there is increasing competition from vegetable crops grown in Mexico that enter the U.S. market during the winter months. This tends to suppress the price of fresh produce on grocery shelves and limits what is available to restaurants and other outlets.

Perfect Circle Corporation operates a greenhouse operation in Lake Mills, Iowa, producing tomatoes on a year-round basis. In an interview with Mr. Michael O'Brien of Perfect Circle (May 11, 2011), he stated that 57 million pounds of tomatoes are consumed annually in Iowa, with a large portion of that amount imported from distant locations. Mr. O'Brien stated that their market studies indicate that local consumers prefer produce that is grown locally. As a result, Perfect Circle grows tomatoes year-round, producing and selling up to 1,200,000 pounds of tomatoes per year within a 250 mile radius of their greenhouse. Because the tomatoes are certified organic and grown locally, they are able to sell them at a premium of approximately $2.50 to $3.00 per pound. Mr. O'Brien stated that the production cost of tomatoes at their facility is approximately $1.50 per pound, and therefore the net return on investment is substantial. More information about the Perfect Circle operation is provided in Section 8.

As indicated in Section 4.2, there are other growers in the Southwest Missouri region. Some producers in various markets in the U.S. have been known to arrange exclusive marketing agreements with some retailers, however, most retailers and producers are reluctant to enter into contracts for fear that the producer is unable to deliver and the retailer needs to find produce from another provider. In marketing their produce, it is important for the greenhouse operator to understand the requirements of potential markets, and how sales of the vegetable crop can be affected by contracts, insurance requirements, production quotas, and/or marketing venues (whether it be to wholesalers, individual outlets, or roadside stands).

In summary, the MSU study provides a very good overview of the market potential for greenhouse grown vegetables in the Springfield area. The key in marketing the greenhouse crops, along with a strong understanding of the market forces affecting revenue generation, is the ability of the greenhouse to supply a steady and consistent supply of vegetables. Therefore, marketing becomes a factor of effective greenhouse operations, understanding the supply and demand of crop needs by the public, and timing of crop production in face of seasonal and distant competition. If a marketing plan can be established that develops a steady client base that enables a greenhouse operation to capture as little as two percent of the Springfield market for vegetables during a given year, the potential for $1,000,000 in gross revenue is realistic. If revenue tracks similar to the Perfect Circle operation, the potential for substantial net revenues in excess of several hundred thousand dollars is great and would support a viable, successful greenhouse operation for the Springfield area.

5.0 ECONOMIC ANALYSIS

The first order of analysis regarding the feasibility of a greenhouse operation is economics. In short, is it economically feasible to construct and operate a greenhouse operation as conceived for the City of Springfield, whether in a public-private partnership, or in solely private operation. As shown in Section 4, a significant market for fresh vegetables exists in the Springfield region, and therefore the potential source of revenue is strong and will likely grow stronger with increasing fuel and food prices.

Existing literature regarding the cost of construction and operation of greenhouses provides a varied range of data. For this economic analysis, several sources were reviewed for construction and operations costs, as well as cost of greenhouse construction estimates from actual vendors. Many sources provide an “all inclusive” cost estimate of the greenhouse structure, including materials and labor for construction, as well as the typical equipment that will be needed to grow vegetable crops. For this analysis, we have attempted to reasonably accurate and detailed in the cost elements for greenhouse construction, equipment, and in operations. Chapter 8 presents conceptual greenhouse design details, with a modeled possible cost of construction provided in the appendix.

The economic analysis is predicated on constructing one-acre of greenhouse space and a 3,500 square foot Headhouse for office space and packing and shipping of produce. The economic analysis considers the cost of a bowed roof-style greenhouse with double layer polyethylene cover, and a rigid gabled roof-style house with solid polycarbonate panels. The analysis includes all equipment constructed with the greenhouses. The analysis also considers operations costs, including 12 full-time employees (two managers and ten workers) with benefits, nominal charges for electricity, costs of materials and supplies, crop production materials (seed, fertilizer, pesticides, etc.), insurance, and maintenance of the houses.

5.1 CONCEPTUAL COST OF DESIGN AND CONSTRUCTION

Table 5-1 provides an estimate of conceptual greenhouse construction costs and financing (assuming the construction of the greenhouses will be constructed as part of a business loan). The conceptual greenhouse lengths are described in Chapter 9, with both greenhouses occupying roughly 35,000 square feet. It was assumed that the construction of the houses included floors (gravel underlain by plastic), electrical (wiring of all electric items, and control panels), cooling fans, ventilation, lighting, The cost estimate also considers a combination of bench and vertical hydroponic growing systems, and a soil-based system on benches. The combination of systems considers that some crops are best grown on benches and not accommodated by vertical systems, but vertical hydroponic systems can maximize production and efficiencies of operations when considered.

The conceptual cost of construction of the bowed roof greenhouse is approximately $2,100,000, and the Gabled Roof-style greenhouse construction is approximately $2,700,000, both including a 3,500 square foot Headhouse. These costs can vary substantially with the style of construction and amenities included with the greenhouses. Cost can also vary depending on who completes construction.

Table 5-1. Probable Greenhouse Construction Costs and Financing

	Model #1 Arch Roof Style Double Polyethylene	**Model #2 Gabled Roof Style Polycarbonate**	**Comments**
Dimensions	205' x 170'	180' x 192'	
Area (square feet)	35,000 SF	35,000 SF	
Cost / square foot	$ 7.00	$ 10.00	Approx. from quotes
Extended structure cost	$ 245,000	$ 350,000	
Construction cost	$ 245,000	$ 350,000	
Site Work	$ 150,000	$ 165,000	Approx. 1 acre of growing space
Floors, lighting, electrical, backup, aisle, etc.	$ 267,200	$ 380,950	
Heat Exchange System	$ 300,000	$ 300,000	
Heat System	$ 105,000	$ 105,000	
Growing System cost – soil/bench	$ 128,000	$ 128,000	Assume approx. cost of bench system plus irrigation
Est. cost of greenhouse (with soil/bench system)	**$ 1,702,700**	**$ 2,660,429**	
Headhouse	$ 262,500	$ 384,000	3,500 SF at $75/sf 4,800 SF at $80/sf
Potential Bid Contingencies (4%)	$ 68,108	$ 86,518	
Potential Construction Contingencies (4%)	$ 68,108	$ 86,518	
Project Expenses (15%)	$ 255,405	$ 324,443	Greenhouse design, permits, fees, furniture, and startup.
Est. cost of greenhouse const (w/ soil-based system)	**$ 2,094,321**	**$ 2,660,429**	
Alternative Cost Options			
Growing System cost - vertical	*$ 230,000*	*$ 230,000*	*Hydroponic system*
Growing System cost - bench	*$ 385,000*	*$ 385,000*	*nutrient flow tech.*
Finance (70% loan)			
up front capital	$ 628,296	$ 798,129	
70% loan amount (20-yr, 4.5%)	$ 1,466,025	$ 1,862,300	
Monthly Payment	$ 9,275	$ 11,782	

In Table 5-1, the costs for alternative growing systems (hydroponic systems) are listed to show possible added costs of using these approaches for greenhouse vegetable production.

As a comparison of the costs presented in Table 5-1 and other greenhouse construction costs, Perfect Circle reported that the cost of construction for their greenhouse structure, covering approximately 46,000 square feet, was about $1,200,000 (compared to our estimate of $1,440,000 for a comparable greenhouse), plus approximately $150,000 for their Headhouse (compared to $262,500 estimated for this study). After all of their expenses were accounted for, however, the Perfect Circle cost of construction was near $4,000,000, including design, research and development of growing systems, permits, startup operations, and other costs.

Financing of the greenhouse construction was included in the economic analysis in consideration of the probability that a private operator of the greenhouses would likely need to borrow money for the greenhouse construction. We assumed a 70 percent loan of the total cost, with a 20-year payment term at 4.5 percent interest. A long term loan may be from three to 10 years--or up to 20 years, depending on the amount. Both long and intermediate term loans require collateral. Business term loans are best for small but financially sound businesses looking to fund construction or other types of business growth projects. Section 5.5 discusses possible financing options that could reduce the loan amount and/or terms of possible funding that could be obtained for design, construction, and initial operation of the greenhouse.

5.2 PROBABLE COST OF OPERATION

Table 5.2 presents the estimated cost of operations of the greenhouse. For this estimate, we assumed year-round operations of the greenhouse, including surrounding grounds.

Table 5-2. Operating Costs (monthly)

	Model #1 Arch Roof Style Double Polyethylene	Model #2 Gabled Roof Style Polycarbonate	Comments
Labor (12 FT people), incl benefits	$ 28,500	$ 28,500	Assumes full time staff
Insurance	$ 600	$ 600	More accurate estimate needed
Electricity	$ 650	$ 650	Assumes electricity from SWEC and approx. 7,500 KWH/month
Heat	NC	NC	Assumes no charges from CU
Building/grounds maintenance	$ 1,483	$ 1,675	Rough estimate
Materials, equipment	$ 300	$ 300	Rough estimate

Table 5-2. Operating Costs (monthly)			
	Model #1 Arch Roof Style Double Polyethylene	**Model #2 Gabled Roof Style Polycarbonate**	**Comments**
Seed, fertilizer, etc	$ 450	$ 450	
Business Loan Payment	$ 9,275	$ 11,782	20 year term at 4.5%
Estimated Monthly Operations	**$ 41,258**	**$ 43,957**	
Estimated Annual Operations	**$ 495,096**	**$ 527,484**	

Labor costs included 10 trained workers at a cost of $10.00 per hour, and managers at a cost of $24 per hour, plus benefits at a multiplier of 1.3. The operations cost analysis considered all 12 personnel working full-time (40 hours per week) year round. The cost of operation did not consider depreciation of equipment or the return on the down payment investment for the greenhouse. As mentioned in earlier in this section, nominal rates were included for electricity. This could vary significantly depending on utility service agreements and ultimately who will be the owner-operator of the greenhouse operation. The monthly costs also did not include rent for the land on which the greenhouse would be built and operated.

Including loan payments, the cost of monthly operations is estimated to be from $41,000 to $44,000, or annual operations costs of approximately $495,000 to $528,000. If construction of the greenhouse can be accomplished with grants, the loan payments are eliminated or significantly reduced, and the monthly operations cost may be closer to approximately $32,000, or annual operations costs of $384,000. There are many variables that affect the monthly operations and maintenance of greenhouses, from the length of terms on a loan for business operations, to the costs for heat and electricity (often cited in literature as demanding approximately 40 percent of the total operations cost), transportation, and/or the cost of materials for growing and packaging crops. The most significant cost used in this analysis, however, is the labor cost that is predicated on 12 full-time employees. The number of employees was determined from our interview with Perfect Circle Corporation. If greenhouse operations can be completed with fewer people, the monthly and annual operations cost can be reduced by approximately $2,100 per month per person.

The literature reviewed indicated that general operations costs of greenhouses typically run approximately $6.65 per square foot of space per year. If we account for approximately three percent inflation per year from the time of the literature publication (2007), this would currently be approximately $7.50 per square foot for 2011. This is the equivalent of operating costs of approximately $262,500 per year ($21,875 per month). These projections did not include loan payments, and are based on a staff of five people. An equivalent comparison of the costs calculated for this analysis using similar assumptions would have a monthly operating cost for Springfield's greenhouse of approximately $17,283. This is a lower figure, but a reasonably close comparison for calculating rough numbers of comparing the two examples.

5.3 POTENTIAL REVENUE PROJECTIONS

For the potential revenue projections, we considered the production of three common vegetable crops grown in greenhouses: tomatoes, cucumbers, and lettuce. There are, of course, many other vegetables and plants that are grown in greenhouses, but these provide a reasonable cross section for consideration of the potential revenue that could be generated. Table 5-3 provides the estimated revenues that could be expected with typical greenhouse crops.

The estimates of potential revenue are purposely conservative, taking into account about 70 percent of the floor space available for plant production, not including vertical growing systems, and with mid-range crop production values (how much crop could be harvested). The off-season price for the vegetables were obtained from data developed by Dr. Rimal for the City of Springfield, and was assumed to be the prevailing source of revenue for crops that will be grown (harvested) in the late fall through early spring seasons. Only the top revenue generating vegetables were used for this preliminary analysis. This analysis does not take into account the production and harvest of potential crops through the summer (either greenhouse or field grown). It is possible that added revenues can be generated from field crops grown outside the greenhouse during the summer months.

Table 5-3. Potential Crop Revenue

Crop	Plants per Square Foot	Average Number of plants	Estimated Production (units/plt)	Number Crops per Year	Typical in-season Price	Typical off-season Price	Potential Revenue (avg of in- an off-season prices
Tomatoes (standard)	0.35	12,000	60	1	$0.61	$2.00	$ 939,600
Tomatoes (organic)*	0.35	12,000	60	1	$ 2.50	$2.50	$1,800,000
Cucumbers	0.33	11,500	22	3	$ 0.39	$0.93	$ 501,000
Lettuce (iceberg)	3.5	120,000	1	5	$ 0.75	$1.67	$ 726,000

*organic tomato prices obtained from Perfect Circle Corporation.

The potential revenue projections show that tomatoes would generate the highest amount of revenue, followed by lettuce, and then cucumbers. In particular, the potential revenue generated from production of organic tomatoes can be substantial. The level of analysis did not take into account the fine details of crop nurturing that may be required for growing each crop that could affect the cost of production and/or revenue. If crops are certified organic, requiring a tightly controlled growing system, crops have been shown to command at least a 30 percent premium over the prices shown in Table 5-3. The addition of other vegetables grown can improve the variety and selection of produce offered by the greenhouse, but will likely result in a drop of potential revenues.

Based on the information used in this analysis, it is apparent that high-value crops such as tomatoes and lettuce will generate sufficient revenue that will sustain the greenhouse operations during the first few years until loans are paid off and the return of initial investment is realized. The prospect for growing certified organic produce increases the potential revenue generated by greenhouse operations. Maximizing floor space production can help expand the types of crops that can be grown to provide sufficient revenue to support the greenhouse based on these numbers.

5.4 RETURN ON INVESTMENT

There are several initial funding sources for construction of the greenhouse. Small business loans are a possibility for obtaining funding with very favorable conditions. It is also possible that the City can finance the greenhouse through special provisions such as bonds or other revenue development means. Additionally, public/private partnership funding options exist to fund this facility. This study is predicated on a standard business loan, with the operator or owner obtaining the funding for the cost of construction of the greenhouse, as this is likely the most . This analysis shows that a greenhouse owner would likely be required to invest a minimum of about 30 percent or between $628,000 and $799,000, depending on the greenhouse structure to be built for this operation. This does not include up front capital that would also be required to facilitate operations until the first crop is sold.

If organic tomatoes are the primary crop grown during the first few years, we may assume annual revenues in excess of $1,000,000 providing the greenhouse operator a surplus of more than $350,000, and probably in excess of $500,000 annually (this assumes revenue equivalent to successfully growing tomatoes with a steady market and prices). It would therefore be possible to pay off any loans within a five-year period, after which operating costs would decrease and profit margins increase. This analysis does not include potential increases in the cost of operations, or the potential for increased prices for produce in the market that would generate higher revenues.

5.5 PUBLIC VS. PRIVATE OPERATION

The question of who would own and operate the greenhouse initiated by the City of Springfield is a critical question that demands attention in determining the potential success and financial operations of the greenhouse facility. This is a decision that must be made by the City of Springfield, but in consideration of operation of a vegetable-producing greenhouse, the following factors must be considered:

5.5.1 Public Ownership and Operation:

This economic analysis of the greenhouse operation indicates that the greenhouse, if operated successfully by an experienced greenhouse and vegetable operations team, can generate revenues that will not only pay for the greenhouse, but contribute funding for the City's operations.

Benefits include:

- The City maintains complete control over operations and management of the greenhouse operation.
- Public sector objectives of having a community service available as a resource for education, public input and food production can be maintained.
- If successful, the greenhouse can generate a positive income stream for the City.

Concerns include:

- Can the City operate the greenhouse with the efficiency and market approach demanding profitable returns that will support it?
- Would public ownership compete with private enterprises and therefore create a potential conflict of interest?
- The City's must create a new layer of management and operation within the City's administrative system, including personnel management, financial operations (including profit/loss).
- The City assumes complete risks for the success of the greenhouse operation.

5.5.2 Public-Private Partnership:

The potential for a public-private enterprise for ownership and operation of the greenhouse is good. Typically, a public-private partnership involves a contract between the City and a private party for the greenhouse ownership and operation. Both the City and the private party would assume substantial financial, technical and operational risk in the project, and the private party would not only operate for their own benefit, but also provide a public service. As an example, in a public-private partnership, the City can retain ownership of the greenhouse and the grounds while a private sector operator conducts all operations, including maintenance, growing, harvesting, and marketing of all produce. An agreement can be established in which the private party provides a public service by conducting classes on sustainability and urban farming, and in which the City can maintain some management oversight and receive a portion of the revenues generated from the operation.

Benefits include:

A commonly-accepted ownership and management strategy for the greenhouse operation.

The ability of the City to maintain control in achieving its objectives for a sustainable greenhouse for local vegetable production.

Public services potentially achieved in opening the operation to public education.

Potential for a positive revenue stream for the City.

Reduced need for management by the City, with operations management provided by experts in the private sector.

Concerns include:

The City must be willing to accept some of the operational and ownership risks in the greenhouse operation.

The City should have an oversight entity to participate in management of the property and revenue generation.

5.5.3 Private Ownership:

Private ownership removes the risk of ownership and operation of the greenhouse from the City. It also removes any input and/or control the City may have for the greenhouse operation, including meeting the City's goals for providing fresh, locally grown vegetables for market in the region.

Benefits include:

After all transfers of ownership are made, the City has no risk in regard to success or failure of the greenhouse operation.

A new business operation will be established within the Springfield region.

Concerns include:

The City has no input regarding crops produced for benefit of local communities.

The City may not realize their goals for public services.

No participation in revenue sharing for the City.

5.6 POTENTIAL FUNDING STRATEGIES

Four funding strategies that are viable options for financing the construction and initial operation of the greenhouse are presented below. These options primarily involve loan programs as these are typically the most successful strategies that will sustain a business over time. The strategies include:

5.6.1 63-20 Corporations

63-20 corporations provide an option to bring both private development funding and public financing together to allow automatic access to municipal bond financing, without volume cap allocation restrictions, for project finance via the public/private partnership.

Since 1963, 63-20 corporations have been authorized by the IRS and general state non-profit law as entities that can issue municipal bonds which are treated as debt obligations funded on behalf of a political subdivision for public purposes. This allows municipalities to create an alter-ego, the 63-20 corporation, which can act in concert with the local government, but holds separate ownership of the project. This also allows the municipality to own assets in an entity that is not direct obligations of the municipality.

The following is an example of how the 63-20 corporation can work with the proposed greenhouse operation:

1. A private developer, which could be a non-profit that is loosely connected to the city, such as the local community development or economic development corporation. Also, it can be a private developer that creates a non-profit shell entity, such as a 501-c3 for the purposes of holding these assets for leaseback to the city.

2. The greenhouse project is brought forth by the developer for consideration and the municipality has a favorable opinion of the project

3. The municipality works with a developer, local community or economic development corporation to form a state organized not-for-profit, 63-20 corporation

4. The project achieves financing through the new not-for-profit 63-20 corporation. Prior to seeking financing, the corporation negotiates a lease arrangement for the life of the project from the municipality, showing the capacity to cover project debt service requirements.

5. The 63-20 would then obtain municipal bond financing and the developer would proceed to complete the project

6. The municipal bond financing would not be an obligation of the municipality and the debt would be repaid from project revenues

7. Financing is typically offered as a 30-year amortization with level debt service requirements

8. Ownership of the project reverts to the 63-20 upon debt repayment and is then offered to the municipality at either 10%, or less, of fair market value.

9. Examples of such developments would be multi-family housing, assisted living facilities, hotels and conference centers, industrial parks, public parking facilities, ice arenas and could also easily include operations such as the proposed greenhouse

10. The benefit to this form of financing is the ability for the city to achieve the development of the proposed greenhouse project without holding the assets on the balance sheet of the city. The long-term lease arrangement with the city makes the bonds attractive to investors and, hence, financially palatable.

    63-20 corporations must meet specific criterion, largely focused on ensuring that the 63-20 engages in activities what are generally public in nature and are not inuring any private person. Proceeds of such funding may be used for planning, construction and permanent financing, are offered as first mortgage revenue bonds and are non-recourse to the borrower. 100% of acquisition and development costs can be financed and project soft costs and entitlement costs are reimbursable. An added benefit is that construction and permanent financing are offered as one structure.

5.6.2 USDA Rural Economic Development Loan and Grant (REDLG) Program

The USDA's REDLG program provides funding to rural projects through local utility organizations. Under the REDLoan program, the USDA provides 0% interest loans to local utilities which they, in turn, pass through to local businesses for project that will create and retain employment in rural areas. The business is ultimately responsible for repayment to the lending utility and the utility is then responsible for repayment to the USDA.

Under the REDGrant program, the USDA can also provide grant funds to local utility organizations which use the funding to establish revolving loan funds. Loans are then made from the revolving loan fund for projects that will create or retain rural jobs. When the revolving loan fund is terminated, the grant is repaid to the agency.

In the case of the proposed greenhouse project, both REDLoan and REDGrant options exist. According to the USDA Missouri Rural Development (USDA MO RD), the location of the greenhouse at the RE/SF site is sufficiently rural to be considered as eligible. While not every utility will qualify, USDA MO RD has identified the nearby Springfield utility, Associated Electric, as an eligible utility recipient.

For the proposed greenhouse project to seek funding through the REDLoan program, specifically, the sponsoring rural utility must agree to receive loan funds from the USDA. In this instance, the identified Associated Electric would need to agree to take loan funds from the USDA to benefit the proposed greenhouse project. Associated Electric would then lend these funds, per the USDA terms, to the developers of the greenhouse project specifically for the benefit of that project only.

Understanding the structure, the following generally assumed caveats should be considered:

- Associated Electric, the only nearby rural-eligible utility recognized by USDA, would need to agree to sponsor the application to the USDA on behalf of the greenhouse development. In this case, Associated Electric doesn't actually have to serve the facility, but they would need to sponsor the loan from the USDA to the project. This may not be an option since it may be difficult getting them interested in doing this and not providing power. However, this could be considered for further investigation because if you used this program, it will be 0% for 10 years.
- Utilities typically will want either a senior lien position on the project or, perhaps in lieu, a bank letter of credit that promises full repayment in the event of default. If a letter of credit is required, the issuing bank will underwrite the letter to determine if the pledged entity has the ability to either immediately repay the loan or can, somehow through operations over a pre-determined period of time, repay the letter. The lien position and/or letter of credit are potential hurdles to this form of financing.

Regardless of the potential hurdles presented in underwriting, if a negotiated lien position can be negotiated, this form of funding can provide the borrower with significant benefits. This partially-inclusive list includes:

- A 10-year, no-interest loan of up to (2011 limit) $740,000
- Relaxed terms and potentially relaxed collateral requirements
- Potential points of negotiation for providing load factor to the local, rural utility
- An opportunity to approach the same utility, Associated Electric, with the idea of obtaining REDGrant funding, the revolving loan pool described above, that may be able to be accessed as purely grant funding to support operating expenses

The option of accessing USDA REDLG funding, while initially a bit cumbersome, could provide the developer of the greenhouse with some unexpected benefits. From no-interest, longer-term lending and operating grants to negotiated electric rates, this financing program is worth discussing for application to the proposed greenhouse project.

As a final bonus, during fiscal year 2010, approximately $33.077 million was available for loans, considerable excess funding remained at fiscal year-end, and the program is slated to be well-funded for fiscal-year 2012.

5.6.3 Agricultural-Specific Financing

First and foremost, the development of the proposed greenhouse operation is an agricultural activity. As such, this development can qualify for special financing options and terms made available to agricultural companies.

It can be anticipated that the proposed greenhouse operation will face some unique challenges from the conventional, private financing market. It is often difficult for traditional banks to understand or effectively underwrite for the sometimes unpredictable operating cycle of these operations. Additionally, the collateral value of assets associated with a greenhouse development may be grossly underestimated by the conventional, private financing market.

Farm Credit, while not the only agricultural lender, is the largest nationwide network of lending cooperatives to rural America. Funding is made possible through a nationwide, regional wholesale bank system that provides funding to retail lenders serving the general public in that area. Through these wholesale banks, debt is issued on Wall Street and the money raised flows from investors through these retail institutions in the form of lendable equity to individual borrowers. As borrowers, in this instance, the developer of the greenhouse will repay their loans and Wall Street receives a return on its investment.

Since agricultural lenders specialize in rural financing, the loan officers involved in extending credit are adept at identifying unique underwriting complexities associated with projects such as the proposed greenhouse operation. Because of federal government allowances, particularly through IRS codes, the beneficiary developer can benefit from ultra-competitive rates. These rates are typically tax-free equivalent and fixed for a longer duration than a standard, conventional bank commercial real estate or equipment loan.

Most importantly, the greenhouse operation will likely need short-term financing assistance to support operations, particularly in the growing season. Agricultural lenders are capable of offering both variable and fixed-rate loans, with terms ranging from 5 to 30 years. This is of extreme importance because a conventional operating line of credit to support short-term business operations, inventory such as seed and materials, accounts receivables and other pertinent inventory will be expected to be repaid within 12 months, which may not compliment the operating cycle of this development.

Finally, in consideration of collateral, it is vital that the lender understand the true value of pledged company assets so that the operation can receive a fair loan rate and not be required to shore-up a gap in collateral by pledging additional assets, outside of the confines of the greenhouse operation. Agricultural lenders rely upon agricultural-specific appraisal companies to accurately determine the value of company assets so that a fair arrangement is set from the very beginning.

Structuring the proposed greenhouse operation's debt equity is of vital importance to the long-term stability of the operation. The more the monthly debt service requirements can be reduced from the beginning, the less the demand on monthly revenues to keep the operation afloat. Utilizing an agricultural lending conduit will benefit the developer by providing for lower rates, for a longer fixed term, with an extended amortization schedule, backed by appropriate and fairly-valued collateral and structured to accommodate the unique operation conditions of the development.

5.6.4 Business and Industry Guaranteed Loans (B&I)

The proposed greenhouse is projected to generate revenue that will be taxable and will bring along with it employment that will be beneficial to the community.

Projects with characteristics such as those described above, located within USDA-qualified rural areas, and are eligible for business and industry guarantees (B&I) from the USDA.

The purpose of the B&I Guaranteed Loan Program is to improve, develop or finance businesses, industries and those companies providing for local employment as a catalyst to improve the economic and environmental climate in rural communities. This purpose is achieved by bolstering the existing private credit structure through the guarantee of quality, bank-underwritten loans with the hope that these company loan investments will provide lasting community benefits.

It is assumed that the proposed greenhouse project will qualify for the USDA B&I loan guarantee program. The guarantee would indirectly benefit the developer or proposed greenhouse project borrower, however, it is applied for through the lending institution holding the primary debt against the project. The main reason as to why this program is applicable to the primary debt is because the USDA will require the bank to take a senior lien position on assets related to the proposed greenhouse project for the guarantee to be valid.

Borrowers may be cooperative organizations, corporations, partnerships or other legal entities organized and operated on a profit or nonprofit basis. Hence, this particular program would allow the extension of a loan guarantee for either public or private ownership of the greenhouse project. However, the borrower must be engaged in activities that will:

- Provide employment
- Improve the economic or environmental climate;
- Promote the conservation, development and use of water for aquaculture; or
- Reduce reliance on nonrenewable energy resources by encouraging the development and construction of solar energy systems and other renewable energy systems

Loan purposes must be consistent with the general purpose contained in the regulation. They include, but are not limited to, the following:

- Business and industrial acquisitions when the loan will keep the business from closing, prevent the loss of employment opportunities, or provide expanded job opportunities
- Business conversion, enlargement, repair, modernization, or development
- Purchase and development of land, easements, rights-of-way, buildings or facilities
- Purchase of equipment, leasehold improvements, machinery, supplies or inventory

The guarantee cap set by the USDA is sufficient to cover the initial capital projections for the proposed greenhouse project. The percentage of guarantee, up to the maximum allowed, is a matter of negotiation between the lender and the USDA; however, the maximum percentage of guarantee is 80% for loans of $5 million or less, 70% for loans between $5 and $10 million and 60% for loans exceeding $10 million.

The USDA will not exceed $10 million to a single borrower, however, at the administrator's discretion, they can, under special circumstances, increase the limit to a cap of $25 million.

The maximum repayment for loans on real estate will not exceed 30 years. Machinery and equipment repayment will not exceed the useful life of the machinery and equipment purchased with loan funds or 15 years, whichever is less; and working capital repayment will not exceed 7 years. Regardless, these amortization periods are favorable to the shorter durations that would be found in conventional lending institutions without the guarantee. The longer amortization and fixed term would be of great benefit to the developers of the proposed greenhouse project as it will alleviate monthly debt service by freeing up cash for ease in covering needs for the business operating cycle.

While the interest rate for the guaranteed loan will be negotiated between the lender and the applicant, and may be either a fixed or variable rate, interest rates are subject to the USDA review and approval. Variable rates may be adjusted only on agency-specified intervals that are favorable to the business.

As in conventional lending, collateral is required and the value of said collateral, in this instance, the greenhouse assets and land, must be of sufficient value to protect the interest of the lender and the USDA. The discounted collateral value will typically be at least equal to the loan amount. The Lender will discount collateral consistent with sound loan-to-value policy. Additionally, it is important to note that with the proposed greenhouse property, there may be assumptions on the part of the conventional lending community that the facility assets will be single-purpose and will look to secure a lower loan-to-value loan (likely somewhere in the vicinity of 50-70% LTV) to ensure that they will not take a significant loss in the case of default. Even with the B&I guarantee, the USDA requires liquidation of collateral and external guarantees before they settle and provide their guarantee payment and, since their highest-level guarantee is 80%, the lender would still stand to lose "some" in the arrangement.

It is important to note that there is a cost to this program, albeit small. Annual fees are charged to the lender and structured in the loan repayment by the lender. However, if the greenhouse developer is able to achieve a loan that they might not have otherwise been able to achieve, without providing excess collateral or exposing the project to unfair rate and amortization terms, the guarantee will prove to be a worthwhile funding option.

Upon understanding of the equity, true debt equity requirements, how the developer chooses to approach the project, the ownership and the utility providers, further work should be considered to structure the best option. The structure of the request depends upon the identification of the unknowns.

5.7 ADDITIONAL FUNDING OPTIONS

There are several potential grant sources that can provide revenue for this project. Potential funding sources include municipal financing through bonds, Federal support either through grants or Federally-insured loans, or through private financing. Some examples include:

5.7.1 Municipal Bonds

If the City of Springfield desires, it is possible to develop a special bond for financing construction of the greenhouse structure. Such a bond can be created specifically for generating the revenue necessary to finance the greenhouse construction and initial operations with a term limit of return on investment. Revenues generated by the greenhouse can be specified in a legal contract between the greenhouse operator and the City to be used for repayment of the principal and interest.

5.7.2 Federal State Marketing Improvement Program

This matching grant program, also known as FSMIP, provides matching funds to State Departments of Agriculture and other appropriate State agencies to assist in exploring new market opportunities for food and agricultural products, and to encourage research and innovation aimed at improving the efficiency and performance of the marketing system.

5.7.3 Specialty Crop Block Grant Program

Specialty crop block grant funds can be requested to enhance the competitiveness of specialty crops. Specialty crops are defined as fruits and vegetables, tree nuts, dried fruits, and nursery crops (including floriculture).

5.7.4 The Farmers Market Promotion Program

This program, or FMPP for short, was created through a recent amendment of the Farmer-to-Consumer Direct Marketing Act of 1976. The grants, authorized by the FMPP, are targeted to help improve and expand domestic farmers markets, roadside stands, community-supported agriculture programs and other direct producer-to-consumer market opportunities.

5.7.5 Organic Cost Share Program

AMS administers two organic certification cost share programs. Each program provides cost share assistance, through participating States, to organic producers and/or organic handlers. Recipients must receive initial certification or continuation of certification from a USDA accredited certifying agent (ACA).

At the time necessary after necessary funds needed are identified and as applying, additional grant sources may be researched and examined to support Springfield's greenhouse project.

6.0 ENERGY ASSESSMENT

6.1 Energy Requirement

Energy is the second largest cost in greenhouse operation behind labor costs, with heating consuming 70% - 80% of the total energy budget. The remaining 20-30% of energy use is for electrical systems such as ventilation, lighting and controls.

6.2 Energy Source Availability

With the Nobel Hill Landfill Renewable Energy Center (NHLREC) generating 3.2 MW of electricity and connecting to a City Utilities transmission line on or adjacent to the proposed greenhouse site, electricity is readily available at the site. There is however no natural gas available at the site so another energy source such as propane stored on site, electricity or an alternate energy source would be needed for heating.

A goal of the project is for the greenhouse to be a sustainable venture and to utilize green, renewable energy sources. Green energy is energy that can be extracted, generated, or consumed without any significant negative impact to the environment. Once equipment and infrastructure has been installed to generate or extract such green energy, the energy is available at no cost or low cost compared with energy purchased from conventional sources. The proposed greenhouse site would appear to have several green, sustainable energy sources available.

6.2.1 Generation Station Waste Heat

The renewable energy source for the proposed greenhouse site would be waste heat generated by the NHLREC. Itself a producer of renewable energy, the NHLREC operates two Caterpillar G3520C generators 24 hours per day 365 days per year, is fueled by methane gas from the landfill, and produces 3.2MW of electricity. The efficiency of even the best engines is fairly low as waste heat energy is a byproduct of the combustion process. This heat loss has long been recognized as a major waste of energy resources and technology has been developed to capture some of this lost energy.

Of the waste heat that is produced by the generators, two sources present an opportunity for capture and reuse. At full load each, each of the generators rejects approximately 61,564 BTU per minute to a water cooling system which in turn rejects the heat to the environment through an air-cooled radiator system. Each generator also loses approximately 57,574 BTU per minute through exhaust that is discharged directly to the atmosphere. Together the two generators are rejecting 238,276 BTU per minute to the atmosphere. Fortunately this energy need not be wasted; technology exists to reclaim much of this resource.

Estimates indicate that a greenhouse maintained at 75 degrees F in Southwest Missouri and constructed of two layers of 6 mil polyethylene would have a heating requirement of approximately 75 Btu per hour per square foot at an outdoor temperature of 15 degrees F. If a system was designed to capture both sources of waste heat rejected by the NHLREC generators, the heating needs of a greenhouse of approximately 4 acres could be fully met.

6.3 ENERGY CAPTURE ASSESSMENT

As mentioned above, the cooling water systems and the exhaust systems present opportunities for heat energy capture and reuse. Different capture technologies exist to capture heat from these two sources.

Reclaiming heat from the jacket water and lube oil/after cooler water circuits can be accomplished fairly easily through the use of plate heat exchangers. These heat exchangers pass two fluid streams through them and exchange heat between the fluids. In this case the generator cooling circuits would pass through the heat exchanger where heat would be transferred to another water loop. This new water loop could then be pumped to the greenhouse where it could be used directly for heating. The generator cooling water would then continue on to the current cooling system where it would dissipate any excess heat and return to the generators as it currently does. Plate heat exchangers are readily available from several manufacturers. Figure 10.8 of the Waste Heat Reclamation System depicts a conceptual idea of this process.

Capturing heat from the cooling water loops would require installation of piping from the cooling loops to heat exchangers, pumps to circulate generator cooling water through the heat exchangers, installation of a water loop from the heat exchangers to the greenhouse and a pumping system to circulate the heating water to greenhouse. Installation of the heat exchangers, pumps and connection to the generator cooling systems would have minimal to no disruption of the operation of the generators. It is estimated that each generator's plate heat exchanger system could recover 55,730 Btu/min (3,343,815 Btu/hr) for a total of 111,460 Btu/min (6,687,630 Btu/hr). The two combined generators can produce enough heat to meet 100% of the heating needs for a two-layer polyethylene covered greenhouse of approximately 2.0 acres in size at outdoor temperatures down to 15 degrees F. A supplemental heating system

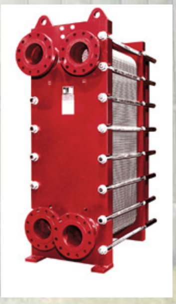


Plate Heat Exchanger

could be installed to provide additional heat at temperatures below 15 degrees F, or the recovered heat could provide 100% of the heating needs of a smaller greenhouse.

Capturing heat from the generator exhaust would require a technology other than the plate heat exchangers described above. Cain Industries is one manufacturer who specializes in heat recovery equipment for generator exhaust systems. Cain manufactures equipment that can capture exhaust heat and create either steam or hot water. As with water heated by plate heat exchangers hot water created by heat captured from generator exhaust could be used directly to heat a greenhouse. Additionally steam created from generator exhaust could be used directly to heat a greenhouse and to create electricity in a microturbine.


Cain Industries HRSR Unit

The Cain Industries model HRSR is designed to receive total exhaust flow from a generator and create hot water. The HRSR unit can be installed in the horizontal or vertical position depending on space considerations and is also provided with a full port exhaust bypass so that the exhaust gases may be vented to the atmosphere when heat recovery is not desired. Each generator's HRSR unit would recover 52,600 Btu/min (3,156,000 Btu/hr) for a total of 105,200 Btu/min (6,312,000 Btu/hr). Each HRSR unit cost $107,000 and would require modification of the existing generator exhaust stack as well as modification to the existing structure to accommodate the HRSR size and 9,000 lb weight.


Cain Industries ESG1 Unit

The Cain Industries model ESG1 is similar to the HRSR unit but creates steam rather than hot water. Each generator's ESG1 unit would recover 47,566 Btu/min (2,853,960 Btu/hr) for a total of 95,133 Btu/min (5,707,980 Btu/hr). Both units operating can produce up to 5,884 lb/hr of 125 psig steam. Each ESG1 unit cost $126,000 and as with the HRSR units would require modification of the existing generator exhaust stack as well as modification to the existing structure to accommodate its size and 9,000 lb weight. In addition to the ESG1 unit itself, additional equipment such as boiler feed pumps, deaerator, condensate pump, and blowdown receiver would be required for a steam producing system. To produce electricity a microgenerator costing $10,000-$30,000 depending on generator size would also be required. Considering the ESG1 recovers less energy than the HRSR while having a higher installed cost, and given the unfavorable economics of installing electricity producing equipment compared with possible energy costs savings that have been discussed previously, installation of a steam generating ESG1 is not recommended.

6.4 ENERGY SYSTEMS CONCLUSIONS

Due to the lack of significant rebates, tax credits, and utility incentives for installation of renewable energy systems, the relatively low cost of electricity in the region, and the high cost of installation of renewable energy systems and some waste heat capture technologies, waste heat capture from the NHLREC generating station cooling water loops is the only viable renewable energy option at the site. Depending on the size of the greenhouse, such a system could provide up to 100% of the heat required.

7.0 GREENHOUSE SIZING

There were six (6) key factors used for determining the optimum/feasible size for a commercial greenhouse facility to be developed and operated at the RE/SF greenhouse site. These are:

- The size of the market's demand for how much crop quantity can be sold versus growing space that can be supported
- The feasibility of capturing a sufficient quantity of waste heat from the NHLREC electric generating station to meet the greenhouse's year-round heating requirements.
- The site size and supporting infrastructure available to accommodate/support the greenhouse operation.
- The optimum design and operation of the greenhouse growing system selected to be developed (durability, modularity and economies of scale etc.).
- The financial resources available (from public and/or private sources) to fund construction and operation of the greenhouse.
- The ability of the greenhouse grower/operator to produce and market the fresh vegetables selected efficiently, reliability and in the quantities necessary to provide adequate revenues to meet/exceed the greenhouse construction and operating costs".

Much of the analysis of this feasibility study is based on the initial sizing of the greenhouse of approximately 35,000 square feet, or close to one acre under roof. This is because much of the literature states that successful greenhouse operations start "small" at about one acre in size, and grow from there. Analyses of the factors that ultimately contribute to the optimal sizing of the greenhouse indicate that a larger greenhouse operation can be supported at the Noble Hill Landfill site.

7.1 MARKET CAPACITY

As presented in Section 4, the market for fresh, locally grown produce in the Springfield area would support the production of the greenhouse operation. It was shown that up to 2,500 lbs of tomatoes along are typically sold per week per grocery store in Springfield. There are approximately 100 grocery stores in the Springfield region. If each store sells, for example, an average of 1,000 lbs of tomatoes per week, this is the equivalent of a total of 100,000 lbs of tomatoes, or approximately 5,000,000 lbs of tomatoes per year. Production capacity equivalent of that achieved by Perfect Circle, Inc. in Iowa is approximately 1,000,000 lbs of tomatoes per one acre of greenhouse. Therefore, it is logical to estimate that a five-acre greenhouse could be supported by the local market for vegetables.



7.2 AVAILABLE ENERGY (HEAT/ELECTRICITY)

A heat exchanger and conveyance system connected to the generator station cooling water system could recover 111,460 Btu/min (6,687,600 Btu/hr). This is enough heat to meet 100% of the heating needs for a two-layer polyethylene covered greenhouse of approximately 2 acres at outdoor temperatures down to 15 degrees F, and 100% of a smaller greenhouse at colder temperatures. A backup heating system could be installed to provide heat if the exchange system had problems.

7.3 CROP PRODUCTION SPACE REQUIREMENTS

Typically, crop production is not a limiting factor for how much greenhouse can feasibly be constructed and operated. The type of structure, however, can provide efficiencies in placement of crop growing systems that can provide more efficient use of available floor space. For example, an arched-roof style greenhouse loses valuable floor space near the outside walls due to their arching angle and shape, especially if taller-growing plants are produced or vertical growing systems are employed.

Approximately 70 percent of floor space of a greenhouse is used for placement of benches or growing pots, leaving room for aisles, workspace, and equipment. Within the 70 percent of floor space used, the density of plants grown will also be a factor on how much crop is produced: wide plant spacing can produce better crops but limit yields, while too dense of plant spacing can create more management needs and reduce plant yield in spite of their being more plants.

Aisle space of tomato greenhouse

The more floor space that is available for crops, the more production per greenhouse unit (or bay) will be realized. Greenhouses that are taller along the walls, such as a gable roof greenhouse, will allow maximizing floor space. Literature reviewed for this feasibility study indicates that most greenhouse units are approximately 20 to 32 feet wide, and from 72 to 96 feet long, although variations on width and length vary more or less from these dimensions.

7.4 VENTILATION AND AIR EXCHANGE LIMITATION

Air and heat distribution is also a factor to be considered, as consistent air flow and temperatures are critical to efficient crop production. Essentially, the ability of the greenhouse to facilitate air movement by fans contributes to determining the optimal dimensions for the greenhouse. In the summer, it is often appropriate to move one volume of air (the total cubic volume of air within the greenhouse) through the house per minute to provide sufficient cooling of the air. In the winter, a minimum of two air changes per hour is recommended. Fans need to be sized accordingly to move air at two or more speeds. Vents within the greenhouse structure also need to be sized to allow passage of the air.

Ventilation fans for commercial greenhouses

7.5 COST LIMITATIONS

Cost limitations in greenhouse sizing are governed by funding or financing that is available, market for crops produced, including the prevailing wholesale prices, the types of growing systems that will be employed to grow crops, and the labor needed (including appropriate pay and benefits) for efficient crop production. Cost considerations must include the following:

- Site preparation
- Utilities
- Greenhouse structure and foundation
- Mechanical systems
  - Ventilation
  - Plumbing
  - Electrical
  - Lighting
  - Environmental control systems (automated)
- Growing systems
  - Tables, benches, pots
  - Irrigation systems (automated or manual)
  - Growing supplies, such as media, fertilizers, pesticides
- Harvesting, packaging, and transportation systems
- Labor
- Maintenance
- Waste management
- Greenhouse administration
  - Marketing
  - Accounting
  - Records

As demonstrated in Section 5, the initial cost of a 35,000 square foot greenhouse operation would be in the range of approximately $2,700,000. There is likely an economy of scale for a larger greenhouse operation in which the cost per unit area decreases. The potential return on investment, however, would be a favorable factor in obtaining financing or startup capital to construct the greenhouse operation.

Therefore, the size of the greenhouse is limited in cost only by the amount of initial capital that the owner/operator can afford to invest.

7.6 AVAILABLE SPACE

The site consists of approximately 40 acres of land, which about 37 acres are available to build the greenhouse facility and site improvements at the RE/SF site. The City-owned property is adjacent to the NHLREC generating station. The first phase will require about 3 acres which will leave several acres for future improvements. Therefore, land area is not limiting of the greenhouse size. See Figure 10.1, 10.2 and 10.4.

7.7 OPTIMAL GREENHOUSE SIZE

In summary, it appears that produce market size, available energy, site size, and growing system designs are not limiting factors in developing and operating a year-round commercial greenhouse. However, through the examination of factors that affect the greenhouse size at the RE/SF site, the most limiting factor to developing the site to its full potential would be funding, the amounts and sources of capital funds available, and the skill and experience of the greenhouse grower/operator.

In addition from this assessment, we can conclude that the maximum greenhouse size for this project would be around 348,800 square feet (8 acres). This is far beyond the initial phase for construction a 35,000 square foot facility.

8.0 GREENHOUSE SYSTEMS

8.1 PARAMETERS

There are a multitude of types and styles of greenhouse structures: tiny to mega-size, plastic to steel, polyethylene flexible sheeting to high-performance glass, moveable or permanent, industrial to decorative. This study will focus on types suitable for commercial production growing, with the following goals in mind:

- Efficiency for workers in the growing process. (Aside from heating, labor is the next biggest operational cost.)
- Good value: low initial cost; economical yet effective and functional (but not necessarily the cheapest system.)
- Low maintenance of the structure and covering
- Durability of the structure (reasonable resistance against wind and hail etc., and can hold up to the rigors of the average workday activities.)
- Simplicity, flexibility, adaptability (ease of modification, changes in growing cycles or types of produce, and for changes to venting, heating, watering systems, etc.)
- Expandable

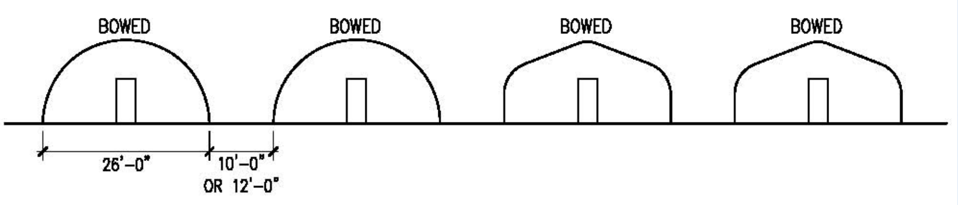
8.2 STRUCTURAL TYPES:

1. Free-standing Quonset Hut - Bowed Frame: The simplest and least expensive commercial systems are single bay, freestanding, up to about 26' wide and up to about 96' long. The covering is usually polyethylene flexible sheeting coming all the way down over a bowed aluminum frame (not intended to be joined together in multiple side-by-side attached bays.) For an acre of production area, ten to twenty of these types of units would be needed, depending on length, with 10' to 12' space between each unit. These units are often anchored to the ground with pins, and without concrete foundations, and are easily moved, with or without built-in wheel systems.

   a. These systems tend to be lower height, and thus have more limitation on type of growing system, irrigation system, aisle widths, and other systems.

   b. Similar to Rimol "Catamount" or "Northpoint". See more information below under "Costs". See link at www.rimolgreenhouses.com

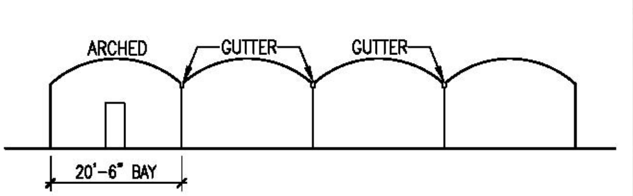
c. Also similar to Hummert "North Slope" or "Thermolator". See web site at www.hummert.com/Catalog.aspx.



Free-standing Quonset Huts – Bowed Frame

2. Arched Roof – Gutter Connected: Next best is arched roofs, vertical walls, with polyethylene flexible sheeting, ganged together in multiple bays, and can cover several acres all under one roof. Each bay requires a gutter between the roofs, and is often referred to as "guttered" or "gutter-connected" greenhouse; also referred to as "furrowed". Larger connected systems are often referred to as a "range". Some manufacturers provide a roof venting system, similar to Nexus Corporation. Side walls and end walls can be polyethylene sheets or polycarbonate rigid panels (see roof and wall materials below), End walls can also be metal siding if desired.

a. Similar to Rough Bros "Poly Arch" system: 20'-6" wide bays. See "Costs" below also. See link at http://www.roughbros.com/products/poly.html.
b. Also similar to Hummert "Continental" (see sample sheet from catalog, next page), or "Insulator". See web site at www.hummert.com/Catalog.aspx .



Arched Roof - Gutter Connected

Agratech Continental

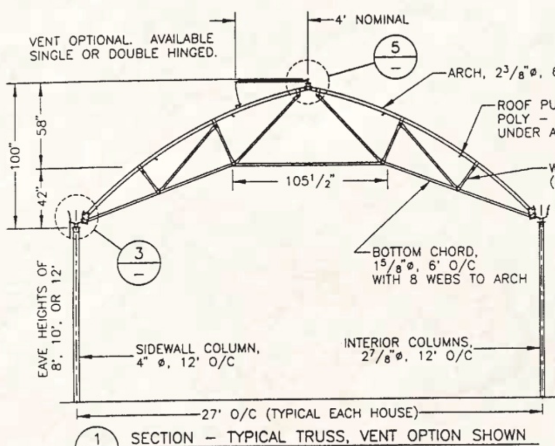
AGRATECH GREENHOUSE MANUFACTURERS

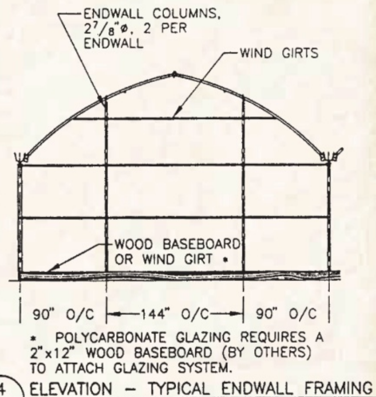
Made in the USA

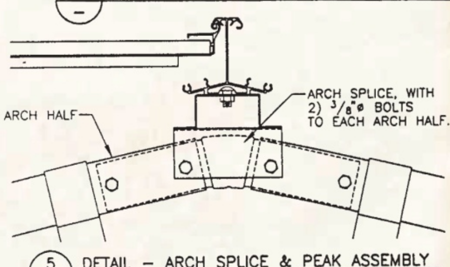
THE CONTINENTAL

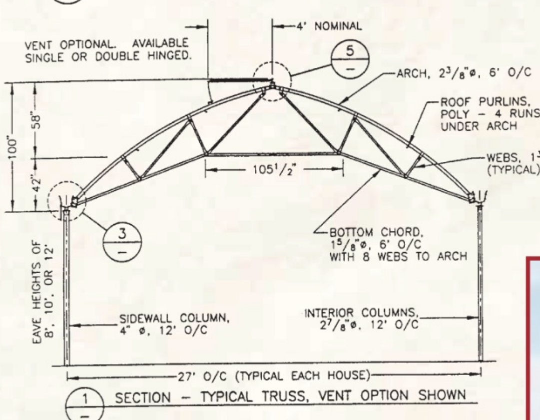
The Continental 27′, 30′ or 35′ Gothic WIDE CLEARSPAN TRUSS GREENHOUSE roof provides a superior growing environment. The higher ridge height of the gothic arch creates a larger air mass encouraging better air circulation, less humidity and more stable air temperatures.

- All galvanized steel bolt-together frame.
- Engineered to meet Uniform Building Codes (UBC).
- Loading: 20# live load or 30# ground snow.
- Wind loads of 90 mph.
- All formed steel is galvanized high strength structural grade steel.
- All frame parts are cut to length and punched for bolt-together erection.
- Available with 54″ roof vent, single or double.
- Readily accepts heat retention systems.
- Double poly roof easily converts to Polycarbonate Corrugated or Structured Sheet.
- 6:12 pitch for condensate control.
- Included are all fasteners, trims, closure stripping and caulking.









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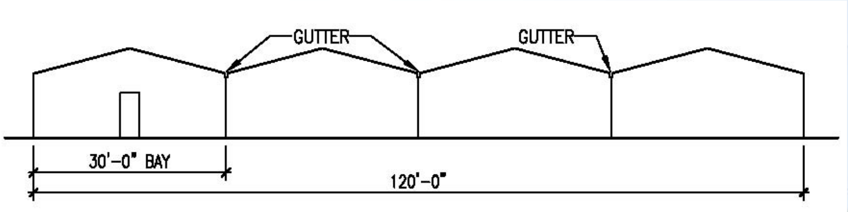
Sample page from Hummert catalog.

3. Gabled Roof - Gutter Connected: A step up from arched roofs is multiple gabled shaped roofs. Walls and roofs can be polyethylene flexible sheets or polycarbonate rigid panels (see roof and wall materials below). Units require a gutter between each bay, also named "gutter-connected", or "furrowed".

   a. Similar to Rimol "Matterhorn": 30' bays: 120' wide (4 bays) by 96' long. See "Costs" below also. See link at www.rimolgreenhouses.com

   b. Also similar to Hummert / Agritech "DryHouseI" (with condensate removal system); (see diagram from catalog, below). See web site at www.hummert.com/Catalog.aspx .



Gabled - Gutter Connected

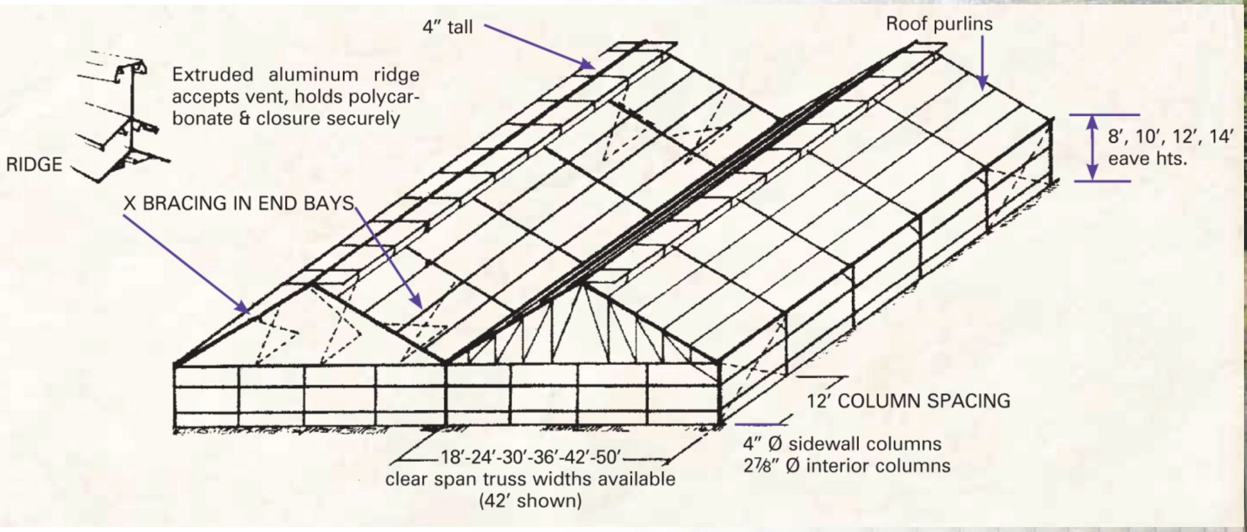


Diagram from Hummert catalog.

4. Manufacturers: (There are many, these below seem to be leaders in the industry, and provide systems and equipment for large growers.)

   a. Rough Brothers: www.roughbros.com
   b. Hummert International: www.hummert.com (Earth City, Mo.)
   c. Rimol: www.rimolgreenhouses.com
   d. Nexus: www.nexuscorp.com

e. International Greenhouse Company: www.igcusa.com
f. Conley (primarily parts, components, and equipment) www.conleys.com.
g. Crop King (some greenhouses, mostly equipment, products, hydroponic products, etc.) www.cropking.com

5. Additional general information is available at the following websites: http://cals.arizona.edu/ceac/research/archive/structures_pe.htm http://www.ces.ncsu.edu/depts/hort/greenhouse_veg/topics/gtp_pages/ghstructures.html

8.3 MATERIALS, OPTIONS, AND EQUIPMENT

1. Roof Coverings: there is a wide range of types of materials and costs.

a. Single layer 6 mil polyethylene flexible sheeting: cheapest; short life expectancy, maybe a year. Clear or white.

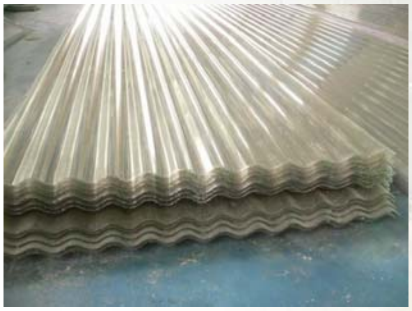
Single layer product

Installed double layer air-filled

Polyethylene flexible sheeting

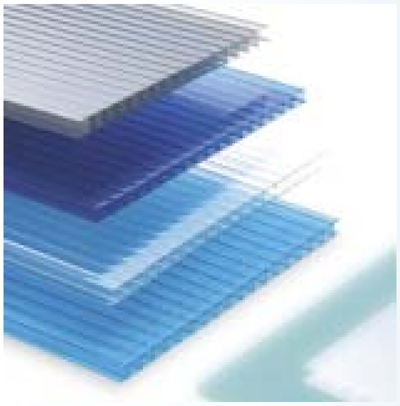
b. Double wall polyethylene flexible sheeting: inner layer has IR-Anti-Condensate film. The space between the layers is filled with pressurized air. (Designed to last 2 to 4 years). Due to light weight and low initial cost, most growers prefer this system. It also allows a lighter weight support system.

c. Corrugated polycarbonate rigid panels; single layer, similar to the products sold and the home improvement big box store's; clear or white, fiberglass reinforced.



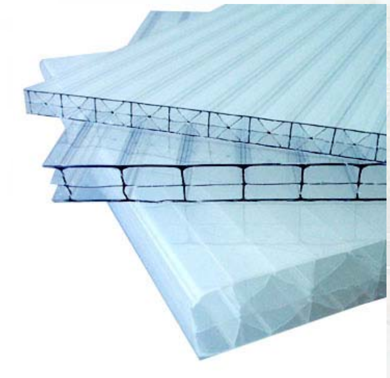
Corrugated polycarbonate sheets

d. Double-wall polycarbonate rigid panels: 8 or 9mm depending on manufacturer.



Double-wall polycarbonate panels

e. 8 or 9mm triple wall polycarbonate rigid panels. There are a few different types of these depending on material thickness and coatings.



Triple-Wall polycarbonate panels

f. Top-of-the-line is glass roof, double or even triple glazed. (You can also get single or double glass side walls, with polycarbonate rigid panels for the roof. Some manufacturer's only have glass systems for the walls and not for roofs.)

Double and triple glazing

g. The polycarbonate and glass systems offer coatings which help control UV degradation, infrared radiation absorbency, and anti-condensation drip surfaces and coatings.

2. Wall Materials: same materials as for roofs above. Walls may be of different material than roof, depending on type of structure. A typical and very common approach for many growers is the inflated double wall polyethylene flexible sheets for both roof and wall. End walls of some commercial units are metal siding, which is more durable against abuse and wear of operations and traffic in and out of the structure.

   a. The wall-to-ground perimeter can be sealed off with various types of plastic or edging materials anchored to the soil and against the wall material, but allowing for some movement. These help in deterring rodents and varmints, but are not a permanent and for sure solution. Dogs, cats, raccoons, foxes, and other larger critters can claw holes in plastic sheeting also which will tear and cause damage that will need repaired.

3. Heat Gain and Heat Loss: none of the materials above offer any significant reduction in heat gain or heat loss. Even triple glazed glass panels will only offer U values in the .2 or .3 range. Thus, for year round growing, winter heating becomes a major operational cost, if not the highest cost. Double or triple layer inflated polyethylene flexible sheet systems provide the most insulation value, but also reduce light transmittance, and reduce heat loss in summer. Most greenhouse web sites do not give any specs for these materials; Rimol's website does provided light-transmittance numbers in the "greenhouse covering" section that were used for reference in this report: www.rimolgreenhouses.com.

   a. One of the more common forms of insulation is the "energy-blanket", which is an insulated blanket deployed below the roof surface or roof framing, and can be rolled up on rollers along the sides of each bay. They can be manual, or powered, and can be controlled by automatic timers or programs. They are effective, yet add considerable cost to cover a large area greenhouse.

"Energy" blanket - fabric cloth with woven aluminum foil

4. Structure: Of the types of structures described above in 8.2, all are framed with aluminum or steel tubes, and have thin tube or pipe columns about 10' to 12' on center. Each column requires a concrete pier or footing, usually a 12" concrete "sonotube" to frost depth. The structure does not require a frost wall around the perimeter, as the perimeter walls span from column to column and are not affected by frost heaving of the soil.

5. Floors: most common is earth or gravel. Less common is concrete slabs, as they are considerably more expensive.

   a. Firm rolled earth is functional, and can be treated to limit weed and grass growth, but is also a constant maintenance item, and depending on type of soil, can be muddy and/or dusty. Mowing grass in a greenhouse is not an option.

   b. Gravel: the preferred floor. Usually about 4" deep of ¾ crushed stone, and can be placed over weed barrier.

   c. A center service aisle for vehicles is common in large greenhouses. Such an aisle may require 6" to 8" of gravel depending on type of soils, or may also be an asphalt or concrete surface.

6. Crop Partitions: usually constructed and supported from the pipes or roof structure. These are used to separate different crop types and prevent certain disease from spreading from one to another, and can also allow some differing climate and humidity conditions.

Suspended crop partition in rolled up position

7. Crop Production Systems: hydroponic (soil-less, grown in water with nutrients); benches, pots, tables. The most common is pots on trays or tables, or benches. Benches are available in a variety of shapes and sizes and materials; some with wheels. The crop type, growing media, and greenhouse dimensions all factor in to the bench layout to achieve maximum utilization of space, and maximum efficiency for labor production. These systems can be seen at many of the greenhouse manufacturer's websites and catalogs.

Hydroponic tomatoes

Variety of hydroponic vegetables

IMPORTANT NOTE: Hydroponic systems are not permitted for purely "organic" crops per USDA rules and Organic certifications, as this system requires water soluble chemicals which do not meet the pure definition of "organic".

8. HVAC SYSTEMS:

General considerations: Ventilation may be by either natural or mechanical means, although natural ventilation may not be as dependable or provide satisfactory uniform and continuous ventilation. Cooling, if required, is typically provided by evaporative cooling means utilizing a mechanical ventilation system, therefore a mechanical ventilation system is proposed for the Sustainable Food Project. As mechanical ventilation and evaporative cooling systems are inextricably linked, these systems will be discussed together. The required ventilation rate varies depending on whether heating or cooling is required. In the winter, a minimum of two air changes per hour is recommended, while summer ventilation at a rate of one air change per minute is recommended. Ventilation is typically provided by exhaust fans on one side of the greenhouse and intake openings on the opposite side. Cooling is provided by evaporating water into the incoming airstream though an evaporative cooling pad placed at the ventilation intake opening. In order to minimize the temperature difference between the air entrance and exit, the fans and air intakes should be located so that airflow is across the short dimension of the greenhouse.

In addition to providing the minimum rate of ventilation, air movement is another important factor to be considered. Continuous air movement of at least 40 feet per minute is recommended to achieve uniform air circulation, and to even out temperature, carbon dioxide and humidity levels throughout the greenhouse. If the greenhouse is of sufficient size that uniform air movement cannot be provided by the ventilation system, horizontal airflow fans are frequently installed to ensure air mixing. Approximately 3 cfm per square foot of growing area is recommended.

Maintaining a warm environment is essential when growing certain types of plants, and heating can be accomplished by many methods. Peak energy use for heating can be as high as 200 Btu per hour per square foot depending on the construction materials and ventilation rates used. The most common method is through the use of unit heaters consisting of a fan for circulating air over a heat-exchange surface. Unit heaters typically are either floor mounted or hung above the floor and utilize natural gas or propane as a fuel source, although hot water unit heaters are also available. Hot water heating systems normally require a boiler utilizing either natural gas or propane; however at the NHLREC hot water can be produced from the generator waste heat recovery systems without the need for an additional fuel source. Another method of heating can utilize hot water piped under the floor or under benches. An underfloor heating system provides more uniform temperatures, but at a higher installed cost than unit heaters. In addition, a heater should be installed directly adjacent to the air inlet location to temper the incoming cold air up to room temperature regardless of which system is installed. This will prevent a cold spot from forming near the air inlets to the building.

a. Heating: most manufacturers offer gas or electric unit-heaters, hung from the structure; in this particular project (and study) heat and/or power will be provided from the Landfill methane generators. An important consideration is the type of heat distribution system. The most desirable is floor heat that rises thru the crop benches. Even distribution is important to ensure uniform growing.

b. Cooling and Ventilation: most manufacturers offer a variety of thru-wall fans. Also available are "Kool-Cells" (or Cool-Air vents) which move large quantities of air and can provide a water mist or fog system to cool incoming air. Mist or fog systems can also be installed throughout the greenhouse from the roof structure.

c. Natural Venting: in addition to wall louvers and wall vents, roof systems are available which allow a portion of the ridge to open mechanically (or by motor operation, even automatic via timers or a computer program.)

d. The length of the greenhouse can limit the effect of end wall ventilation and coolers, implying the need for roof ventilation in longer structures.

9. <u>Water and Irrigation systems</u>: drip systems are common, using PVC piping run in the overhead structure usually, with drops into the pots, trays or tables, or whatever growing system may be used. General use hydrants (fed by a well system, domestic, or other pressurized system) should be located for hoses, clean up, maintenance, and convenience throughout the structure. Provisions for freeze protection, and/or for drain-down or winterizing should be included. An underground supply system is preferred, but is more expensive.

10. <u>Roof guttering</u>: for ganged or multiple bay systems, either bowed or gabled, internal gutters are located between the bays. For greenhouses longer than about 40' to 50', internal downspouts are required. Gutters are 6" or 8", and one downspout per roughly 500 sq. ft. of roof area, or about every 25' to 35' of gutter. The downspouts are connected to underground pipes, or overhead pipes, sloping out of the building to daylight or connecting to other collection systems. The internal gutter systems are functional but not always water tight as for a commercial building, and often leak, but which is of minor consequence.

11. Rainwater Collection: from the internal guttering system described above, various collection systems for rainwater are possible, so as to supplement the irrigation system. These can be engineered with large holding tanks and sophisticated controls and valves, above or below ground, or can be simple lower cost systems fashioned from common parts. The larger the storage system, the more efficient the system will be. More sophisticated systems add considerable costs. Low budget systems can be fashioned from tanks or barrels mounted on the ground or on stands to allow gravity flow irrigation. The water feed system from domestic water piping or a well can also feed to the barrels/tanks with simple float systems to maintain a minimum level, whether by rain or water piping. A bypass or overflow drain system is necessary when rain fall exceeds the storage capacity.

12. Lighting: basic and simple. Depending on the growing season and operations, only minimal lighting is needed for security or nighttime maintenance and caretaking. Many greenhouses have no lighting, depending only on portable units or caretaker lamps (flashlights). If planting and harvesting operations are expected to be done after dark, then a more extensive system may be required, but obviously adds costs, and should be weighed against the production benefits and gains.

13. Electric Outlets: minimal power outlets are needed, and only for maintenance operations. In a larger multi-bay system with center aisle, one outlet every 30' to 40' should be sufficient along the aisle, and perhaps along each end wall. These should all be weather proof type boxes on GFI circuits or panels.

8.4 COSTS OF GREENHOUSE SYSTEM

1. Greenhouse systems are typically sold as a commodity or an off-the-shelf-product, similar to pre-engineered metal buildings. Comparatively, a commercial custom building normally requires a contractor and a complex detailed bid-proposal of all the various materials and labor to erect, fabricate, and install. Some greenhouse manufacturers provide pricing for their systems on line, but do not include labor and other components that the developer must provide. There are also a wide range of options, equipment, and other variables with a wide range of potential costs. Providing an estimate for a completed greenhouse structure can be tricky, because this type of structure is much less common than other building types, and trade contractors are less familiar with the costs. The irony of the pricing process for an architect is that, while common commercial buildings are much more complex than a greenhouse, with hundreds of parts, systems, and

assemblages, it is much easier to obtain historical data and predictable cost ranges for a cost per square foot average of completed structures. Yet comparatively little data exists for completed greenhouses. The information below is compiled from various sources, and is believed to be reasonably accurate, in terms of providing general information as to probable costs of various types, systems, and equipment. When this project moves forward with an actual developer, the developer or their contractor must prepare estimates of actual costs of the specific systems they wish to construct. None of the "packages" below include delivery, installation, concrete, electrical work, flooring material, permits, and any site work. These costs are for preliminary planning through second quarter of 2011; actual costs may vary.

2. Quonset Hut: Bowed shape (below): as in Rimol "Catamount"; up to 15' wide. Basic package of 1440 sf (15' x 96'), double layer 6 mil polyethylene, per unit is about $2500 = $1.75/sf material only, (without any options or concrete, or floor material.) www.rimolgreenhouses.com

Exterior of Rimol "Catamount" Model

3. Quonset Hut: Bowed shape (below): Rimol "Northpoint"; up to 26' wide and 96' long. Basic package of 2500sf, double wall inflated polyethylene, per unit is about $6200 ($2.50/sf material only, without any options or concrete, or floor material.)

Exterior of Rimol "Northpoint" Model

4. Arched Roof, Gutter Connected (below): similar to Rough Brothers, "Poly-Arch". Standard bay widths are 20'-6", 36', and 41' wide. 6 mil double polyethylene inflated fill, some doors. Basic package that is 6 bays wide (123') and 96'' long (multiples of 12' spaces) – 11,808 sf, 10' high side walls = $35,500 ($3.00 per square foot material only, not including delivery. Can upgrade to truss system, polycarbonate panel roofs and roof vents. www.roughbros.com/products/poly.html


Exterior of Rough Bros. "Poly Arch" Model


Interior of Rough Bros. "Poly Arch" Model

5. Gabled Roof, Gutter Connected (see photo below): similar to Rimol "Matterhorn": 30'bays: 120' wide (4 bays) by 96' long, basic manufacturer's package = 11,520 sf; double wall inflated polyethylene roof; side walls are 10' high double wall polycarbonate rigid panels; includes some doors, gas heaters, and exhaust fans. $142,000 material only, not including delivery; about $12.30/sf, material only. Can upgrade to polycarbonate rigid panel roofs, vented roof, etc.


Exterior of Rimol "Matterhorn" model


Interior of Rimol "Matterhorn" model

8.5 “HEADHOUSE” CONSIDERATIONS

1. The “Headhouse” or “Production House” is typically an independent structure, usually attached to one side of a greenhouse “range”. Depending on the type of operation, it houses offices, toilets, work areas, storage areas, etc. for the workers and staff.

2. The Headhouse is constructed of usual commercial building materials, and is commonly a pre-engineered metal building due to low initial cost.

Images of various Headhouses

3. The program (or list of needed spaces) for a Headhouse must be developed by the grower/developer as to the specific type of operation and number of workers, etc. The probable or assumed program for this project is as follows:

   a. Manager's Office: assume 1 general manager, approx. 200 sf office.

   b. Business Office: space for 2-3 clerical/secretarial staff, and space can double as a reception and waiting area for visitors.

   c. Locker Room/Break Room: space for lockers, time clock, lunch room for workers. Large enough for 10 to 20; with sink, refrigerator(s), vending machines, etc.

   d. Toilets: minimum number of fixtures as required by code, at least one single occupant toilet room per sex, and double occupancy preferred for 20 or more workers. A shower space in each toilet is convenient, but not absolutely necessary. It may be convenient to provide a separate set of toilets, or at least one unisex toilet for visitors near the front of the building.

   e. Storage spaces: for production equipment, supplies, tools, etc. Lockable storage as may be required by the grower.

   f. Packing and Processing Space: a room or area large enough for handling of the crop produce, packing, preparing, and loading. In some cases most of this type of work can be done in the greenhouse, depending on time of year. This space may or may not need to store one or more vehicles inside, but likely has one or more overhead doors to allow convenient handling and loading of crop materials. This space may also double as storage for production equipment, and as repair and maintenance shop for the operation.

Packing and processing area

4. Probable Costs: A building of this type, in the 4,000 to 5,000 square foot range, of modest or basic quality level and finishes, could be in the range of $50 to $90 per sq. ft. (Not including site work, utility services, or special construction types, etc.) Actual costs may vary. See the hypothetical project budget, located in the Appendix at back of this study.

8.6 LIFE EXPECTANCY

8.6.1 Polyethylene

Polyethylene is flexible sheeting that typically lasts around 2 to 4 years.

8.6.2 Polycarbonate

Polycarbonate consists of rigid panels that could last up to 10 years. Most growers find it less expensive to replace polyethylene flexible sheeting every 2-4 years than initial cost of polycarbonate rigid panels and additional steel structure.

8.7 CASE STUDIES

8.7.1 Buckley Growers, Taylorville, Illinois

1. A large commercial, year round operation near Springfield, IL, producing a wide variety of flowers products for distribution nationally and internationally. This grower has recently declared bankruptcy due to declining markets.
2. 163,000 s.f. under roof or about 3.75 acres.
3. Total of 18 houses or bays, each 42' x 216'.
4. 8 of the "houses" are double polyethylene flexible sheet roof, arched top, with rigid polycarbonate panel walls. Each house consists of a double arched bay. (This description of "houses" is per the greenhouse owner, but most growers and manufacturers would seem to define this as a total of 16 bays or modules.)
5. 10 of the "houses" are gable shaped glass roof system, with rigid polycarbonate panels for walls. There are four gables per "house"
6. All of the houses have operable roofs that open for venting; the entire roof panel is hinged (as compared to a ridge vent which is only a partial roof opening.)
7. No other ventilation is provided.

8. The two types of houses was a conscious decision based on type of light transmittance, and humidity control for different types of flowers.
9. An access aisle is located along one end of the houses.
10. A Headhouse of about 20,000 square feet and is located near one end of the access aisle.
11. The arched top houses have concrete slab.
12. The gabled houses have gravel flooring, including the main access aisle.
13. Heating is hot water radiant tube beneath the slab and the gravel floors.
14. Hot water is provided from excess heat from a landfill methane generation plant.
15. The Headhouse has three loading docks. Two or three semi-trucks would access the building each day.
16. Original budget for entire installation was about $3.5M. Actual costs were about $5M after several unanticipated situations involving heat piping and other issues.
17. These costs are assumed to be total costs including all expenses, and may not reflect actual raw construction-only costs.
18. At $5M, for 163,000sf plus a 20,000sf Headhouse, the overall cost per total sq. foot is about $27/sf, which seems very low based on other research. This greenhouse facility would be considered a top-of-the-line structure.
19. The costs included a fully automated conveyor system, watering system, computer controlled climate and roof vent system, glass roof, under floor heating, and concrete slab for 8 of the “houses”.

8.7.2 Perfect Circle Growers, Lake Mills, Iowa

1. Fairly large commercial operation. Primary crop is tomatoes.
2. 16 bays, each 36’ x 126’; manufacturer is PolyTech.
3. Total of 46,000sf; with a 5,000sf Headhouse
4. Headhouse is basic metal building. Cost about $150,000 in 2009. ($30/sf)
5. Greenhouse is a “dutch” type roof (which is a gable with curved ridge)
6. Greenhouse is divided into four zones which allows for rotation of crops during the growing process.
7. Computer controlled climate system for fans and vents.
8. Total initial cost was around $4M including operating costs.
9. Greenhouse structure was about $1M to $1.2M ($26/sf)
10. Expandable up to 340,000sf if necessary.
11. Ventilation is via end wall fans, and roof vents.

9.0 GREENHOUSE RECOMMENDATIONS AND CONCEPT DESIGN

9.1 CONCEPTUAL SITE LAYOUT

9.1.1 Site Topography

The site consists of approximately 40 acres of open pasture with gently sloping relief located approximately 9 miles north of Springfield on Farm Road 34, just south of the Springfield landfill. Overall, there is approximately 15 feet of relief across the site extending from low areas at the northeast corner of the property to a ridgeline that extends generally from the north west part of the site toward the south east, with a gentle slope to the southwest corner of the property. Approximately one-half of the site drains to the west, with the remainder draining north and east. Because of the gentle slopes, drainage is slow, and the site tends to stay moist after rainfalls for an extended period of time and the soil becomes soft when saturated.

The site consists of pasture grasses (primarily fescue and brome) with some native grasses (little bluestem, grama grass). It is situated on relatively shallow, silty clay soils that are poorly drained. There are no known existing wetlands on the property.

9.1.2 Site Infrastructure

There are no existing structures or utilities present on the site, with the exception of overhead electric and telephone. The existing overhead electric occurs close to the road right-of-way along the south and sets within the property along the west. There are no existing drives and road improvements on the site, future improvements will need to be made to provide necessary utilities.

9.1.3 Site Access

The site is bordered on along the west and south property lines by Farm Road 34, which connects to State Highway Route 13. There is an existing access to State Highway Route 13 with a median crossing that provides full access to travel from the north and south bound lanes. The existing section of Farm Road 34 is fairly narrow with 8'-9' lane widths and no shoulder. In fall of 2010, the road had an asphalt overlay applied. There are drainage swales along the road shoulder that stores stormwater or carries it out as the terrain allows. At the southwest property corner, Farm Road 34 makes a 90 degree turn which makes travel by larger vehicles difficult and sometimes impassable due to oncoming traffic.

The site access is limited to just existing farm drive access points that are not paved and are narrow. These drives are not in the general vicinity of where future drives will need to occur.

9.2 GREENHOUSE LOCATION AND ORIENTATION

9.2.1 Location

Location of the greenhouse will be dictated by proximity to the heat generation plant, roadway access, and to minimize slope of the land across the width and length of the structure. For greenhouse operations, a flat site is most desirable, to minimize level changes, and earthwork, etc., but some amount of slope is desired for positive drainage away from the structure. This site offers a good balance of all these parameters.

9.2.2 Orientation

(See proposed site plan as appendix at back of this study.)

As noted in a report titled *Greenhouse Structures* by Dr. Gene A Giacomelli of the University of Arizona. See entire report at the following link:
https://ag.arizona.edu/ceac/sites/ag.arizona.edu.ceac/files/Greenhouse%20Structures.pdf

> *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 degrees 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.*

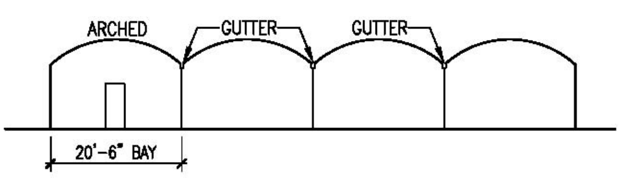
9.3 GREENHOUSE DESIGN

9.3.1 Greenhouse Description

1. Planning Models: This section defines the most probable systems and applications of the preceding information and analysis in this study. In order to establish the feasibility of a production greenhouse operated by reclaimed energy from a landfill, certain assumptions are made, in order to establish a Model for probable development costs, and operating costs, in order to complete the analysis as to whether a project of this type is financially viable. These assumptions/recommendations are based on the most common systems found among growers, and as recommended by manufacturers' representatives, and as recommended by various university extension services, and based on case studies. Other choices and options may be equally valid, and an actual developer/grower may make different decisions.

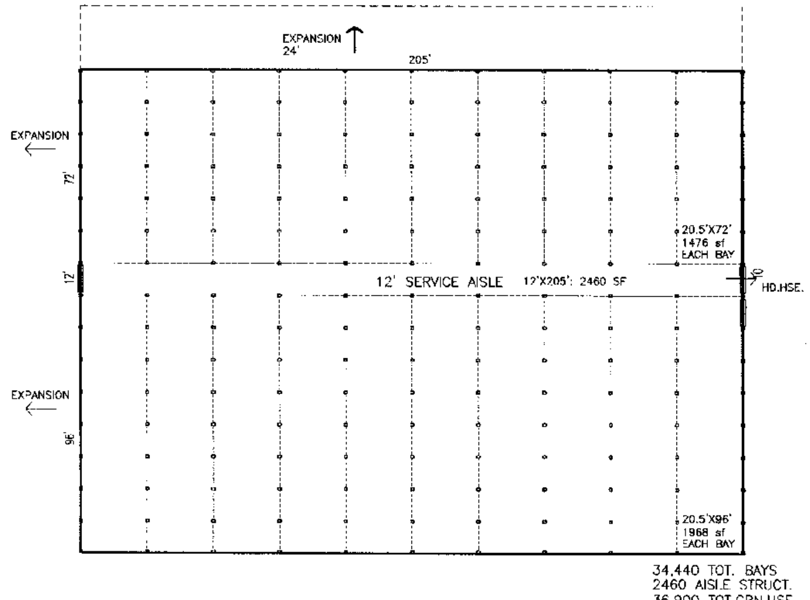
2. Two Models: Our study will explore two of the most feasible and commonly used systems. Both Models are based on gutter connected systems, due to functional need for large area under-roof, and taller wall and ceiling heights, for efficiency of production. Model 1 is somewhat more economical in terms of materials and options. Model 2 is somewhat of an upgrade, yet may be considered a minimum approach by some growers. Both are based on same square footage of greenhouse for comparison, but Model 2 includes costs for upgrading to a larger footprint also. The Headhouse is smaller in Model 1, without a classroom, and a more streamlined operation.

3. MODEL 1: ARCHED ROOF – GUTTER CONNECTED:



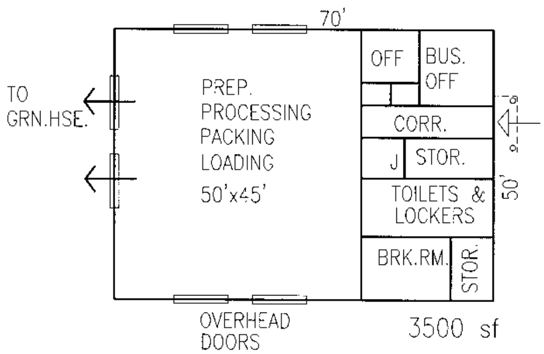
Arched Roof – Gutter Connected

   a. 35,000 s.f. Greenhouse. 20.5' wide bays, 10 bays; total width 205' wide; one range of 96', and one range of 72', or any combination of 12' modules for total length of about 170' ; each range separated by a 12' to 16' w.



GREEN HOUSE STRUCTURE: MODEL 1

b. *<u>Headhouse</u> of about* 3000 to 3500 sq. ft. See Floor Plans. Headhouse is a pre-engineered metal building, OR a woodframe-woodtruss structure; whichever is more economical at time of actual development.



HEAD HOUSE: MODEL 1

c. <u>Roof and Walls of Greenhouse Structure</u>: Double layer polyethylene flexible sheeting, inflated, for roof and walls. With anti-condensate coating.

d. <u>Insulation</u>: none included.

e. <u>Guttering</u>: heavy gauge gutters between each bay with downspouts at end of each bay, draining to surface splash blocks. No internal downspouts.

f. Floors: Dirt floors, with weed barrier covering under the crop benches.

g. Aisles: Main center aisle is gravel, and connects to Headhouse. Gravel aisles down center of each bay between growing benches/pans.

h. Mechanical Ventilation: fans with fog mist, each end of each bay. Suspended intermediate fans at about 24' on center down the length of each bay.

i. Natural Ventilation: not included; except ability to roll up side wall polyethylene flexible sheeting.

j. Lighting: Minimum utility lighting.

k. Plumbing: Water supply piping system from on-site well.

l. Rainwater Collection: not included in Model 1.

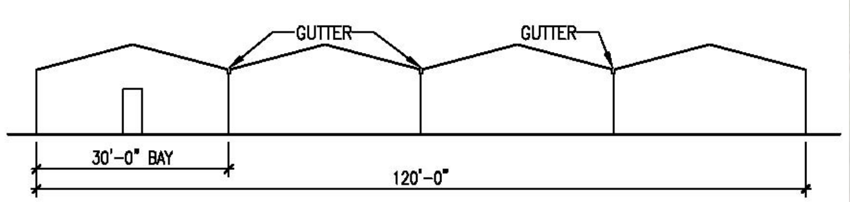
m. Growing Media: Hydroponic growing media with nutrient tank(s) and irrigation system.

n. Equipment: Benches and/or hydroponic pans or trays.

o. HVAC Heating system: Underfloor, hot water radiant heating system with unit heater next to ventilation air inlet location.

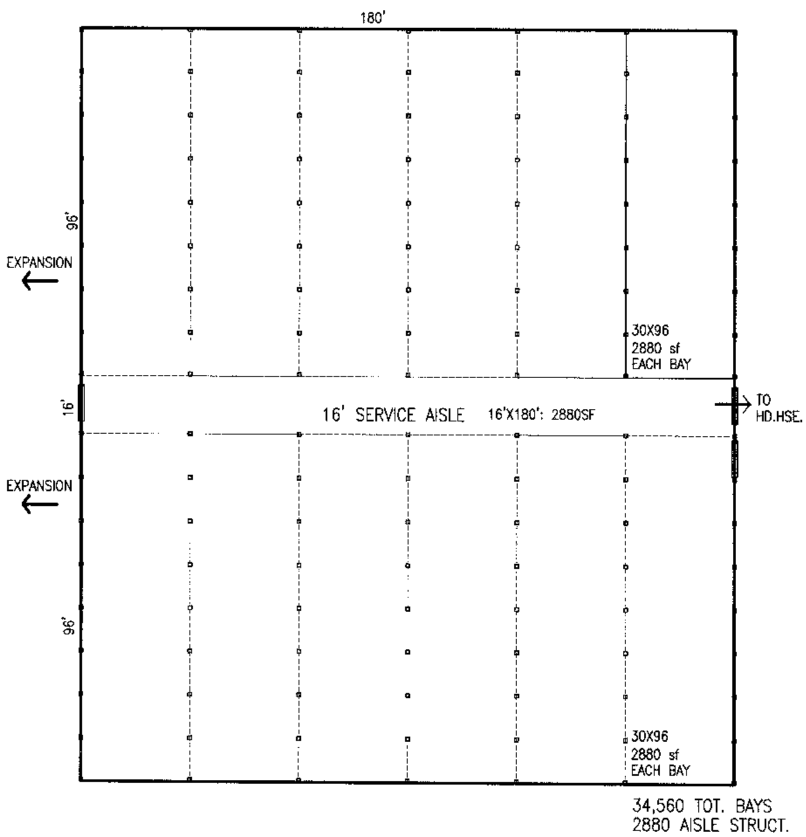
p. Backup Heating System: Propane heaters.

4. MODEL 2: GABLED ROOF- GUTTER CONNECTED



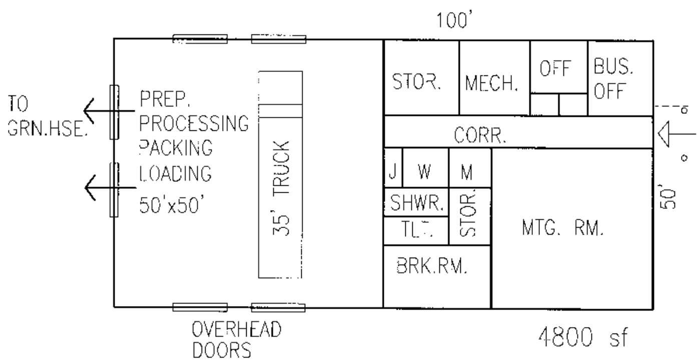
Gabled Roof – Gutter Connected

a. 35,000 s.f. Greenhouse. 30' wide bays, 6 bays; total width 180' wide; two ranges of 96'each, for total length of about 192'; each range separated by a 12' to 16' wide aisle structure. See Plans.



GREEN HOUSE STRUCTURE: MODEL 2

b. Headhouse: about 4500 to 5000 sq. ft. See Floor Plans. Headhouse is a pre-engineered metal building, OR a woodframe-woodtruss structure; whichever is more economical at time of actual development.



HEAD HOUSE: MODEL 2

c. Roof and Walls of Greenhouse Structure: 8-9mm double wall rigid polycarbonate panels, clear; structural system includes heavier members and additional purlins to support the rigid wall panels.

d. Guttering: heavy gauge gutters, with downspouts each end, and interior drains at mid-points of each bay length, piped to end walls and combine with exterior downspouts connecting to underground drain piping, conveyed to detention basin.

e. Floors: Gravel floors, with weed barrier covering under the crop benches.

f. Aisles: Main center aisle is gravel, and connects to Headhouse. Gravel aisles down center of each bay between growing benches/pans.

g. Mechanical Ventilation: fans with fog mist, each end of each bay. Suspended intermediate fans at about 24' on center down the length of each bay.

h. Natural Ventilation: operable roof vents.

i. Thermal insulation (energy blankets): roll out blankets full length of each bay.

Polycarbonate panel walls and energy blankets

j. Lighting: upgraded type and quantity of lighting from Model 1.

k. Plumbing: Water supply piping system from onsite well.

l. Rainwater Collection: site fabricated tanks or barrels and simple controls.

m. Growing Media: Hydroponic growing media with nutrient tank(s) and irrigation system.

n. Equipment: Benches and/or hydroponic pans or trays.

o. HVAC Heating system: Underfloor, hot water radiant heating system with unit heater next to ventilation air inlet location.

p. Backup Heating System: Propane heaters.

9.3.2 Floor Plans

See attached 11X17 conceptual floor plans for Model 1 and 2 in the figure drawings

9.3.3 Elevations

See attached 11X17 conceptual elevation plans for Model 1 and 2 in the figure drawings

9.3.4 Greenhouse Mechanical, Electrical and Plumbing Requirements

The goal of greenhouse construction is to provide an optimum environment for crop production under varying ambient conditions while also providing a space in which to work efficiently. The mechanical, electrical, and plumbing systems aid in providing this optimum environment.

9.3.4.1 Mechanical Requirements

The primary concern for the greenhouse environment is the ability to control and maintain varying temperature and humidity during all stages of the plant growing season. Ventilation must be provided year round to control high temperatures, humidity, and gas concentrations. During different times of the year it may be necessary to provide only ventilation or ventilation in addition to either heating or cooling.

Ventilation may be by either natural or mechanical means although natural ventilation may not be as dependable or provide satisfactory uniform, continuous ventilation. Cooling, if required, is typically provided by evaporative cooling means utilizing a mechanical ventilation system, therefore a mechanical ventilation system is proposed for the Sustainable Food Project. As mechanical ventilation and evaporative cooling systems are inextricably linked, these systems will be discussed together. The required ventilation rate varies depending on whether heating or cooling is required. In the winter, a minimum of two air changes per hour is recommended, while summer ventilation at a rate of one air change per minute is recommended. Ventilation is typically provided by exhaust fans on one side of the greenhouse and intake openings on the opposite side. Cooling is provided by evaporating water into the incoming airstream though an evaporative cooling pad placed at the ventilation intake opening. In order to minimize the temperature difference between the air entrance and exit, the fans and air intakes should be located so that airflow is across the short dimension of the greenhouse.

In addition to providing the minimum rate of ventilation, air movement is another important factor to be considered. Continuous air movement of at least 40 feet per minute is recommended to achieve uniform air circulation, and to even out temperature, carbon dioxide and humidity levels throughout the greenhouse. If the greenhouse is of sufficient size that uniform air movement cannot be provided by the ventilation system, horizontal airflow fans are frequently installed to ensure air mixing. Approximately 3 cfm per square foot of growing area is recommended.

Maintaining a warm environment is essential when growing certain types of plants, and heating can be accomplished by many methods. Peak energy use for heating can be as high as 200 Btu per hour per square foot depending on the construction materials and ventilation rates used. The most common method is through the use of unit heaters consisting of a fan for circulating air over a heat-exchange surface. Unit heaters typically are either floor mounted or hung above the floor and utilize natural gas or propane as a fuel source although hot water unit heaters are also available. Hot water heating systems normally require a boiler utilizing either natural gas or propane; however at the NHLREC hot water can be produced from the generator waste heat recovery systems without the need for an additional fuel source. Another method of heating can utilize hot water piped under the floor or under benches. An underfloor heating system provides more uniform temperatures, but at a higher installed cost than unit heaters. A heater should be installed directly adjacent to the air inlet location to temper the incoming cold air up to room temperature regardless of which system is installed. This will prevent a cold spot from forming near the air inlets to the building.

9.3.4.2 Electrical Requirements

Electricity is used for ventilation, lighting and controls for ventilation, heating, and sprinkler systems. Lighting needs are typically minimal with lights only needed for short periods in the early morning or late afternoon depending on the time of year and the hours of operation of the greenhouse. Electrical energy use of approximately 1 W per square foot can be expected.

9.3.4.3 Plumbing Requirements

General use hydrants (fed by a well system, domestic, or other pressurized system) should be located for hoses, clean up, maintenance, and convenience throughout the structure. Provisions for freeze protection, and/or for drain-down or winterizing should be included. An underground supply system is preferred, but is more expensive.

9.3.4.4 Backup System Requirements

Unanticipated loss of power can have devastating effects on a greenhouse. Loss of ventilation, heating, cooling, or water if provided from a well can damage plant material. Successful operation of a greenhouse requires the constant availability of all of these; therefore standby systems should be provided to ensure that both heat and power are always available. In addition to a gasoline, propane, or diesel backup generator and transfer switch sized to power all critical equipment, a backup heating system consisting of propane or electric boilers should be provided.

9.3.5 Surrounding Grounds and Land Use

The focus of this feasibility study has been a sustainable greenhouse operation. The greenhouse, however, will be situated on approximately 40 acres of land, availing a substantial area that can be used for several purposes, including waste water treatment and recycling, solids waste management and composting, and in developing outdoor gardens that can be used for supplemental vegetable production that can provide additional revenue supporting the greenhouse operation. In addition, the surrounding grounds, in these uses, can provide educational opportunities for local residents to learn more about vegetable production and, potentially, urban gardening. The Site Concept Plan Figure illustrates a layout on how water treatment, composting and waste management, and outdoor gardens can be organized at the greenhouse site.

9.3.5.1 Water Treatment and Recycling

Recycling of water is very important in a truly sustainable crop production operation. Water collection from the greenhouse must include excess water used for irrigation, as well as gray water that is used during everyday operations for washing vegetables and cleaning the facilities.

The existing terrain of the site is such that minimal modifications to the land by grading would need to occur to create treatment wetlands and swales that can direct wastewater to specific areas, and facilitate pollutant (nutrients, detergents, possibly sediments) removal. Typically, treatment wetlands can be built in a series of ponds and swales that sequentially remove pollutants. Water can then be stored for re-use in irrigation of outdoor crops, possibly for irrigation within the greenhouse, and for sanitary applications for greenhouse facilities.

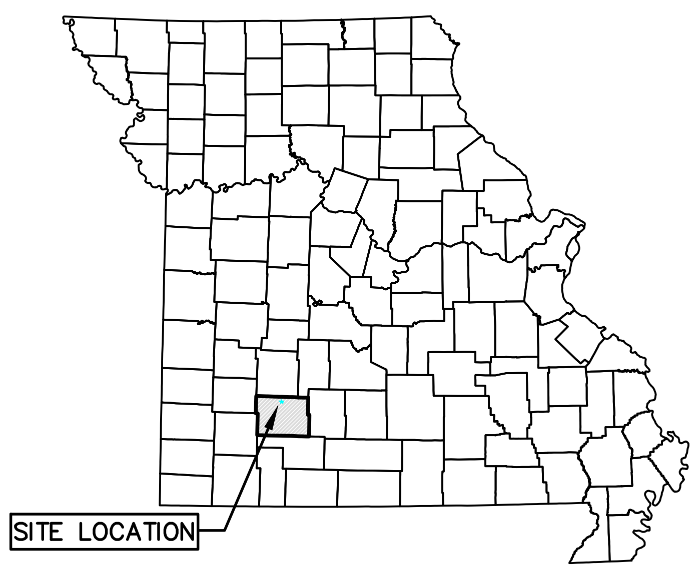
9.3.5.2 Waste Management

Most of the solid waste that will be generated at the greenhouse facility will consist of plant material, discarded vegetables, and other non-hazardous organic wastes such as paper, cardboard, and similar materials. Even though the greenhouse facility will be located adjacent to a landfill, it doesn't make sense to occupy landfill space with materials that can be composted and reused both within or around the greenhouse, and for distribution to local residents if sufficient quantities are generated. Composting can easily be implemented at the site, not requiring much space, probably less than one-half acre. It may be advantageous to construct a composting pad with runoff controls on the northeast portion of the site on "high" ground that won't impact or be impacted by rainwater runoff.

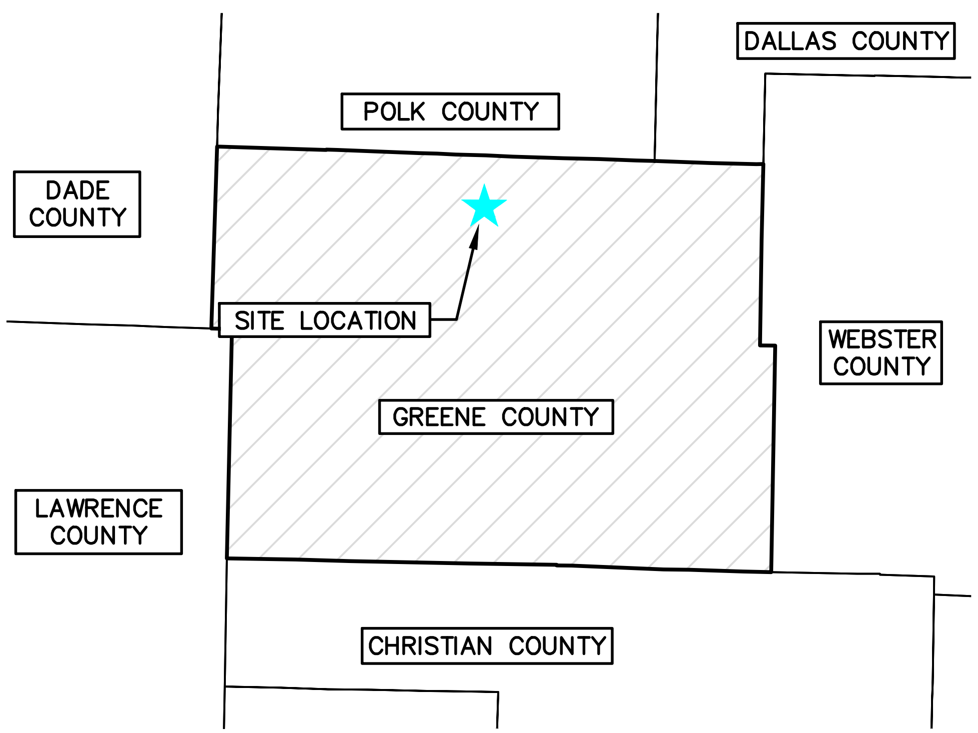
9.3.5.3 Outdoor Crop Production

With a substantial amount of land available for use, the surrounding grounds at the greenhouse facility can also be used for developing outdoor vegetable gardens for produce that can be sold on the market, or perhaps at an on-site farmer's market. The relief of the land makes it well suited for crop production. Gardens can be developed in several open areas that are or can be well drained, based on topographic relief. Compost and treated water produced on site can be used to support the gardens and enrich the vegetables grown outdoors. The gardens would be ideally located on the southern half of the property, and could occupy as much as 15 to 20 acres of the ground. This would also enable the greenhouse operation to hire additional seasonal employees to manage the vegetable gardens.

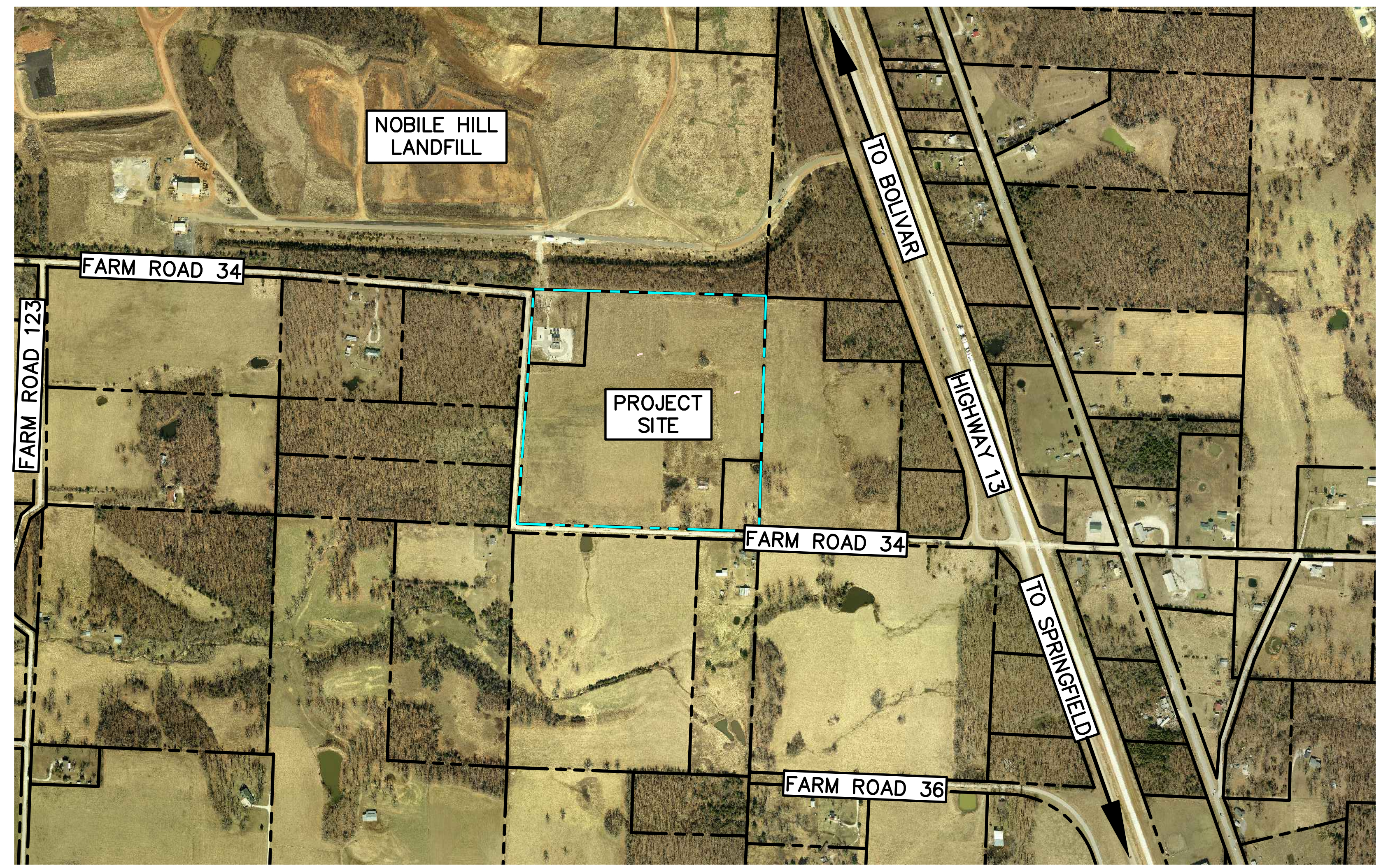
10.0 FIGURES



MISSOURI STATE MAP



GREENE COUNTY MAP



SITE MAP

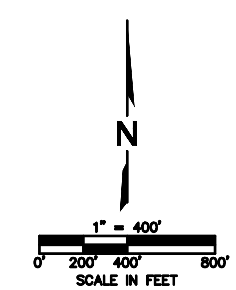
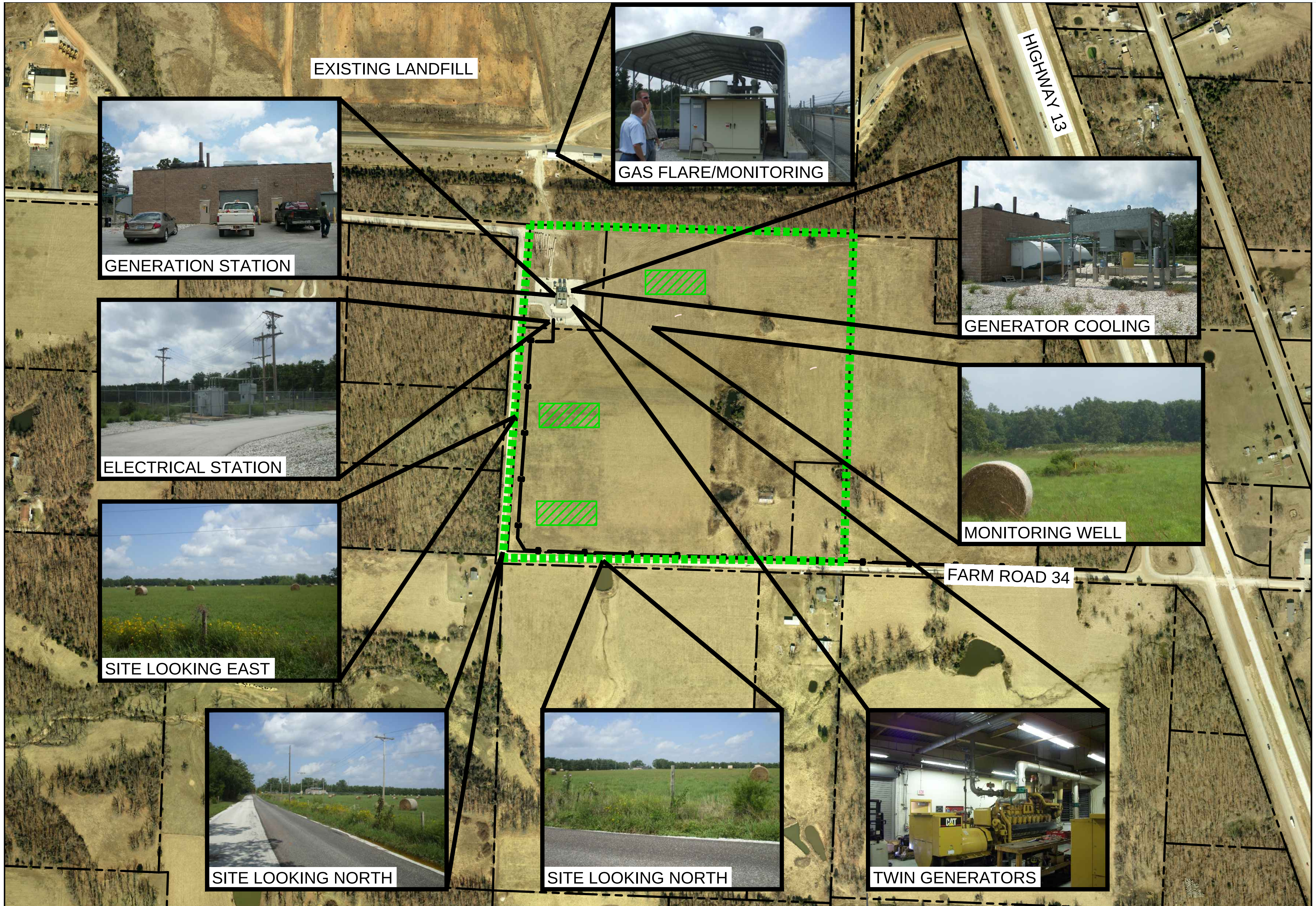


FIGURE 10.1 - SITE LOCATION MAP

FIGURE 10.2 - EXISTING SITE MAP



SITE LEGEND

- PROJECT SITE
- POTENTIAL GREENHOUSE LOCATION

SITE OPPORTUNITIES

- GREAT ACCESS
- OPEN SITE
- ELECTRIC AVAILABILITY
- RELIABILITY OF GENERATORS
- MULTIPLE PLACES ON SITE FOR GREENHOUSE LOCATION
- POWER AND HEAT CAPTURE AND MANAGEMENT
- REDUCE STRESS ON EXISTING SYSTEM
- CAPTURE AND UTILIZE SITE STORMWATER
- CAPTURE, TREAT AND REUSE WASTE WATER
- STORMWATER BMP'S
- REUSE WATER FOR CROP PRODUCTION AND IRRIGATION
- GREENHOUSE OPERATION FOR PLANT PRODUCTION AND JOB CREATION

SITE CONSTRAINTS

- NO EXISTING POTABLE WATER
- NO EXISTING SEWER TREATMENT
- NO PUBLIC FACILITIES
- FLAT SITE CAUSES POOR DRAINAGE
- MONITORING WELL LOCATION
- LIMITED SPACE IN GENERATION BUILDING FOR HEAT RECOVERY AND CONVEYANCE EQUIPMENT

FIGURE 10.3 - SITE OPPORTUNITIES AND CONSTRAINTS

N

1" = 200'
0' 100' 200' 400'
SCALE IN FEET

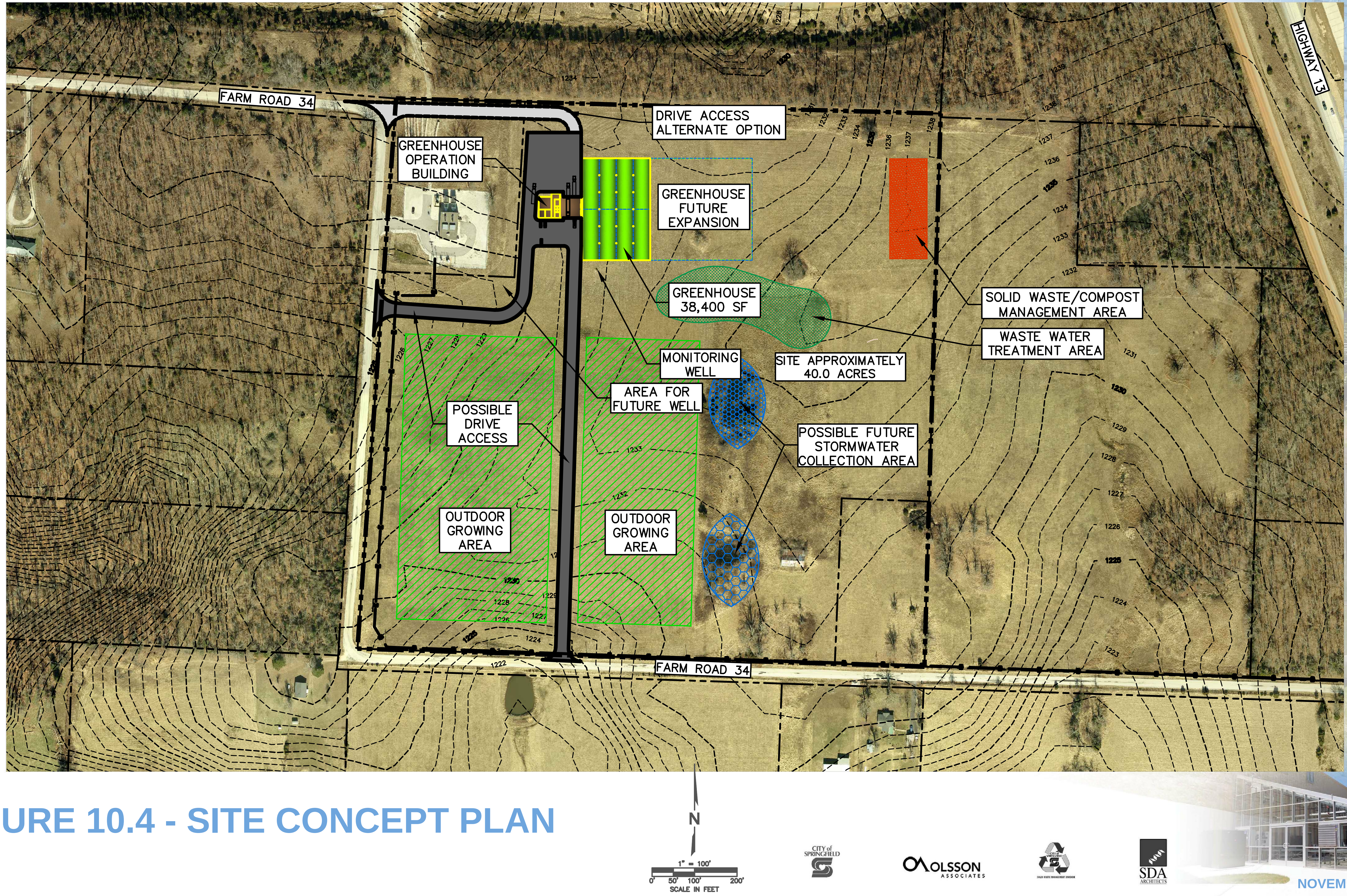


FIGURE 10.4 - SITE CONCEPT PLAN

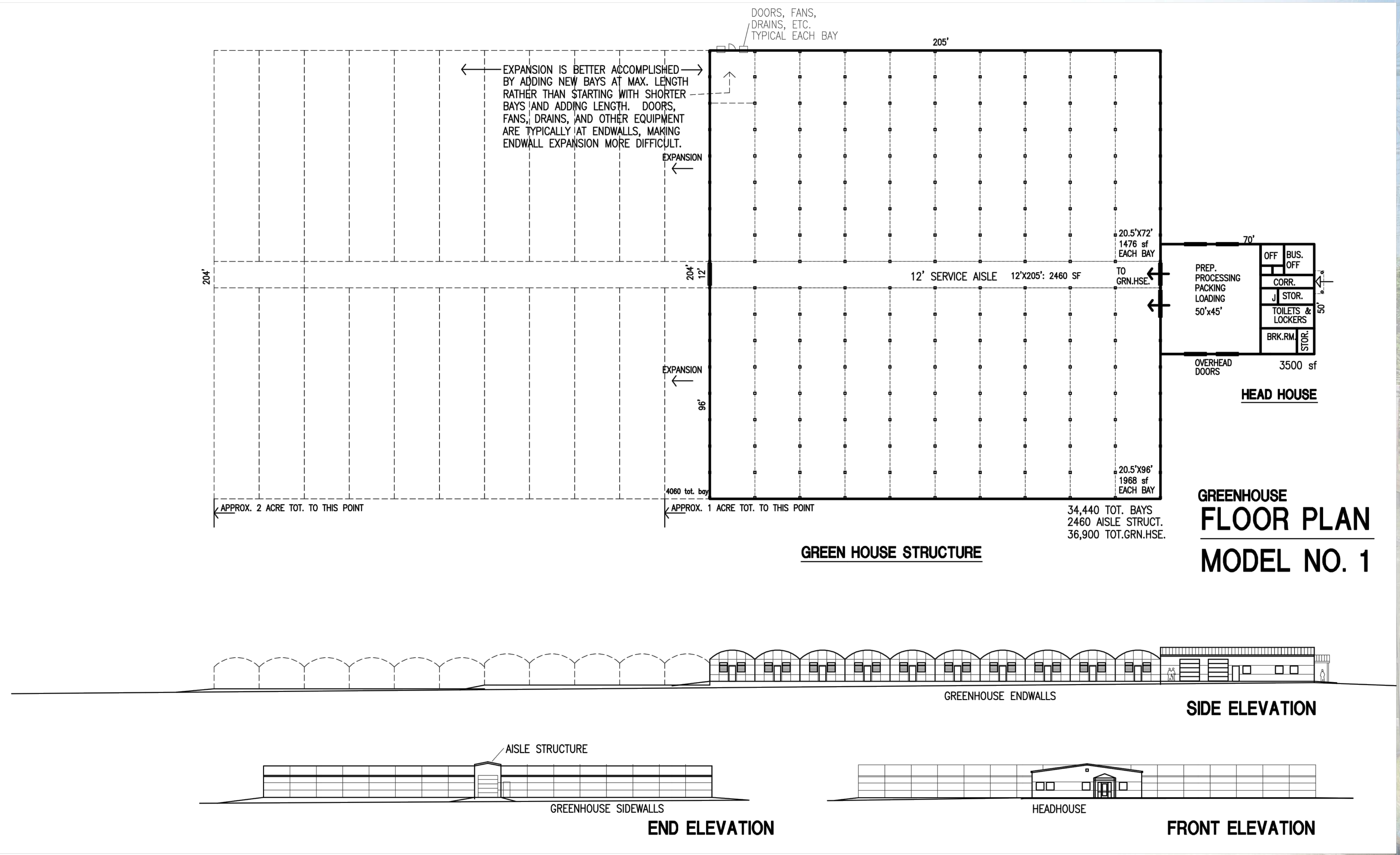


FIGURE 10.5 - GREENHOUSE MODEL 1

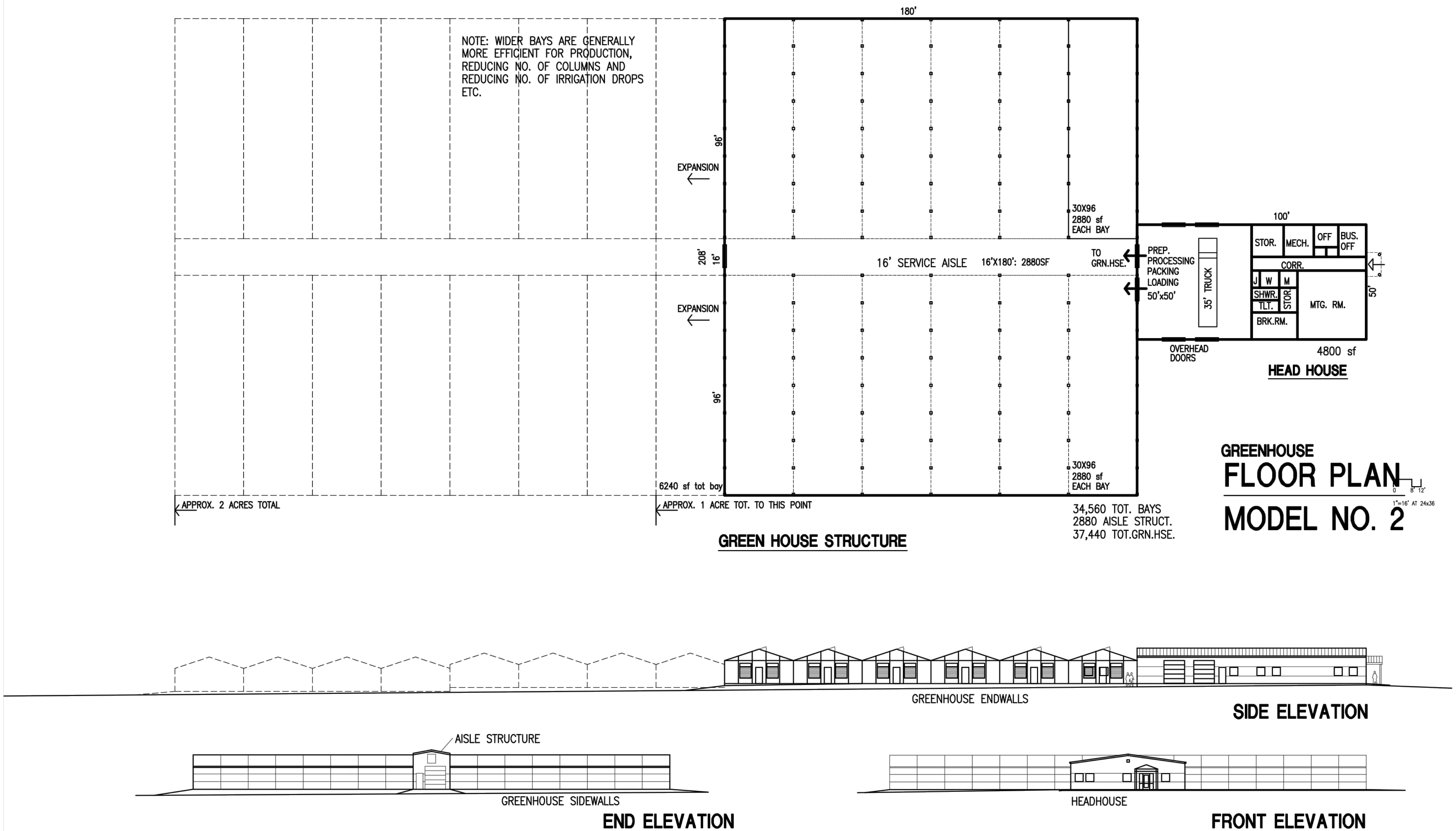


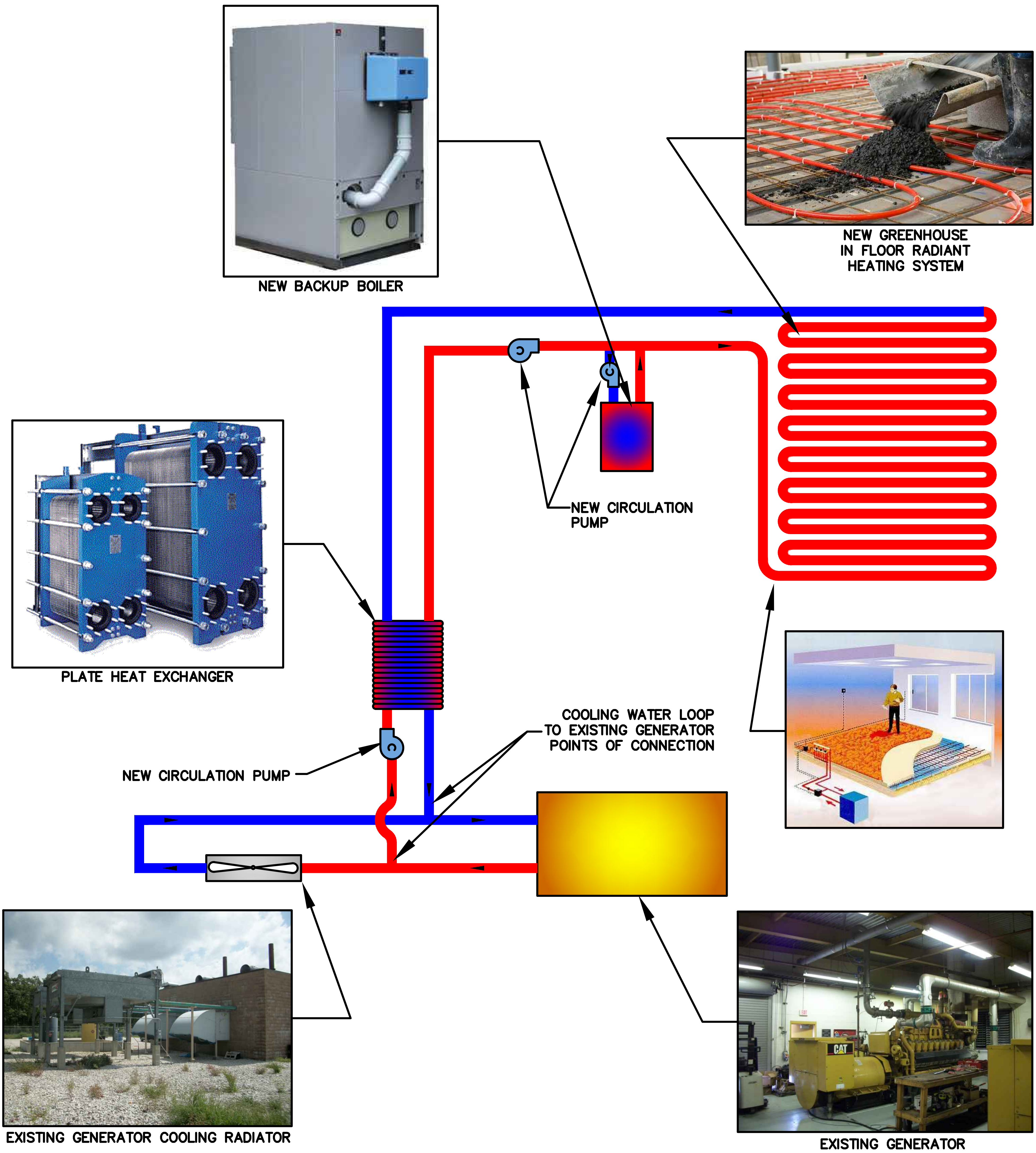
FIGURE 10.6 - GREENHOUSE MODEL 2

GREENHOUSE MODEL NO. 1

GREENHOUSE MODEL NO. 2

FIGURE 10.7 - GREENHOUSE PERSPECTIVES

WASTE HEAT RECLAIM SYSTEM



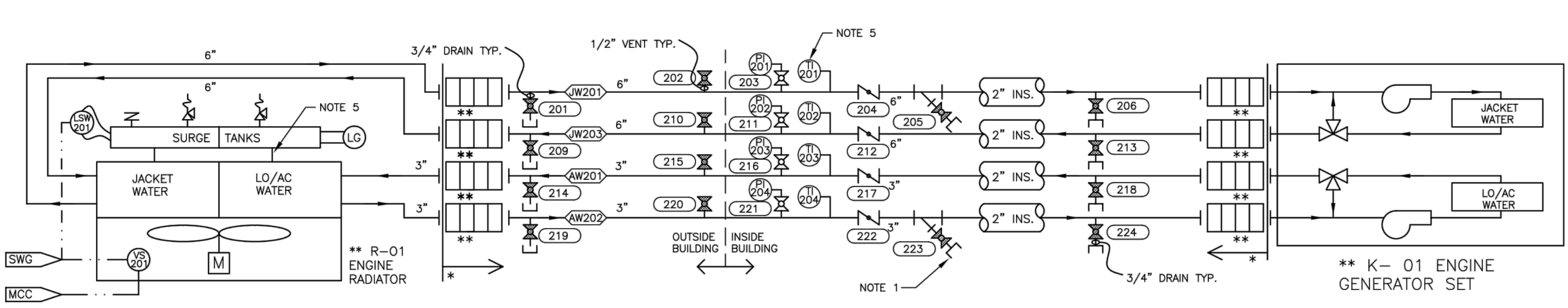
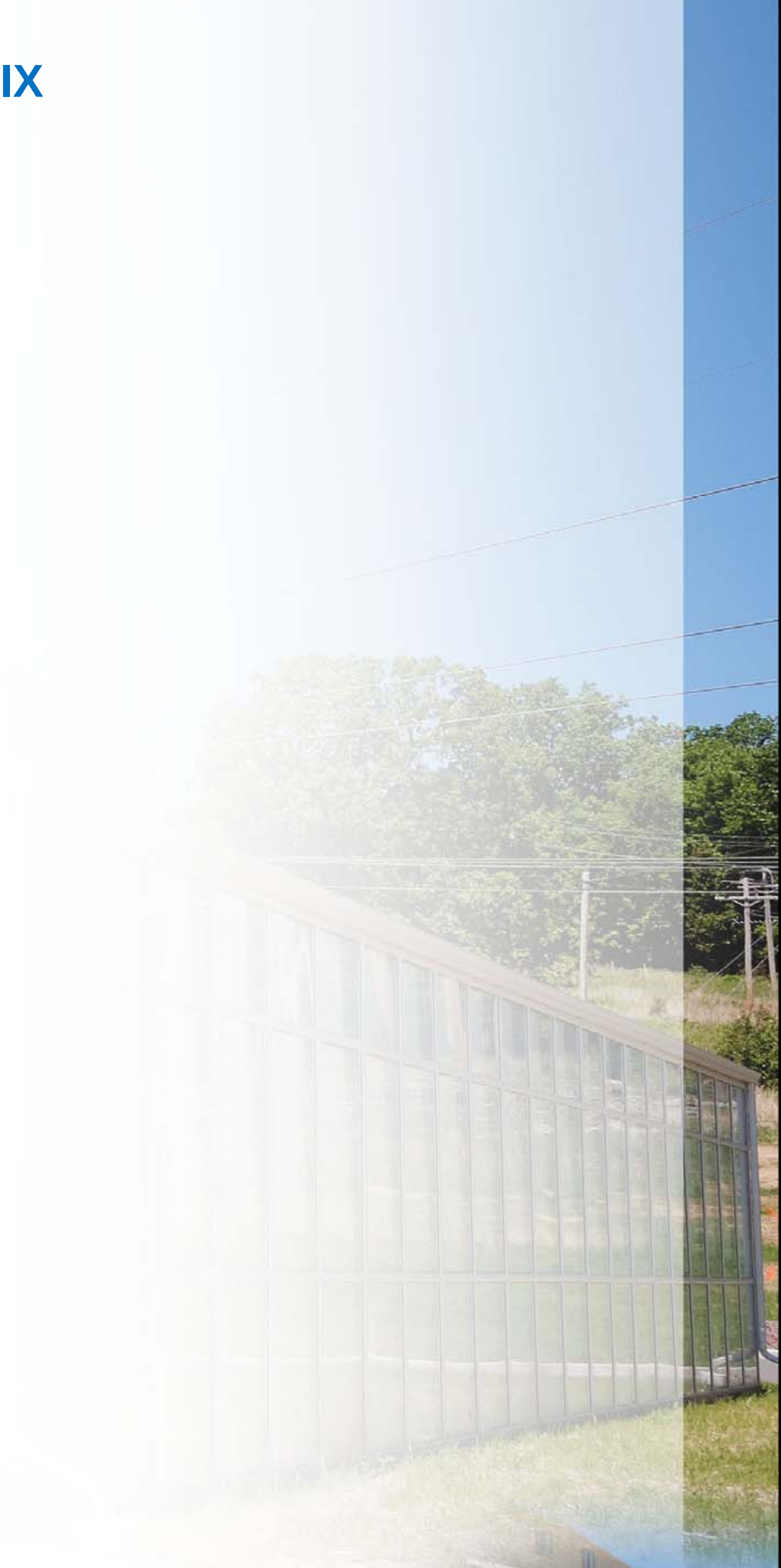


FIGURE 10.8 - WASTE HEAT RECLAMATION

11.0 APPENDIX



PRELIMINARY BUDGET TEST: MODEL 1

FEASIBILITY STUDY: RENEWABLE ENERGY & SUSTAINABLE FOOD PROJECT

GREENHOUSE STUDY

CITY OF SPRINGFIELD, MO.

OLSSON ASSOCIATES

SDA ARCHITECTS

11/18/2011

(The following values are allowances only; actual costs may vary. Assumed bidding by end of 2011)

Item	Size	Quantity		Unit	Unit cost	Basis		Amount
A. CONSTRUCTION CONTRACTS								
1. GREENHOUSE STRUCTURE: arched roof	205'x170'	35000		sf	$7	mfr. estimate	$	245,000
Poly roof/walls; building only delivered to site: 10 bays wide								
a. GREENHOUSE ERECTING:		35000			$7	mfr. estimate	$	245,000
b. Concrete Pier Foundations: 156 piers 30" deep		156			$200	each	$	31,200
c. Floor prep, and covering; dirt floor with gravel main aisles		35000			$2		$	70,000
d. Electrical, Lighting		35000			$2		$	70,000
e. Backup heating; propane unit heaters						allowance	$	30,000
f. Aisle structure, rigid polycarb panel roof, on alum frame.		3300	(205' x 16')		$20		$	66,000
g. Soil-based growing system (bench top)							$	128,000
i. Heating system: radiators, piping, etc….		35000			$3		$	105,000
						sub-total	**$**	**990,200**
2. SITE WORK:								
a. grading, drainage, paving, building pad						allowance	$	75,000
b. Utilities to site: well, electrical, etc.						allowance	$	75,000
c. Heat Exchanger system and Thermal piping from generator house.						allowance	$	300,000
					$13	sub-total	**$**	**450,000**
3. HEADHOUSE: PRODUCTION BUILDING		3500			$75	allow	**$**	**262,500**
Process Room, Storage, Office, Toilets, etc.								
PROBABLE TOTAL CONSTRUCTION CONTRACTS BUDGET							**$**	**1,702,700**
These values include a 5% markup for inflation and market conditions								
B. BID ALTERNATES:								
POSSIBLE BID ALTERNATES: TO BE DETERMINED								
Expanded parking lot								
Fencing								
Outdoor Growing and Working Areas								
Etc.								
TOTAL OF ALL ALTERNATES							**$**	**-**
TOTAL OF BASE BID AND ALL ALTERNATES:							**$**	**1,702,700**
FEES AND CONTINGENCIES FOR ALTERNATES: add 12% to each item selected to add to total project costs.								
Approx. Sub-total for Fees and Contingencies for ALL Alternates:				0.12		$ -		
C. CONTINGENCIES:								
1. BIDDING CONTINGENCY: 3-5% of Construction above				$0.04			$	68,108
(cushion for market conditions to allow for higher than expected bids)								
2. CONSTRUCTION CONTINGENCY: 3-5% of Construction above				$0.04			$	68,108
(cushion for unacticipated modifications during construction)								
3. SUB-TOTAL OF CONTINGENCIES							**$**	**136,216**
4. SUB-TOTAL OF CONTINGENCIES AND CONSTRUCTION:							**$**	**1,838,916**
C. PROJECT EXPENSES CATAGORIES - by percentage allowance only for preliminary budgeting								
A/E Fees, Landscaping, Signage, Admin. And Legal Expenses, Furniture, Equipment, Phones								
Data Systems, Security Systems, etc.								
POSSIBLE TOTAL PROJECT EXPENSES		***ALLOWANCE OF 15% OF CONSTRUCTION***					**$**	**255,405**
E. POSSIBLE TOTAL PROJECT BUDGET							**$**	**2,094,321**
F. POSSIBLE TOTAL PROJECT BUDGET INCLUDING ALL ALTERNATES							$	2,094,321

PRELIMINARY BUDGET TEST: MODEL 2

FEASIBILITY STUDY: RENEWABLE ENERGY & SUSTAINABLE FOOD PROJECT

GREENHOUSE STUDY

CITY OF SPRINGFIELD, MO.

11/18/2011

(The following values are allowances only; actual costs may vary. Assumed bidding by end of 2011)

A. CONSTRUCTION CONTRACTS							
1. GREENHOUSE STRUCTURE: gabled roof	180'x192'	35000		sf	$10	mfr. estimate	$ 350,000
Rigid polycarb roof/walls; building only, delivered to site: 10 bays wide; incl. fans, operable roof vents,							
a. GREENHOUSE ERECTING:		35000			$10	mfr. estimate	$ 350,000
b. Concrete Pier Foundations: 156 piers 30" deep		156			$200	each	$ 31,200
c. Gravel floor prep, and covering; gravel main aisle and bay aisles		35000			$2.25		$ 78,750
d. Electrical, Lighting		35000			$3		$ 105,000
e. Backup heating: propane unit heaters.						allowance	$ 50,000
f. Aisle structure, rigid polycarb panel roof, on alum frame.		3300	(205' x 16')		$20		$ 66,000
g. Computer controlled fan and vent system		35000				allowance	$ 50,000
i. Heating system: radiators, piping, etc.…		35000			$3		$ 105,000
j. Soil-based growing system						allowance	$ 128,000
						sub-total	**$ 1,313,950**
2. SITE WORK:							
a. grading, drainage, paving, building pad						allowance	$ 90,000
b. Utilities to site: well, electrical, etc.						allowance	$ 75,000
c. Heat Exchanger System and Thermal piping from generator house.						allowance	$ 300,000
					$13	sub-total	**$ 465,000**
3. HEADHOUSE: PRODUCTION BUILDING		4800			$80	allow	**$ 384,000**
Process Room, Storage, Office, Meeting Room, Toilets, etc.							
PROBABLE TOTAL CONSTRUCTION CONTRACTS BUDGET							**$ 2,162,950**
These values include a 5% markup for inflation and market conditions							
B. BID ALTERNATES:							
POSSIBLE BID ALTERNATES: TO BE DETERMINED							
Expanded parking lot							
Fencing							
Outdoor Growing and Working Areas							
Etc.							
TOTAL OF ALL ALTERNATES							**$ -**
TOTAL OF BASE BID AND ALL ALTERNATES:							**$ 2,162,950**
FEES AND CONTINGENCIES FOR ALTERNATES: add 12% to each item selected to add to total project costs.							
Approx. Sub-total for Fees and Contingencies for ALL Alternates:				0.12		$ -	
C. CONTINGENCIES:							
1. BIDDING CONTINGENCY: 3-5% of Construction above				$0.04			$ 86,518
(cushion for market conditions to allow for higher than expected bids)							
2. CONSTRUCTION CONTINGENCY: 3-5% of Construction above				$0.04			$ 86,518
(cushion for unacticipated modifications during construction)							
3. SUB-TOTAL OF CONTINGENCIES							**$ 173,036**
4. SUB-TOTAL OF CONTINGENCIES AND CONSTRUCTION:							**$ 2,335,986**
C. PROJECT EXPENSES CATAGORIES - by percentage allowance only for preliminary budgeting							
A/E Fees, Landscaping, Signage, Admin. And Legal Expenses, Furniture, Equipment, Phones							
Data Systems, Security Systems, etc.							
POSSIBLE TOTAL PROJECT EXPENSES		***ALLOWANCE OF 15% OF CONSTRUCTION***					**$ 324,443**
E. POSSIBLE TOTAL PROJECT BUDGET							**$ 2,660,429**
F. POSSIBLE TOTAL PROJECT BUDGET INCLUDING ALL ALTERNATES							$ 2,660,429